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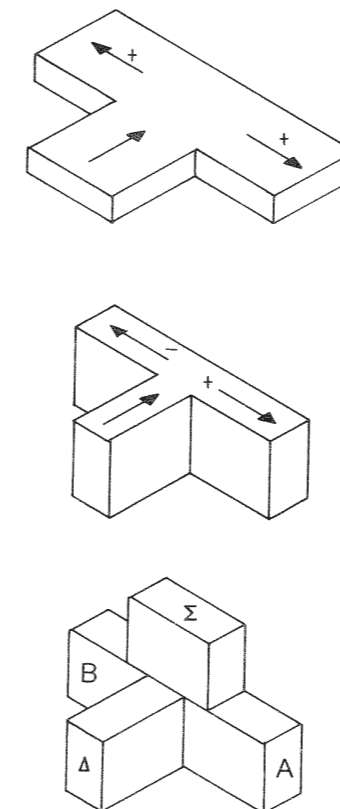


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Coherent power division was first accomplished by means of simple Tee Junctions. At microwave frequencies, wave-guide tees have two possible forms — the H-Plane or the E-Plane tee. These two junctions split power equally, but because of the different field configurations at the junction, the electric fields at the output arms are in-phase for the H-Plane tee and are antiphase for the E-Plane tee. The combination of these two tees to form a hybrid tee allowed the realization of a four-port component which could perform the vector sum (Σ) and difference (Δ) of two coherent microwave signals (A and B). This device is, of course, the magic tee.

Figure 1 - Tee Junctions



Components which perform the same function as the Magic Tee have been realized in many different forms in balanced, coaxial and stripline configurations. Also, lumped component devices which make use of a center-tapped transformer have been built at frequencies up to 1 GHz. (See Figure 2.) The frequency limitation in this device is principally due to the decline of the scalar permeability and the increase in loss of ferrite materials at microwave frequencies.

The distributed versions bear little or no physical resemblance to the waveguide hybrid, but are still sometimes referred to as Hybrids. The Rat Race is an example of a TEM version of the waveguide Magic Tee.

Figure 2 - Distributed Version Of Magic Tee

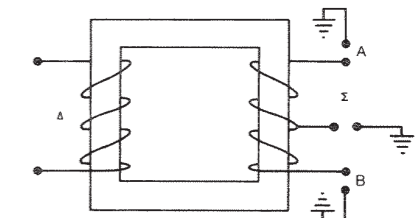
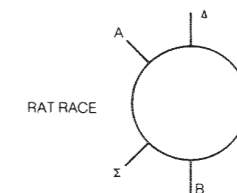
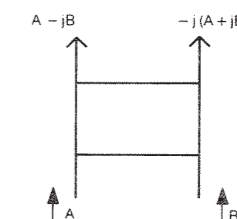


Figure 3 - TEM Version Of Magic Tee



Another device which is also called a hybrid is a Branch-Line Hybrid. This device, however, differs from the Magic Tee and the Rat Race in that the output signals are $\pm 90^\circ$ relative to each other instead of 0° and 180° . To differentiate between these two types of devices, one is called a 180° Hybrid, and the other a 90° Hybrid.

Figure 4 - Branch Line Hybrid



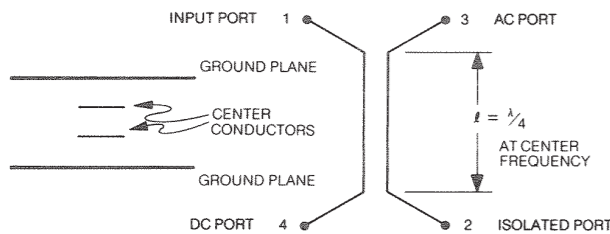
There are many techniques for realizing both quadrature and 180° hybrids in stripline, however, the most versatile versions from a point of view of both performance and bandwidth make use of the backward wave 3 dB coupler. The simplest version of this device is the single section coupler which allows octave bandwidth coverage. The device can easily be designed to cover decade bandwidths and this will be discussed later.

Quadrature (90°) Hybrid

A cross-section and top-view of a backward wave coupler is shown in Figure 5. This consists of a pair of printed lines in close proximity sandwiched between two common ground planes. Analyses of this device may be found elsewhere, meanwhile we will employ an extremely simplified description of operation.

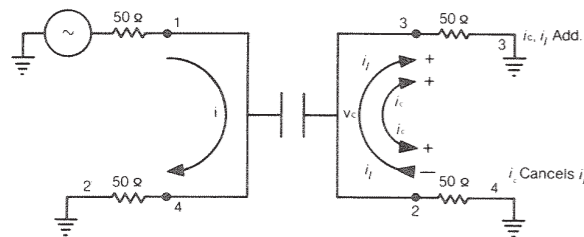
If the length l of the coupled section is very small compared to a wavelength, we can ignore propagation effects and assume that the device is simply a pair of loops whose extremities are terminated in 50 ohm to ground. Because of proximity, the loops are coupled both inductively and capacitively.

Figure 5 - Cross-Section And Top View of Backward Wave Coupler.



Referring to Figure 6, a generator at port 1 will drive a current to ground through port 4. In addition, an inductively coupled current (Lenz's Law) will circulate the coupled loop in the opposite direction as shown. This inductively coupled current will create a potential difference across the 50 ohm terminations at ports 2 and 3 with opposite polarities as shown.

Figure 6 - Illustrating the Coupling Mechanism.

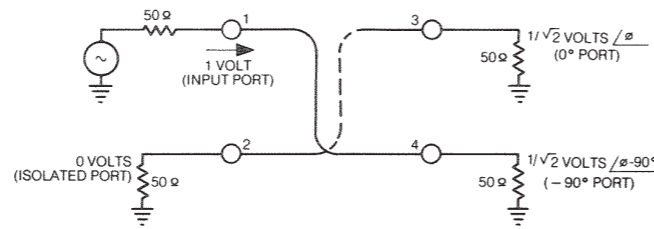


Meanwhile, a capacitive voltage is picked up on the coupled loop owing to the capacitive coupling at the coupled section. This voltage drives a current through the terminations at ports 2 and 3 and creates potential differences across these terminations which have the same polarity.

If we design the device so that the capacitively induced current is equal in magnitude to the inductively induced current, then the voltages across port 2 will cancel each other, while the voltages at port 3 are additive.

This device is a reciprocal 4-port network and can be represented graphically as shown in Figure 7. Note that, for convenience in circuit design, the coupled lines are made to crossover at one extremity. Figure 7

Figure 7 - Signal Relationships in a Properly Terminated 3 dB, 90° Hybrid



An input signal applied to any port (port 1, for example) will divide equally to the two opposite ports (3 and 4) with port 2 remaining isolated. The voltage at port 4 lags the voltage at port 3 by 90°. This phase quadrature relationship is independent of frequency and is the unique property which makes the 90° coupler so versatile.

The power split, however, is frequency sensitive. The frequency characteristics of a backward wave coupler are most easily described by means of a coupling angle θ . This angle is a function of the propagation constant, the width and proximity of the coupled lines and the electrical length of the coupled section. The coupling angle θ varies almost sinusoidally with frequency as:

$$\theta \approx \theta_{\max} \sin 2\pi l / \lambda^{(1)}$$

The maximum coupling angle thus occurs when the coupler length is an odd multiple of quarter wavelengths. θ_{\max} depends only on the cross-sectional geometry.

If a signal of strength one volt is applied to one port of the coupler, then the signals appearing at the dc and the coupled (ac) ports are respectively, (ignoring a slight dispersion):

$$V_{dc} = \cos \theta e^{-j\beta l^{(2)}}$$

and

$$V_{\text{coupled}} = j \sin \theta e^{-j\beta l}$$

If the coupler geometry is arranged such that $\theta_{\max} = 45^\circ$, then at the frequency where the coupler length is a quarter wavelength, the output voltages are:

$$V_{dc} = 1/\sqrt{2} \text{ volts } \angle \phi - 90^\circ$$

and

$$V_{\text{coupled}} = 1/\sqrt{2} \text{ volts } \angle \phi$$

This is, of course, a 3 dB coupler.

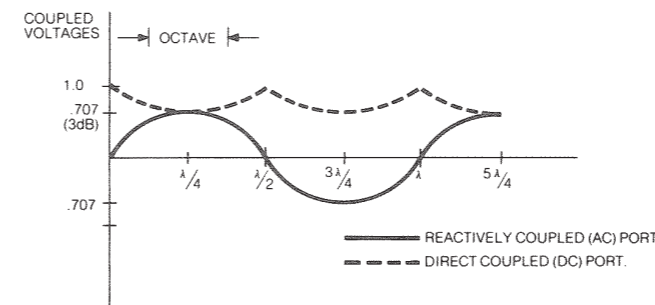
(1) This is an approximate expression. The exact expression is:

$$\theta = \tan^{-1} \left[\frac{1}{2} \left(Z'_{\text{oe}} - \frac{1}{Z'_{\text{oe}}} \right) \sin \beta l \right]$$

This introduces a term Z'_{oe} called "normalized even-mode impedance". The use of even and odd mode excitation to facilitate the analysis of a four-port coupler is discussed in an internal Anaren Technical Note "Coupled Lines — Hybrids". Copies of this note can be

As noted earlier, the power split is frequency sensitive. As frequency increases and the length l becomes an appreciable fraction of a wavelength, the coupled voltage varies approximately sinusoidally with frequency as shown in Figure 8. The coupled voltage reaches a maximum when the length l is a multiple of odd quarter wavelengths, and is zero at multiples of half wavelengths. The dc coupled voltage varies approximately cosinusoidally.

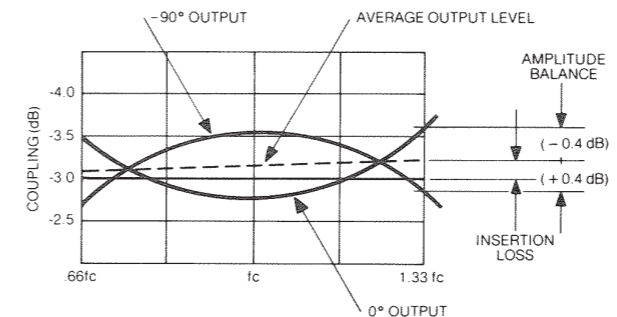
Figure 8 - Amplitude Variation of Coupled Voltages with Frequency



Note in Figure 8 the coupler power split is exactly 3 dB only at band center. When an octave bandwidth must be covered with minimum deviation from a 3 dB coupling value, the coupler geometry is adjusted to make $\theta = 45 \pm 2$ degrees. This gives $-3 \text{ dB} \pm 0.3 \text{ dB}$ of coupling to the output ports. This is a theoretical value and actual practice may result in a maximum of $-3 \text{ dB} \pm 0.5 \text{ dB}$ due to manufacturing and material yields and tolerances.

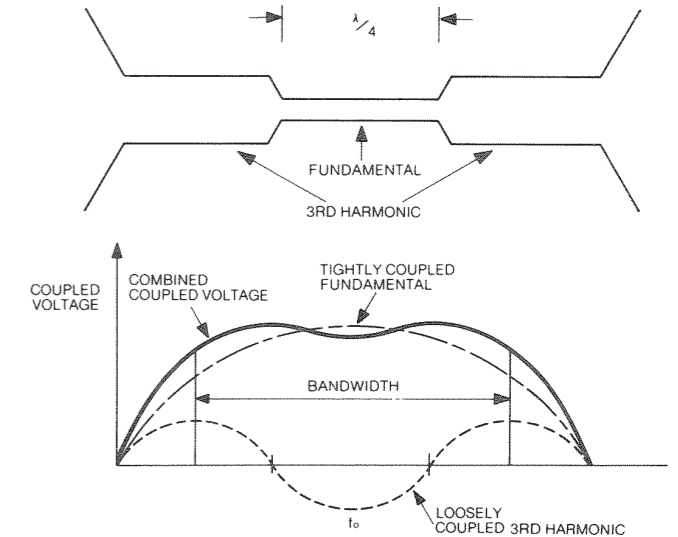
Typical output characteristics of an octave band, 3 dB, 90° hybrid are shown in Figure 9.

Figure 9 - Typical Output Characteristics Octave Band, 3 dB, 90° Hybrid.



To achieve bandwidths greater than octave, we add 3rd, 5th, 7th, etc., harmonics in the form of extensions shown in Figure 10 and with a form of Fourier synthesis we can achieve quadrature hybrids with decade bandwidths where the power split is within $\pm 0.5 \text{ dB}$ and the differential phase-shift between the output voltages is 90°. This technique can also be used to reduce the amplitude imbalance of an octave bandwidth hybrid. Adding more sections, however, adds directly to the insertion loss; for some applications, e.g. balanced transistor amplifiers, benefits gained by the reduction of amplitude imbalance may be negated by this increased insertion loss.

Figure 10 - Illustrating Bandwidth Increase by Adding Loosely Coupled Harmonic Sections.



Common couplers have coupling values of 3 dB, 6 dB, 10 dB and 20 dB. The last three devices are normally called *directional* couplers. The first device is usually called a 3 dB quadrature coupler, or simply 3 dB coupler.

Performance characteristics of 3 dB, 90° hybrids (3 dB couplers) deserve some discussion.

Frequency Coverage

Most designs make use of the single-section coupler which allows octave band coverage. Multi-octave designs are usually 3 or 5 section devices which are larger and generally have poorer isolation and VSWR specifications. Anaren provides hybrids to cover the frequency ranges from 30 MHz to 18 GHz in octave and multi-octave bands.

Isolation

Coupler isolation is defined as the difference in dB between the signal levels at the input port and the isolated port when the two output ports (0° and -90°) are terminated in 50 ohm loads. Since the coupler is a reciprocal device, isolation can also be defined as the signal level difference in dB between the 0° and -90° ports (using one as an input) when the other two ports are terminated in 50 ohm loads.

Theoretically, the backward wave hybrid has perfect isolation independent of frequency. In reality, isolation is limited primarily by turn-to-turn coupling between coupled lines in the meander-line technique. (The meander-line technique does not reduce the physical length of the coupled line but it significantly improves the form factor: 35 inches of coupled line can be meandered in a 2.1 by 2.0 inch package!) As the meander becomes tighter the turn-to-turn coupling causes forward-wave coupling. This not only limits the maximum isolation but also makes the isolation frequency dependent.

When meandering is not a limiting factor on isolation

the VSWR at the output connectors may become so. If the combined VSWR of the stripline/connector transitions and their terminations is not perfect, some energy will be reflected and focused to the isolated port (a VSWR of 1.22 at the output ports would result in an isolation *measurement* of only 20 dB even if the coupler were a truly “perfect” device). The tendency for measured isolation to degrade at the high frequency end of an octave-band hybrid is usually due to the combined effects of increased forward-wave coupling and the poorer VSWR at the output.

VSWR

The input and output impedance match of the coupler is a function of the coupled section and the input/output lines. An additional factor is the quality of the stripline/connector transition.

The effect of VSWR on isolation has previously been discussed. VSWR, like isolation, is also theoretically independent of frequency and dependent upon minimizing the effects of forward-wave coupling. Some internal impedance compensation is possible where the coupled and uncoupled lines interface but tends to be effective over less than octave bandwidths.

Tight manufacturing controls and computer-aided designs assure typical VSWR specifications of 1.10 for tests made with proper test instrumentation.

Amplitude Balance

Amplitude Balance is defined as the difference (in dB) of the signals at the 0° port output and the -90° port output, when compared to the average output level.

Another term sometimes used for Amplitude Balance is “Coupling Frequency Sensitivity”. This terminology emphasizes the frequency dependent character of the coupled power from both the 0° and -90° output ports. As noted earlier the amplitude of the coupled voltage varies almost sinusoidally with frequency, reaching a maximum when the electrical length of the coupled section is an odd number of quarter wavelengths.

Because the amplitude of the coupled voltage “rolls-off” each side of band center it is sometimes possible to use a standard 3 dB hybrid to quickly and/or economically obtain a specific coupling value at some lower, or higher, frequency of interest.

Phase Balance

The output ports of a backward wave coupler theoretically remain in phase quadrature independent of frequency. The same factors that affect isolation (forward-wave coupling and poor VSWR at the connector interface) also can degrade phase balance and make it frequency sensitive. The phase balance is not as sensitive to the degrading factors however and a typical phase balance specification of $\pm 1.0^\circ$ approaches the limits of resolution, accuracy and repeatability for most phase measurement schemes.

Insertion Loss

Coupler insertion loss is defined as the net unrecoverable power (in dB) based on one-way transmission through the coupler.

The insertion loss is dependent upon several factors and can be considered to be the sum of several losses. The first of these is the I²R loss due to the copper conductor resistance. The lost energy is dissipated as heat.

The second loss is dependent on the degree of match obtained at the coupler inputs and outputs. Any departure from the optimum match will result in a loss of signal delivered to the coupler and a subsequent loss of available signal to the output loads. A VSWR of 1.20 at the input and output ports will result in a mismatch loss of approximately .09 dB.

The third loss is in the form of directivity losses. A perfect coupler would focus all the input power to the two output ports and none would show up at the isolated port. If the measured isolation of the coupler is 20 dB the directivity is equal to 17 dB (Directivity = isolation minus coupling loss). 17 dB directivity results in .085 dB of the input power not being directed to the output ports.

Power Handling

Power handling capability of a 90° hybrid coupler decreases with increasing signal frequency. For example, a standard coupler handling 220 watts at 440 MHz could be expected to handle 160 watts at 880 MHz.

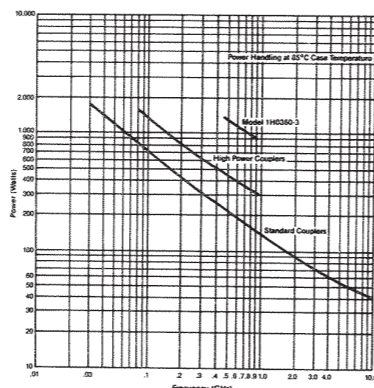


Figure 11 - Power Handling vs. Signal Frequency for Anaren 90° Caseless Couplers

Output Configurations

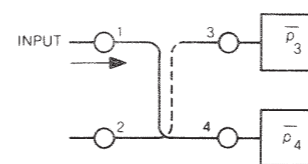
To provide the maximum flexibility for installing the hybrids in a system Anaren offers miniature hybrids with two choices of output port configurations: Standard and H-Style.

Applications of the 3 dB, 90° Hybrid

Because of the 90° relative phase difference in the output signals, the 3 dB, 90° hybrid is used extensively in many microwave applications.

If the output ports (3, 4) of the 3 dB hybrid in Figure 7 are short-circuited to ground, then power into port 1 is reflected to port 2. In fact, if ports 3 and 4 are terminated with any *identical* components, then any reflections from these components will appear at port 2. This simple behavior allows us to obtain an apparent input match to badly mismatched components.

Figure 12 – 3 dB, 90° Hybrid Terminated with Reflection Coefficients, $\bar{\rho}$



Let us examine this behaviour in more detail using Figure 12. Let $\bar{\rho}$ be a complex voltage reflection coefficient:

$$\bar{\rho} = \rho e^{j\theta}$$

where

- ρ = magnitude of the complex voltage reflection coefficient
- θ = phase angle of the complex voltage reflection coefficient

With ports 3 and 4 terminated with voltage reflection coefficients $\bar{\rho}_3$ and $\bar{\rho}_4$ respectively, and a signal applied to port 1, the reflection coefficient at Port 1 is:

$$\frac{1}{2}(\bar{\rho}_3 - \bar{\rho}_4)$$

and at Port 2:

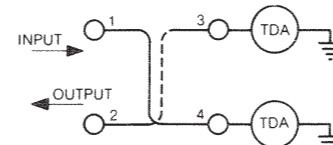
$$\frac{1}{2}(\bar{\rho}_3 + \bar{\rho}_4)$$

If the output reflection coefficients are equal ($\bar{\rho}_3 = \bar{\rho}_4$) then the input port is perfectly matched. This is true even for such drastic output conditions as open or short circuits.

This characteristic of directing reflected energy away from the input port to the normally isolated port applies not just for open or short circuit output ports but for any equal impedance terminations. This simple behavior provides a very low input VSWR to badly mismatched but similar components. These features are used in balanced transistor amplifiers, tunnel diode transmission line amplifiers, phase shifters, and balanced detectors and balanced mixers, to name a few.

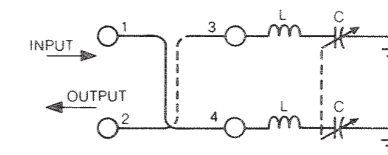
Two identical tunnel diode amplifiers (TDA) connected to the coupler, as shown in Fig. 13, form a transmission line amplifier.

Figure 13 – TDA Transmission Line Amplifier



A manually controlled phase-shifter can be obtained by using variable L-C networks as shown in Fig. 14. The insertion phase (from input to output) varies as C is varied but the input match is maintained.

Figure 14 – Manual Phase Shifter



An electronically controlled phase shifter is obtained by replacing the manually variable capacitors of Fig. 14 with the bias-variable varactor diodes of Fig. 15.

Figure 15 – Electronic Phase Shifter

A single-bit, electronic time delay or phase shift is obtained by means of a coupler and two PIN SPST switches, as shown in Fig. 16.

Figure 16 – Single-Bit Phase Shifter

A manually controlled attenuator with good input match is shown in Figure 17. A pair of variable, tracking resistors controls the amount of input signal absorbed or reflected. This varies the attenuation level from minimum to maximum.

Figure 17 – Manual Attenuator

An electronically controlled, matched attenuator is obtained by replacing the variable resistors with PIN diodes and associated bias networks. Varying the PIN diode bias current controls the diode RF impedance, thereby controlling the attenuation level. Fig. 18 illustrates the technique.

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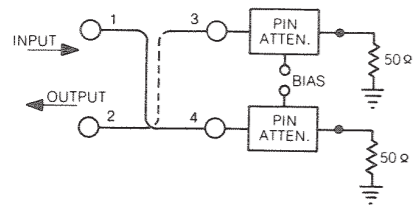
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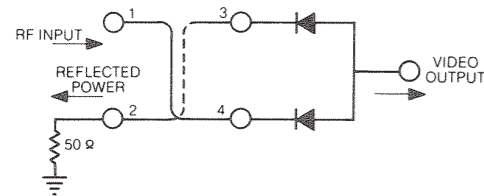
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Figure 18 – Electronic Attenuator



A matched detector is obtained by using a pair of similar detector diodes as shown in Fig. 19.

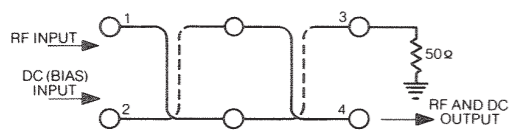
Figure 19 – Balanced Detector



If two 3 dB, 90° hybrids are connected in tandem, the resulting four-port network displays some additional interesting properties. This occurs because two couplers connected back-to-back behave like a single coupler with a coupling angle equal to the sum of the two individual coupling angles.

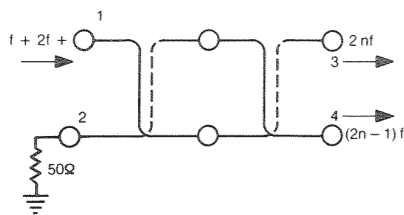
If each of the two couplers have maximum coupling angles of 45° (3 dB couplers) the combined coupling angle is 90° (a 0 dB coupler). This allows a simple biasing input to active RF components because it provides a crossover at the RF frequency but a straight-through path at dc, as shown in Fig. 20.

Figure 20 – Separation of RF and Bias Inputs



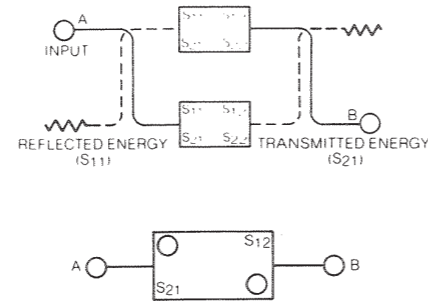
When octave bandwidth 3 dB couplers are used in the tandem network of Fig. 21, the circuit can be used to separate even and odd harmonics, to losslessly combine harmonic signals, or as a signal diplexer. See page 90 for a detailed treatment of the diplexer application.

Figure 21 – Signal Diplexer



When two identical two-port devices are placed between two 3 dB, 90° hybrids, a new matched two-port network is obtained which retains the cross-scattering coefficients.

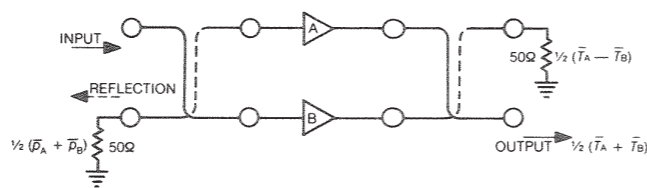
Figure 22 – Use of 3 dB, 90° Hybrids to Obtain a Matched Two-Port Devices by Paralleling Identical Devices.



The input signal divides equally in the first hybrid as usual, but the second hybrid now acts as a summing tee network and all the original signal (except for circuit losses) appears at only one output port of the second hybrid. The other output port is isolated.

When any two circuit components (transistors, for example) have complex voltage transmission coefficients T_A and T_B (and reflection coefficients $\bar{\rho}_A$, $\bar{\rho}_B$) are placed between two hybrids, the voltage transmission of the complete network is: $\frac{1}{2}(T_A + T_B)$

Figure 23 – Balanced Amplifier



(The voltage $\frac{1}{2}(T_A - T_B)$ is absorbed in the termination of the isolated output port).

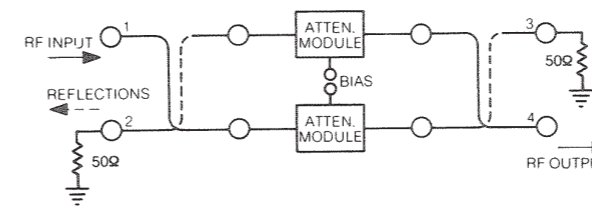
When the transmission coefficients are identical ($T_A = T_B$) then none of the transmitted signal is lost to the isolated port and all appears at the output. When the input reflection coefficients ($\bar{\rho}_A$, $\bar{\rho}_B$) are identical the input hybrid sums all the reflected voltage, $\frac{1}{2}(\bar{\rho}_A + \bar{\rho}_B)$, to the termination at the isolated input port.

The new network of Fig. 23 is a balanced amplifier having low input VSWR and output power twice that a single transistor.

Replacing the transistors of Fig. 23 with PIN diode attenuator modules, where the reflection and transmission coefficients are varied by the use of dc bias, results in a series of useful electronically controlled devices. (A PIN diode acts as a variable RF resistance, the RF resistance being controlled by a bias current).

Analog control of the bias inputs of Fig. 24 results in a matched, variable attenuator also useful as an amplitude modulator. Digital bias results in a matched on-off switch or pulse modulator.

Figure 24 – Matched Analog/Digital Attenuator/Switch



Using the reflected energy results in a single-pole, double-throw (SPDT) switch:

Figure 25 – Matched SPDT Switch

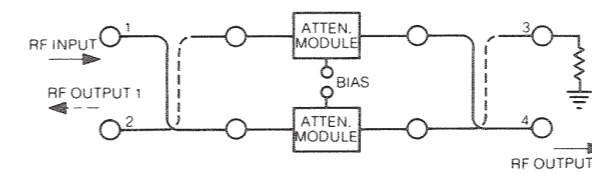


Figure 26 – Matched DPDT Switch

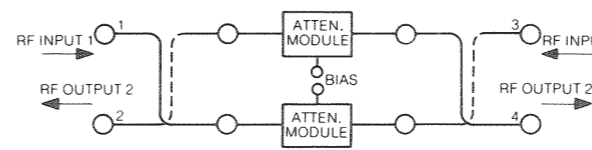
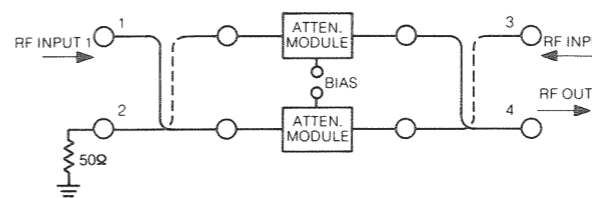


Figure 27 – Matched DPST Switch



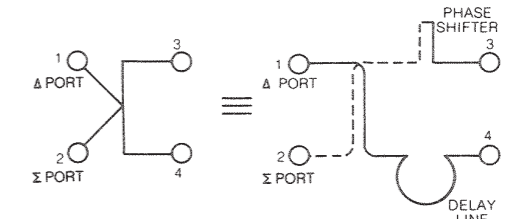
Anaren 3 dB, 90° hybrids are also used as the RF and IF building blocks for more complex devices; balanced mixers, balanced (bi-phase) modulators, double-sideband and single-sideband modulators, image-rejection mixers, quadrature and vector modulators, frequency and phase discriminators and a variety of adaptive networks. More details on these devices can be found by consulting the overall contents in the front of the catalog.

3 dB, 180° Hybrids

Many signal processing applications also make use of the 3 dB, 180° hybrid as well as the 90° hybrid. The waveguide "magic tee" and the stripline/microstrip "rat-race" configuration are narrow-band examples of the 180° hybrid. This device is similar to the 90° hybrid in most respects except that the output voltages are either in-phase or anti-phase, depending on which input port is used.

To convert a 90° hybrid to a 180° hybrid a fixed 90° phase shift is required at one of the outputs as shown in Figure 28. This is achieved, over octave bandwidths, by using a Schiffman⁽¹⁾ phase-shifter which is simply a dispersive transmission line inserted in one output of a quadrature hybrid.

Figure 28 – 180° dB Hybrid

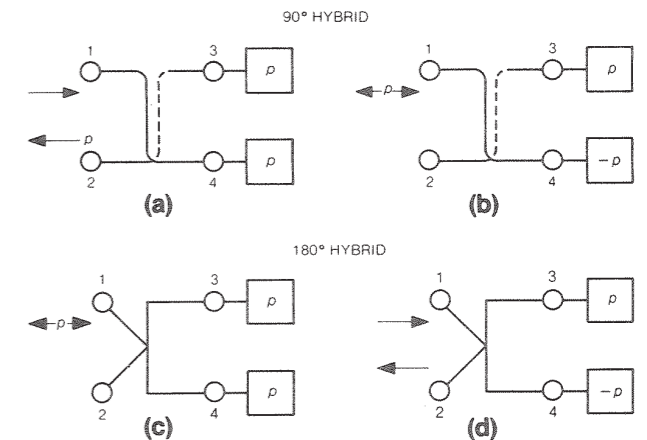


The 180° hybrid shown in Figure 28 is non-reciprocal. 180° phase difference between outputs 3 and 4 occurs only when the difference (Δ) port is excited. The outputs are in-phase when the sum (Σ) port is driven.

The simple addition of a 90° phase-shift results in a considerable difference in characteristics of the 180° hybrid as compared to the 90° hybrid. These are best illustrated when the output ports are terminated with devices having like reflection coefficients.

In Figure 29 we see that the reflected energy comes out at the isolated port for a 90° coupler (Figure 29a) and the input port of a 180° hybrid (29c).

Figure 29 – Reflective Properties of 90° and 180° Hybrid with Even and Odd Reflection Coefficients



If the reflection coefficient of one of the mismatches were changed by 180°, the situation would be reversed. That is, the reflected energy would come out the input port of a 90° coupler (29b) and out the isolated port of a 180° coupler (29d). These properties are fundamental to devices such as absorptive PIN modulators, balanced modulators, single sideband modulators and image rejection mixers.

⁽¹⁾Schiffman, D.M., "A New Class of Broadband Microwave 90 Degree Phase Shifters," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, Vol. MTT-6, pp. 232-237, April, 1958.

Applications of the 3 dB, 180° Hybrid

The 3 dB, 180° hybrid is used in many of the same applications as the 90° hybrid. If a power split is required the 180° hybrid has the option of providing in-phase or anti-phase outputs. This property finds use in polarization schemes for antenna feeds and beam-forming networks. In many cases it is the reflective properties that make the 180° hybrid useful. A balanced mixer can be constructed by utilizing two mixer diodes and either a 90° or 180° hybrid. If a 90° hybrid is used, both the LO and RF would see a relatively good match, but the LO to RF isolation would be poor. In the case of a 180° hybrid, the VSWR of the LO and RF is poor, but the LO to RF isolation is greatly improved over that obtained by means of the 90° coupler balanced mixer (like reflection coefficients in Figure 29c).

Figure 30 - 180° Balanced Mixer with Good LO/RF Isolation, Poor VSWR

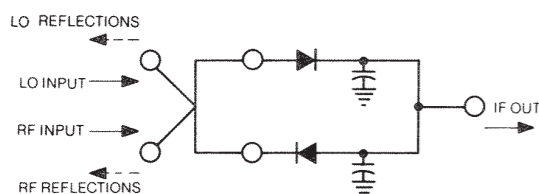
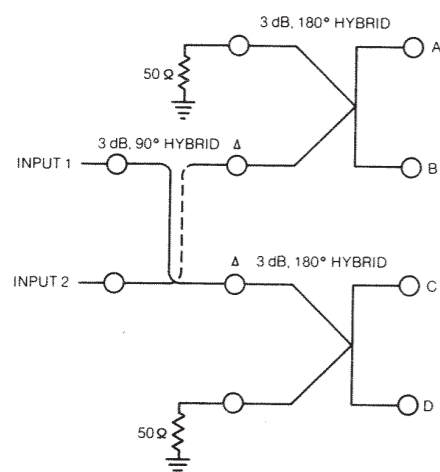


Figure 31 illustrates the use of Anaren's hybrid couplers to produce a circular polarization antenna feed network. The network will generate both right hand (RHC) and left hand (LHC) circular polarization depending on which input to the 90° hybrid is chosen as the feed input.

The relative phasing of the output ports versus the excited input port is shown below.

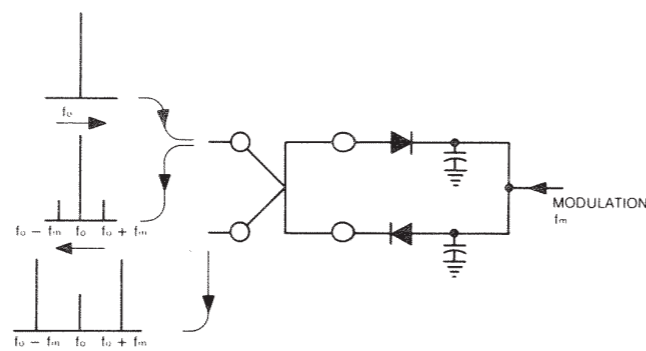
Output Port	Using Input 1	Using Input 2
B	0°	90°
C	90°	0°
A	180°	270°
D	270°	180°

Figure 31 - Circular Polarization Network, LHC, RHC, Using Anaren Hybrids



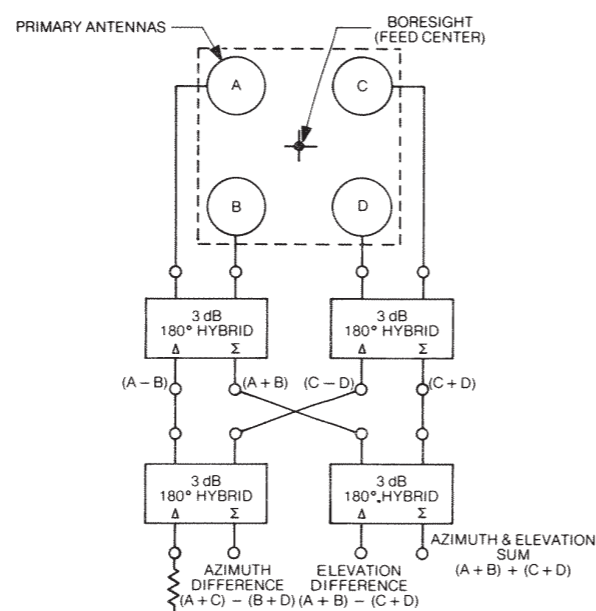
A balanced modulator can be constructed by placing two mixer diodes with reverse polarity behind a 180° hybrid, and combining the IF in a tee as shown in Figure 32. (The same circuit as Fig. 30.) The incident RF would see like reflection coefficients at the diodes and reflect back to the input port. The biasing signal in the IF port produces opposite polarity reflection coefficients at the sum and difference frequencies and the modulated signals appear at the remaining port. The amount of carrier suppression depends on the quality of the 180° coupler and the similarity between the diodes. Octave bandwidth carrier suppression of 10 dB and narrow bandwidth suppression of 25 dB are typical.

Figure 32 - 180° Balanced Modulator with Good Carrier Suppression, Poor VSWR



Monopulse tracking systems obtain tracking information by fixed (rather than scanning) beams. A typical two-dimensional system utilizes four primary antennas grouped around the feed point as shown in Figure 33. The feed network consists of four, 3 dB, 180° hybrids.

Figure 33 - Monopulse Tracking System



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The received energy is focused to either the sum or difference port of a 180° hybrid, depending on the phase relationship of the received RF signal. From the input ports (A, B and C, D) of the hybrids, in-phase RF energy combines at the Sum (Σ) ports and out-of-phase energy at the Delta (Δ) ports. These sum and difference outputs are further combined to provide elevation (and azimuth) differential patterns. These patterns are zero (nulled) along boresight, and maximum on either side of boresight. The tracking error signal is produced by comparing the sum signal to each of the differential patterns. When the received signal is on boresight, the azimuth and elevation difference information is at a null and the sum information is at a peak output level. As the received signal deviates from boresight, the sum channel output level decreases as either (or both) difference channel outputs increase. Thus the relative level of the outputs determines the target location.

Directional Couplers

The directional coupler provides a simple, convenient means for monitoring or sampling RF energy. Because it can sample transmission line power by a known amount, accurate measurements can be made without system interruption. The directional coupler can also monitor system operating frequency, provide a signal sample for automatic leveling and frequency control loops and provide indications of reflected power on the transmission line.

Coupling Values

Anaren provides standard coupling values of 6, 10, 20 and 30 dB. The choice of coupling value normally depends on the power levels involved. For example, if the coupler is used to monitor mainline power the coupling value would be selected to provide sufficient power to the monitoring device for proper operation. It must also be remembered that any coupler reduces power flowing in the main line by the amount coupled off: a 6 dB coupling value reduces the main line power output by 1.25 dB, while a 20 dB coupler reduces it by only .044 dB.

Directivity

Directivity indicates the degree to which the coupled port is isolated from the main line load. Open or short circuiting the output port of a directional coupler having 20 dB directivity would affect the coupled output power by only about 1%. High directivity is especially important if the coupler is being used to measure VSWR of a test device on the output port.

Insertion Loss

Low insertion loss is desirable because it means there is more power available to the rest of the system. Insertion loss increases with increasing frequency and coupler bandwidth. The insertion loss specification for Anaren directional couplers *does not* include the losses due to coupling.

VSWR

Low mainline VSWR is perhaps more important than coupled port VSWR simply because the main line ports produce the possibility of mismatch errors into the

system. Any coupled port mismatch is isolated from the main line input by the amount of coupling and from the main line output by the coupling and directivity.

Bandwidth

Selecting a coupler with broad bandwidth involves some tradeoffs. Broad frequency coverage is usually accompanied by reduced coupling accuracy, reduced directivity, increased VSWR, increased frequency sensitivity, increased insertion loss and larger size. When a choice is available, it is better to specify the narrowest bandwidth possible.

Power Handling

Power ratings for Anaren's directional couplers are specified for CW power, in both the forward and reverse directions. The ratings for the "in-line" style of couplers takes into account the possibilities of an open or short circuit output load which would reflect the transmitted load power back to the coupler's internal termination. Since some of these terminations will dissipate only 300 mW at 95°C the 6 dB couplers are rated at 1 Watt max reverse power. The H-style couplers have isolated ports that are available for external terminations. Greater reverse power can therefore be handled dependent on the power rating of the external termination actually used.

Input/Output Configurations

Anaren offers two input/output port configurations which are referred to as In-Line and H-Style. Representatives of each style are shown in Figure 34 and 35. Two styles provide optimum flexibility for solving system packaging problems.

Figure 34 - In-Line Directional Coupler

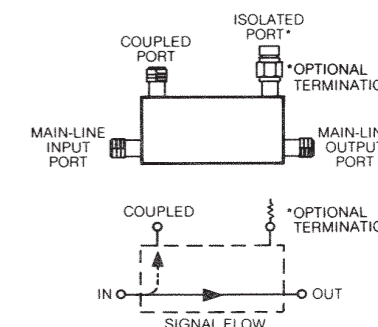
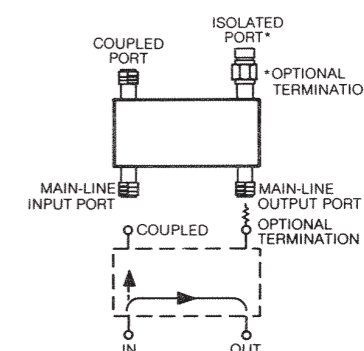


Figure 35 - H-Style Directional Coupler



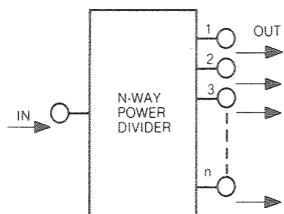
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Although both in-phase (Wilkinson) and quadrature (90°) hybrid couplers may be used for coherent power divider/combiner applications, fundamental differences exist making each more suitable for specific applications. The following note discusses the technical properties of these devices.

Basic N-Way Power Dividers

Figure 1 - Basic Power Divider



An n-way power divider is shown in Fig. 1. The device has a single input port and n output ports. Ideally, input power would be divided equally between the output ports. The output phase relationship would depend upon the construction of the device. If the device were an in-phase divider, the output ports would be in phase. In a quadrature hybrid divider, the output ports would have a 90° (multiple of 90°) phase relationship.

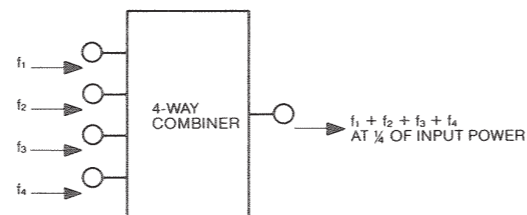
Using Dividers As Combiners

These devices, either quadrature hybrid or in-phase dividers, can be used as coherent combiners as well as dividers providing the reciprocity of the device is understood. For lossless recombination, the same amplitude and phase relationships which exist at the output of the device when used as a divider must drive the n input ports of the device when used as a combiner. A divider will losslessly combine n input signals providing they are of the proper input phase and amplitude relationship. If this is not the case, power is lost in the combiner.

In many applications coherent addition of signals is not a requirement. An example of this is where n signals of different frequencies are applied to a device with a single output port (multiplexer). One wishes to see the sum of the signals at the output. This may be accomplished using hybrid or in-phase combiners provided losses can be tolerated. Using an n-way combiner in this manner, only 1/n of the input power will appear at the output.

A four-way combiner used as a multiplexer is shown in Fig. 2. Four signals at four different frequencies of unit power level each are applied at the inputs. The output is the sum of the four signals but each has 1/4 unit of power. The signals have been combined, but at the expense of a loss in power. Lossless multi-plexing can only be done with filter networks.

Figure 2 - 4-Way Combiner as a Multiplexer

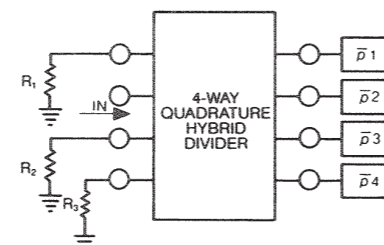


Quadrature (90°) Hybrid Power Dividers

Anaren Application Note, "90° Hybrids for Transistor Power Amplifiers," (P. 86) discusses the match and transfer properties of quadrature hybrid couplers. The conclusions drawn are that poorly matched devices may be placed at the output ports of a hybrid divider without deteriorating the input match to the divider. In a sense, then, the hybrid divider acts like an isolator provided the devices have nearly identical reflection coefficients.

Four-way Divider

Figure 3 - 4-Way Quadrature Hybrid-Divider with Reflection Coefficients, $\bar{\rho}$



The case for a four-way hybrid power divider is illustrated by Fig. 3. The divider is terminated by four devices having complex reflection coefficients, $\bar{\rho}_1$, $\bar{\rho}_2$, $\bar{\rho}_3$, and $\bar{\rho}_4$. An expression for the input reflection coefficient of the divider is given by:

$$\bar{\rho}_{in} = 1/4 (-\bar{\rho}_1 + \bar{\rho}_2 - \bar{\rho}_3 + \bar{\rho}_4)$$

It can be seen that if $\bar{\rho}_1 = \bar{\rho}_2 = \bar{\rho}_3 = \bar{\rho}_4$, then $\bar{\rho}_{in} = 0$. The reflected power from the mismatch at the output goes to the terminations, R_1 , R_2 and R_3 as can be seen by the expression for the power to the loads:

$$P_{R1} = \frac{P_{in}}{8} (\bar{\rho}_1 + \bar{\rho}_2)^2$$

$$P_{R2} = \frac{P_{in}}{8} (\bar{\rho}_3 + \bar{\rho}_4)^2$$

$$P_{R3} = \frac{P_{in}}{8} (\bar{\rho}_1 - \bar{\rho}_2 + \bar{\rho}_3 - \bar{\rho}_4)^2$$

Note: R_3 is the "isolated" termination for the input hybrid in the 4-way quadrature hybrid divider.

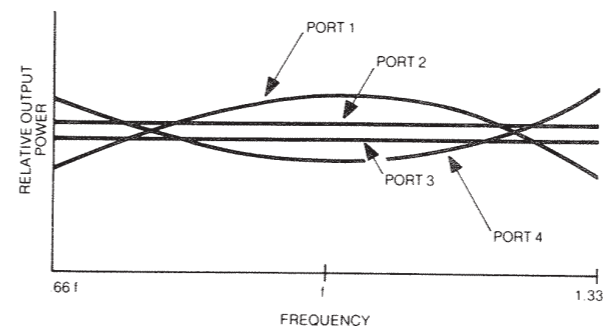
Power Handling

Another advantage of the quadrature hybrid divider is power handling capability. The terminations may be brought out of the device so that high power terminations may be used (i.e., relatively largely heat-sink or finned loads.). The stripline circuitry has a power handling capability in excess of 200 watts CW. In any given application, the power handling is usually limited by the loads. The table on page 86 gives expressions for power dissipated in terminations for hybrid dividers and combiners.

Amplitude Balance

The primary disadvantage of quadrature hybrid dividers is power imbalance between output ports. The imbalance which occurs for a four-way divider over an octave bandwidth is shown in Fig. 4. As can be seen, two ports track closely while the other two diverge at the band edges and at the center of the band (f_c). Specifications for a four-way divider are usually ± 1 dB for an octave bandwidth device. Better results, of course, can be achieved over narrow bandwidths with optimization of the divider.

Figure 4 - Typical Output Characteristics: Octave Band 4-Way Quadrature Divider



Phase Balance

A possible disadvantage of a quadrature hybrid divider (for certain applications) is that the output ports are not in phase. The ports have a 90° (or a multiple of 90°) phase relationship which remains constant over octave bands. Specifications for hybrid dividers are for the relative phase variation from 90° (or multiple of 90°) over the frequency range specified.

Binary Outputs

Quadrature dividers can only be constructed with a binary number (2ⁿ) of output ports (i.e. 2, 4, 8, 16). The final section of this note discusses the construction of n-way power dividers.

In-Phase (Wilkinson) Power Divider

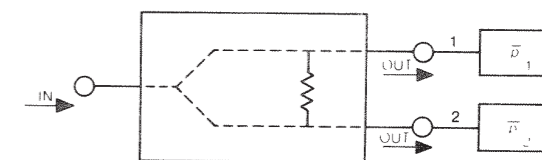
The in-phase (Wilkinson) power divider has the advantages of excellent output port amplitude balance (over octave or wider bandwidths) and in-phase power division. The power split and phase balance is theoretically perfect and nearly ideal results can be achieved in practice.

Power Handling

The chief disadvantage (for power applications) is that the terminations cannot be brought out externally to the device. A constraint on the internal terminations is that the terminations must be much less than a wavelength in any dimension. This constraint limits worst case power handling of some devices to approximately 200 milliwatts. These are "fail safe" specifications. The final power handling capability depends upon the external terminations of the divider. As an example, a two-way divider with terminations is illustrated having complex reflection coefficients $\bar{\rho}_1$ and $\bar{\rho}_2$. The power (P) lost in the internal termination is given by:

$$P = \frac{P_{in}}{4} (\bar{\rho}_1 - \bar{\rho}_2)^2$$

Figure 5 - 2-Way In-Phase Divider



It can be seen that if the reflection coefficients are nearly identical no power will be lost in the internal termination. The worst case is for one reflection coefficient to be 180° out of phase with the other. In this case, all reflected power is dissipated in the internal termination. A good example is if both terminals are open ($\bar{\rho}_1 = \bar{\rho}_2 = 1.0$) or short ($\bar{\rho}_1 = \bar{\rho}_2 = -1.0$). In this case no power is dissipated in the external termination. If, however, one output port is open circuited and the other short circuited, ($\bar{\rho}_1 = 1.0$, $\bar{\rho}_2 = -1.0$) then all of the input power is dissipated in the internal termination.

Figure 5a - Input Power (P_{in}) for 2-Way In-Phase Power Dividers.

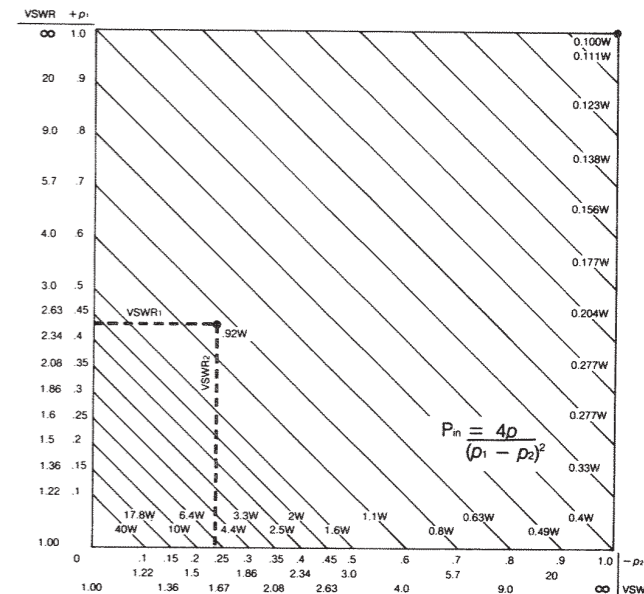


Figure 5A is useful for determining the power handling capabilities of the 2-way, in-phase power dividers of Figure 5.

Worst case phase (180°) is assumed for the external terminations. Internal load dissipation of only 100 mW is assumed (to provide a safety factor).

Example:
VSWR of 2.5:1 is expected at port 1 and 1.6:1 at port 2. The graph shows that the 2-way, in-phase power divider can accept approximately 0.92 W at the input port under these conditions.

Input Match

Unlike the quadrature hybrid power divider, if the output ports are loaded with devices of nearly identical reflection coefficients, the input match degrades according to the magnitude of the reflection coefficients. This is seen by an expression for the input reflection coefficient.

$$\bar{\rho}_{in} = 1/2 (\bar{\rho}_1 + \bar{\rho}_2)$$

Unlike the quadrature hybrid divider, if the outputs are open or short circuited, ($\bar{\rho}_1 = \bar{\rho}_2 = 1.0$ or $\bar{\rho}_1 = \bar{\rho}_2 = -1$) the input reflection coefficient is unity.

N-Way Outputs

In-phase power dividers, like the quadrature hybrid dividers are most easily constructed with a binary (2ⁿ) number of output ports. N-way dividers can be constructed but are most easily done in cylindrical geometries (more difficult from a construction point of view) than the binary dividers which lend themselves to planar geometries.

In-Phase Power Dividers as Power Combiners

The in-phase power divider may be used for combining RF signals. There are two types of signal combining:

- Coherent signal combining, where the signals have exactly the same period or frequency, but not necessarily the same amplitude or phase code.
- Non-coherent signal combining, where the combined signals do not have the same period, and may not have the same amplitude.

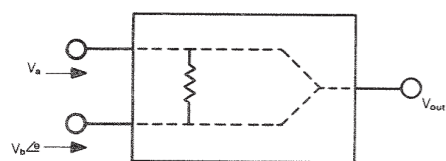
Coherent Signal Combining

The output of a 2-way in-phase power divider (see Figure 6) when used as a coherent signal combiner can be determined by the following equation:

$$V_{out} = 1/\sqrt{2} \sqrt{(V_a + V_b \cos \theta)^2 + (V_b \sin \theta)^2}$$

where V_a and V_b are coherent input voltages and θ is the phase difference between V_a and V_b.

Figure 6 - 2-Way Power Divider Used As Coherent Signal Combiner



Non-coherent Signal Combining

Combining two non-coherent signals will cause 3 dB loss for each input signal in addition to the losses normally incurred when the device is used as a power divider. This is because the signals are asynchronous and will not correlate. Therefore, the power divider output will be $1/\sqrt{2} V_{in}$ for each input signal.

Quadrature and In-Phase Combinations

Both quadrature hybrid and in-phase power dividers have common properties of good match at all ports and high isolation between output ports. Devices may be constructed using combinations of both types of power dividers to gain the advantages of both. For example, an eight-way divider can be constructed from in-phase and quadrature hybrid dividers. Using this approach, input match under matched load conditions can be guaranteed and the divider would have better amplitude balance than a device made up of quadrature hybrid dividers alone.

In power applications (i.e. amplifiers), in-phase dividers can be kept in the low power region of the device with hybrids in the higher power region. Again, better amplitude balance is obtained while maintaining the advantage of good input match.

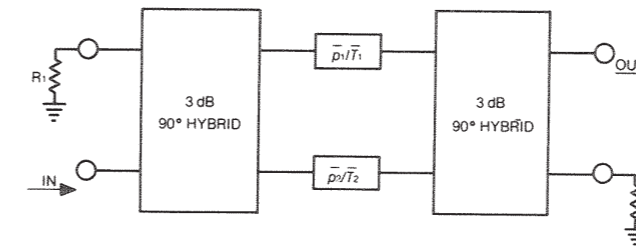
Finally, where output phase is not important, n-way dividers, for odd division or even division other than 2ⁿ, may be done using any combination of quadrature hybrid dividers, in-phase power dividers, and backward wave couplers. In this manner, 3, 5, 6, . . . way dividers have been constructed for particular applications.

Input Match and Power Relationships

The following tables have expressions for input reflection coefficients, output power and power lost to terminations for two-way and four-way quadrature hybrid and in-phase combiner/dividers. The expressions are in terms of reflection and transmission coefficients for devices placed between the divider and combiner. From these tables, one can also obtain data for dividers and combiners and combiners taken by themselves.

For example, as dividers, one only need be concerned with the reflection coefficients. As combiners, one can start with the amplitude and phase at the input ports which will give perfect combination. Then by progressive perturbation of phase and amplitude at any one of the ports, one can determine power output and power lost to any one of the loads.

Two-Way Quadrature (90°) Hybrid Combiner—Dividers



$$\text{Input Reflection Coefficient} = 1/2 (\bar{\rho}_1 - \bar{\rho}_2)$$

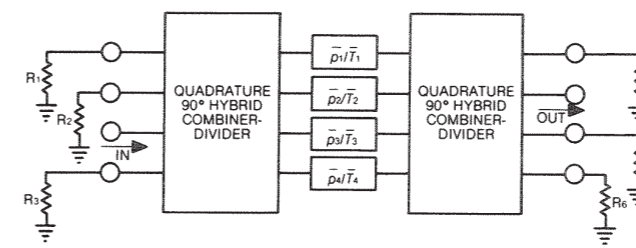
$$\text{Power Output} = \frac{P_{in}}{4} (\bar{T}_1 + \bar{T}_2)^2$$

$$\text{Power Lost in } R_1 = \frac{P_{in}}{4} (\bar{\rho}_2 + \bar{\rho}_1)^2$$

$$\text{Power Lost in } R_2 = \frac{P_{in}}{4} (\bar{T}_2 - \bar{T}_1)^2$$

$\bar{\rho}$ = Voltage Reflection Coefficients
 \bar{T} = Voltage Transmission Coefficients

Four-Way Quadrature (90°) Hybrid Combiner-Dividers



$$\text{Input Reflection Coefficient} = 1/4 (\bar{\rho}_1 - \bar{\rho}_2 + \bar{\rho}_3 - \bar{\rho}_4)$$

$$\text{Power Output} = \frac{P_{in}}{16} (\bar{T}_1 + \bar{T}_2 + \bar{T}_3 + \bar{T}_4)^2$$

$$\text{Power Lost in } R_1 = \frac{P_{in}}{8} (\bar{\rho}_1 + \bar{\rho}_2)^2$$

$$\text{Power Lost in } R_2 = \frac{P_{in}}{16} (\bar{\rho}_1 - \bar{\rho}_2 + \bar{\rho}_3 - \bar{\rho}_4)^2$$

$$\text{Power Lost in } R_3 = \frac{P_{in}}{8} (\bar{\rho}_3 + \bar{\rho}_4)^2$$

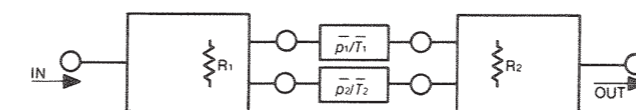
$$\text{Power Lost in } R_4 = \frac{P_{in}}{8} (\bar{T}_1 - \bar{T}_2)^2$$

$$\text{Power Lost in } R_5 = \frac{P_{in}}{16} (\bar{T}_1 + \bar{T}_2 - \bar{T}_3 - \bar{T}_4)^2$$

$$\text{Power Lost in } R_6 = \frac{P_{in}}{8} (\bar{T}_3 - \bar{T}_4)^2$$

$\bar{\rho}$ = Voltage Reflection Coefficients
 \bar{T} = Voltage Transmission Coefficients

Two-Way In-Phase Combiner-Dividers



$$\text{Input Reflection Coefficient} = 1/2 (\bar{\rho}_1 + \bar{\rho}_2)$$

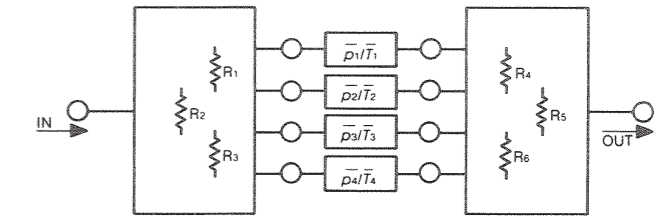
$$\text{Power Output} = \frac{P_{in}}{4} (\bar{T}_1 + \bar{T}_2)^2$$

$$\text{Power Lost in } R_1 = \frac{P_{in}}{4} (\bar{\rho}_1 - \bar{\rho}_2)^2$$

$$\text{Power Lost in } R_2 = \frac{P_{in}}{4} (\bar{T}_1 - \bar{T}_2)^2$$

$\bar{\rho}$ = Voltage Reflection Coefficients
 \bar{T} = Voltage Transmission Coefficients

Four-Way In-Phase Combiner-Dividers



$$\text{Input Reflection Coefficient} = 1/4 (\bar{\rho}_1 + \bar{\rho}_2 + \bar{\rho}_3 + \bar{\rho}_4)$$

$$\text{Power Output} = \frac{P_{in}}{16} (\bar{T}_1 + \bar{T}_2 + \bar{T}_3 + \bar{T}_4)^2$$

$$\text{Power Lost in } R_1 = \frac{P_{in}}{8} (\bar{\rho}_1 - \bar{\rho}_2)^2$$

$$\text{Power Lost in } R_2 = \frac{P_{in}}{16} (\bar{\rho}_1 + \bar{\rho}_2 - \bar{\rho}_3 - \bar{\rho}_4)^2$$

$$\text{Power Lost in } R_3 = \frac{P_{in}}{8} (\bar{\rho}_3 - \bar{\rho}_4)^2$$

$$\text{Power Lost in } R_4 = \frac{P_{in}}{8} (\bar{T}_3 - \bar{T}_2)^2$$

$$\text{Power Lost in } R_5 = \frac{P_{in}}{16} (\bar{T}_1 + \bar{T}_2 - \bar{T}_3 - \bar{T}_4)^2$$

$$\text{Power Lost in } R_6 = \frac{P_{in}}{8} (\bar{T}_3 - \bar{T}_4)^2$$

$\bar{\rho}$ = Voltage Reflection Coefficients
 \bar{T} = Voltage Transmission Coefficients

90° Hybrids for Transistor Power Amplifiers

Recent advances in RF power transistors have made it technically feasible and economic to replace tube-type amplifiers with solid state power amplifiers. At this time, power amplifiers operating at 1kW (CW) over the UHF band 225-400 MHz are entirely feasible. The more common power requirements in this frequency range, however, are in the 10 W to 100 W range.

Design Problems

Design problems for wideband amplifiers center around two main areas:

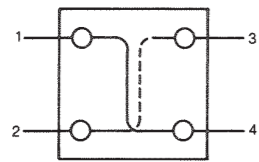
- The higher the power rating of an RF transistor, the lower and more complex is the input impedance. This makes it difficult to match the device successfully over any bandwidth.
- The cost and reproducibility of the transistor increases non-linearly with the power rating. Increased power handling capability is usually achieved by dc paralleling many low power stages on a single chip. Maintaining an even power division over an increasingly larger number of stages is both a difficult materials problem and a fabrication feat. This increases the probability that a few stages will be stressed beyond capability, and the transistor is destroyed.

Using the 3 dB, 90° Hybrid

Techniques for overcoming these difficulties have been described by Benjamin^(1,2) and others. These techniques are based primarily on the use of quadrature (90°) hybrids (3 dB couplers).

The 90° hybrid (Fig. 1) is a reciprocal four-port device that behaves like a pair of matched tees with common output ports, and isolated input ports (hybrid tee). The two tees are different only in the relative phasing of the voltages in the output ports. A signal into port 1 divides equally between ports 3 and 4 and ideally, port 2 is perfectly isolated. The voltage at port 4 lags the voltage at port 3 by 90° (hence, the term quadrature).

Figure 1 - 3 dB, 90° Hybrid



A signal into port 2 also divides equally between ports 3 and 4 with port 1 isolated, but in this case the voltage at port 4 leads the voltage at port 3 by 90°. Since the device is reciprocal, the same situation holds true when ports 3 and 4 are used as the isolated input ports.

If ports 3 and 4 are terminated in mismatches with voltage reflection coefficients $\bar{\rho}_3 - \bar{\rho}_4$ respectively and a signal is incident on port 1, then the voltage reflection coefficient at port 1 is given by:

$$\frac{1}{2} (\bar{\rho}_3 - \bar{\rho}_4)$$

and at port 2

$$\frac{1}{2} (\bar{\rho}_3 + \bar{\rho}_4)$$

Thus, if port 2 is terminated in a matched load, the hybrid behaves like a tee with an input reflection coefficient half the difference between the reflection coefficients of the output loads.

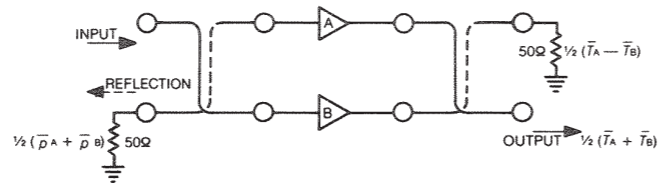
If the output reflection coefficients are equal ($\bar{\rho}_3 = \bar{\rho}_4$), then the input port is perfectly matched. Note that this is true even for such drastic output conditions as open or short circuits.

Thus, if the output ports are terminated in equal mismatches the 90° hybrid behaves like a tee where the reflected power never reaches the input port.

When any two circuit components (transistors, for example) having complex voltage transmission coefficients \bar{T}_A and \bar{T}_B (and reflection coefficients $\bar{\rho}_A, \bar{\rho}_B$) are placed between two hybrids, the voltage transmission of the complete network is: $\frac{1}{2} (\bar{T}_A + \bar{T}_B)$

(1) J. Benjamin, "RF Power Combinations Using Hybrid Junctions," and "Broadband Transistor Power Amplifier Concept," IIT Semiconductors.
(2) J. Benjamin, "Use Hybrid Junctions for More VHF Power," Electronic Design, August 1, 1968.

Figure 2 - Balanced Amplifier



The voltage is $\frac{1}{2} (\bar{T}_A - \bar{T}_B)$ and is absorbed in the termination of the isolated output port.

When the transmission coefficients are identical ($\bar{T}_A = \bar{T}_B$) then none of the transmitted signal is lost to the isolated port and all appears at the output. When the input reflection coefficients ($\bar{\rho}_A, \bar{\rho}_B$) are identical the input hybrid sums all the reflected voltage $\frac{1}{2} (\bar{\rho}_A + \bar{\rho}_B)$ to the termination at the isolated input port.

The new network of Figure 2 is a balanced amplifier having low input VSWR and output power twice that of a single transistor.

Wideband Power Amplifiers

Now let us consider some of the problems of building a wideband power amplifier. The RF transistors have low complex input impedances and some attempt at matching must be made to realize the gain potential. To obtain flat gain response across the band, however, it is not necessary to match the transistor completely across the band. Since the maximum available gain decreases with frequency (approximately 6 dB per octave), the matching network can be chosen to maximize the gain at the high frequency end of the band and allow the mismatch to increase towards the lower end of the band. The reflection coefficient of such an amplifier can be as high as 0.8 at the lower end of an octave band. However, combining two such amplifiers by means of a pair of quadrature hybrids allows the realization of a matched power amplifier module with a flat gain response.

Using this module as a building block, high power octave bandwidth amplifiers can be constructed (paralleling modules) by means of the same quadrature hybrid technique.

In some instances, four or even eight modules could be combined in the last power stage. To facilitate construction and lower the cost, Anaren can provide four-way combiner divider networks for selected bands.

Many power transistor manufacturers have developed application information on this subject^(3,4). The effects of hybrid characteristics (phase and amplitude balance) on balanced amplifier performance are discussed at length on page 88.

(3) J. Johnson, et al., "Solid Circuits," (Chapter 16), Application Book 2.2.8.0A Communications Transistor Company, San Carlos, Calif.
(4) Application Notes AN-6010, AN-6118, AN-6126; RCA Solid State Division, Somerville, N.J.

Effect of Hybrid Phase and Amplitude Balance on Balanced Amplifier Performance

90° Hybrids For Balanced Amplifiers

The Ultra-Miniature series of 3 dB, 90° hybrids is specifically intended for installation directly in the microstrip circuitry employed for most balanced transistor amplifier designs. Thirty-four standard models in 15 case styles cover the frequency ranges from 30 MHz to 6.0 GHz. The popular 225-400 MHz band is covered by 4 standard case styles.

A balanced transistor stage usually consists of two electrically similar transistors whose inputs and outputs are combined in 3 dB, 90° hybrid couplers. The characteristics of the hybrids provide an amplifier module with good impedance match at input and output while simultaneously giving good phase and amplitude characteristics. (Anaren Application Note, "90° Hybrids for Transistor Power Amplifiers," discusses the match and transfer properties of quadrature hybrid couplers more completely.)

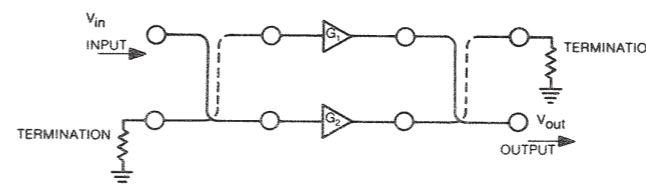
Using a balanced amplifier module as a building block, high power amplifiers can be constructed by paralleling modules using the same quadrature hybrid technique. Anaren offers 4 models of 4-way Combiner-Dividers designed specifically for this application; these devices use the same lightweight construction and microstrip solder terminals as the Ultra-Miniature 90° hybrids.

Hybrid Phase and Amplitude Balance

The balanced amplifier module provides good input and output match. It also provides good power handling ability (up to 1,000 W CW for specially constructed units) because the terminated ports can be brought out of the unit and high power terminations used. A disadvantage of the module is the power imbalance between coupled ports of the quadrature hybrids, which results in some power lost at the output port. This is not as serious a problem as it might first appear.

The effects of the amplitude and phase balance of the hybrids on balanced amplifier performance can be evaluated using Figure 1.

Figure 1 - Balanced Amplifier



Let the input be $V_1 = 1$ volt and G_1, G_2 be the voltage gains for the two transistors.

The output voltage can be shown to be:

$$\frac{V_{out}}{V_{in}} = V_{out} = e^{-j(\phi - \frac{\pi}{2})} [(G_1 + G_2) \sin \theta \cos \theta] \quad (1)$$

Where: ϕ = total insertion phase from input to output
 θ = coupling angle
 $V_{in} = 1$

θ is a function of the length of the coupled section of the hybrid, the propagation constant and the coupler geometry. A narrow band hybrid that has exactly -3 dB coupling to each output at midband has $\theta = 45^\circ$.

Amplitude Performance of "Perfect" Hybrids

Evaluating equation (1) at midband for $\theta = 45^\circ$:

$$V_{out} = e^{-j(\phi - \frac{\pi}{2})} [(G_1 + G_2)(.707)(.707)] \\ = e^{-j(\phi - \frac{\pi}{2})} [(G_1 + G_2)(.5)] \quad (2)$$

Assume $G_1 = G_2 = 1$ for ease of computation: equation (2) becomes

$$V_{out} = e^{-j(\phi - \frac{\pi}{2})} [(2)(.5)] \\ = e^{-j(\phi - \frac{\pi}{2})} [1.00]$$

Letting $\phi = 0$ (no phase imbalance):

$$V_{out} = e^{-j\frac{\pi}{2}} \quad (1)$$

In other words, an amplifier module using "perfect" hybrids (no phase or amplitude imbalance) delivers all its power to the output port and the output has a phase of -90° relative to the input.

Amplitude Performance of Octave-Band Hybrids

A normal octave band hybrid is specified with a maximum differential power split at its outputs of 1 dB (amplitude balance of ± 0.5 dB) and could therefore have a coupling angle $\theta = 48.5^\circ$:

Evaluating equation (1) at midband for $\theta = 48.5^\circ$.

$$V_{out} = e^{-j(\phi - \frac{\pi}{2})} [(G_1 + G_2)(.749)(.663)] \\ = e^{-j(\phi - \frac{\pi}{2})} [(G_1 + G_2) .496] \quad (3)$$

Assuming $G_1 = G_2 = 1$ equation (3) becomes

$$V_{out} = e^{-j(\phi - \frac{\pi}{2})} [(2) .496]$$

Letting $\phi = 0$ (no phase imbalance)

$$V_{out} = e^{-j\frac{\pi}{2}} (.992)$$

$V_{out} = .992$ of the input voltage (at a relative phase of -90°)

$$V_{out} = -.07 \text{ dB}$$

Signal Diplexer ("Crossover")

Using 3 dB 90° Hybrids

Therefore, a coupler imbalance of ± 0.5 dB results in a power loss of only .07 dB at the amplifier output.

Note: Even if the amplitude balance was ± 1.0 dB, the power loss would only be:

$$\begin{aligned} V_{out} &= e^{-j(\frac{\pi}{2} - \frac{\pi}{2})} [(G_1 + G_2)(\sin 51.5^\circ)(\cos 51.5^\circ)] \\ &= 2 (.782)(.623) \\ &= .974 \\ &= -0.2 \text{ dB} \end{aligned}$$

Phase Performance of Hybrids

The power lost due to a phase imbalance of 3° ($\pm 1.5^\circ$) for each hybrid in the amplifier can most easily be calculated by assuming that the imbalance is due to an additional line length of 6° (let the couplers and amplifiers be "perfect"). This assumes the phase errors are adding up in a worst case fashion:

$$\text{Then } \phi = 180^\circ + 6^\circ = \pi + 6^\circ$$

$$\begin{aligned} V_{out} &= e^{-j(\pi + 6^\circ - \frac{\pi}{2})} [(1 + 1)(\sin 45^\circ)(\cos 45^\circ)] \\ &= e^{-j(\frac{\pi}{2} + 6^\circ)} [(2)(.707)(.707)] \\ &= e^{-j(96^\circ)} [1] \\ &= (\cos 96^\circ - j \sin 96^\circ)[1] \\ &= (-\sin 6^\circ - j \cos 6^\circ)[1] \end{aligned}$$

$$V_{out} = (-.1045 - j .995)$$

The output voltage vector at a relative phase of -90° is now equal to .995 of the input.

$$V_{out} = -.04 \text{ dB}$$

Hybrid phase imbalance of $\pm 1.5^\circ$ (adding in worst case fashion) results in a power loss of only .04 dB at the amplifier output. Please note that the phase imbalance of most Anaren hybrids is *typically* $\pm 0.5^\circ$ and not the maximum spec of $\pm 1.5^\circ$.

Summary

Balanced transistor amplifiers using 3 dB hybrids provide good input and output impedance match and offer good power handling capability.

An amplifier using "perfect" hybrids (no amplitude or phase imbalance) will focus all the power to the output port. Any amplitude or phase imbalance will cause some power to be directed to the terminated port and will result in power lost at the output port.

The effects of amplitude and phase imbalance for an amplifier using octave band hybrids were examined. Only 0.11 dB is lost to defocusing; about 0.07 dB for amplitude imbalance and 0.04 dB for phase imbalance.

A closing comment: Better hybrid amplitude balance could, in fact, be provided by using multi-section hybrids. However, production tolerances would make it impossible to economically provide octave-band amplitude balance better than ± 0.2 dB. More importantly, any amplifier performance improvement due to better amplitude balance is usually nullified by the increased insertion loss of the multi-section hybrid.

Derivation of Output Expressions for 90° Hybrids

The general expression for any backward wave 90° hybrid coupler with two inputs (a, b) is:

$$\begin{aligned} \text{Port 1: } & j(a \sin \theta) e^{-j(\beta l + \epsilon)} + (b \cos \theta) e^{-j(\beta l + \epsilon)} \\ \text{Port 2: } & (a \cos \theta) e^{-j(\beta l + \epsilon)} + j(b \sin \theta) e^{-j(\beta l + \epsilon)} \end{aligned}$$

where: $(\beta l + \epsilon)$ is the coupler insertion phase plus a small dispersive phase error

and: β = propagation constant ($\frac{2\pi}{\lambda}$)

l = coupled length

ϵ = small phase dispersion error term

θ = coupling angle and a, b are voltages

The output expressions simplify if a is the only input ($b = 0$):

$$\begin{aligned} \text{Port 1: } & j(a \sin \theta) e^{-j(\beta l + \epsilon)} \\ \text{Port 2: } & (a \cos \theta) e^{-j(\beta l + \epsilon)} \end{aligned}$$

Letting $a = 1$ (volt) and ignoring ϵ :

$$V_{coupled} = j(\sin \theta) e^{-j\beta l}$$

$$V_{dc} = (\cos \theta) e^{-j\beta l}$$

These expressions can be simplified even further at midband where:

$$\beta l = \frac{\pi}{2} \quad (l = \frac{\lambda}{4})$$

$$\text{then } e^{-j\beta l} = \cos \frac{\pi}{2} - j \sin \frac{\pi}{2} = 0 - j = -j$$

$$\text{and } V_{coupled} = j(\sin \theta)(-j) = \sin \theta$$

$$V_{dc} = (\cos \theta)(-j) = -j \cos \theta$$

$$\text{If } \theta = 45^\circ \text{ (perfect 3 dB coupling)}$$

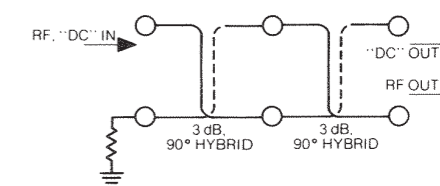
$$V_{coupled} = \sin 45^\circ = 1/\sqrt{2}$$

$$V_{dc} = -j \cos 45^\circ = -j/\sqrt{2}$$

When two 3 dB, 90° hybrids are connected in tandem, the resulting four-port network (Fig. 1) displays some interesting properties. This occurs because two couplers connected back-to-back behave like a single coupler with a coupling angle equal to the sum of the two individual coupling angles. If each of the two couplers have maximum coupling angles of 45° (3 dB couplers) their combined coupling angle is 90° (a 0 dB coupler). This device is useful as a diplexer and can be used to separate low frequency signals (IF, video, dc) from high frequency (RF) signals.

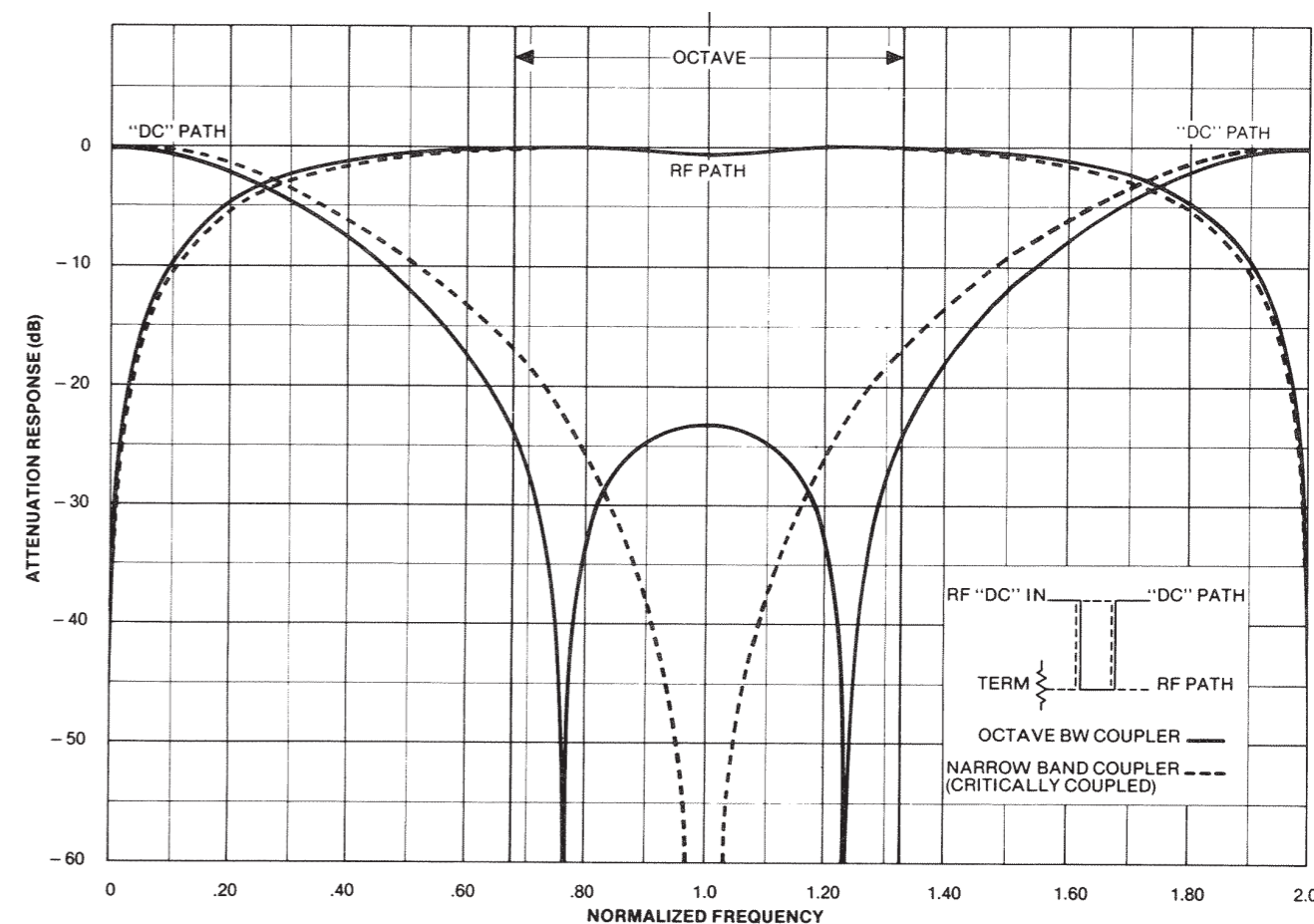
Figure 2 is a graph showing the attenuation response of the network to signals of different frequencies. (1) The frequency scale is normalized to the hybrid's band center ($f_c = 1.0$) to make the graph usable for all tandem connected 3 dB,

Figure 1 - Signal Diplexer ("Crossover")



90° hybrids (having the same model number). The attenuation scale is dB loss from the RF, "DC" input (ignoring coupler insertion loss).

Figure 2 - Diplexer ("Crossover") Response

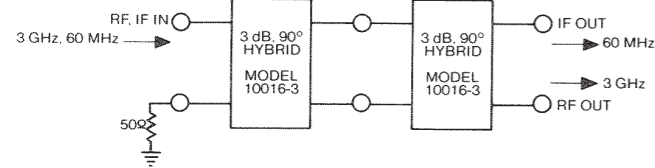


(1) The solid curves on Figure 2 show the response when using typical octave band devices. The dashed curve shows the response when using critically-coupled hybrids, i.e. devices that have 3 dB coupling only at band center. The difference in attenuation response characteristics between the octave and narrow-band devices is most evident when looking at the low frequency ("DC") path. The nulls in the attenuation response occur at points of exactly 3 dB coupling: band center (f_c) for the critically coupled hybrids and at the crossovers ($.77f_c$ & $1.23f_c$) for the octave band hybrid. Production variations that affect the crossover (3 dB) points will affect the position and depth of the nulls.

Using the Graph

Assume that a transmission line contains signals at 3 GHz and 60 MHz. Two 3 dB, 90° hybrids (Anaren Model 10016-3) can be used to direct the low frequency (60 MHz) signal to one output port and the 3 GHz signal to the other output, as shown by Fig. 3.

Figure 3 - RF/IF Diplexer



The normalized freq. of 1.0 (f_c) on the chart corresponds to the hybrid center frequency (3.0 GHz for the Model 10016-3). The chart shows that there is negligible loss between the RF, IF IN port and the RF OUT port for the 3 GHz signal; the 60 MHz signal (a normalized frequency of .02) is down approximately 24 dB at the RF OUT port.

The 60 MHz signal exits at the “DC” port with negligible loss while the 3 GHz signal is down approximately 24 dB. (If the coupler was critically coupled, meaning it was designed for exactly 3 dB coupling at band center, the rejection at the “DC” port to the 3 GHz signal would be infinite.)

The diplexer in the example just cited could be used for increasing the LO/IF or RF/IF isolation of an S-band mixer having a 60 MHz IF. If the mixer alone had 20 dB LO/IF isolation, the diplexer would provide at least 24 dB additional rejection at any point in the 2-4 GHz octave. In addition, the LO and RF signals would be terminated in a matched load and would not reflect back into the IF port to cause additional intermodulation problems. In this case, the diplexer performs as a low-loss, low-cost filter, matched at all frequencies.

Extended Band Coupling Data for Single-Section Hybrids and Directional Couplers

The coupled power from both the dc (mainline) and ac (coupled) ports of single-section 3 dB and directional couplers is frequency sensitive. The charts and examples in this section are designed to provide out-of-band coupling data for these devices.

Figure 1 shows typical extended-band characteristics for an octave-band 3 dB, 90° hybrid. The frequency scale is normalized to 1.0 at the coupler center frequency (f_c).

Example 1: A model 10016-3 hybrid is to be used at 1200 MHz rather than its octave band design range of 2-4 GHz. What are the coupling values at the 0° and -90° ports?

First; calculate f_c for the 10016-3:

$$f_c = \frac{f_{LO} + f_{HI}}{2} = \frac{2 \text{ GHz} + 4 \text{ GHz}}{2} = 3 \text{ GHz}$$

Second; normalize 1200 MHz to f_c : $\frac{1200}{3000} = 0.4$

Third; read the coupling values from the two curves at $f_c = 0.4$:

Coupling value at coupled (0°) arm = -5.45 dB

Coupling value at dc (-90°) arm = -1.45 dB

Figure 1 - Extended Band Coupling Data For Octave Band 3 dB, 90° Hybrids

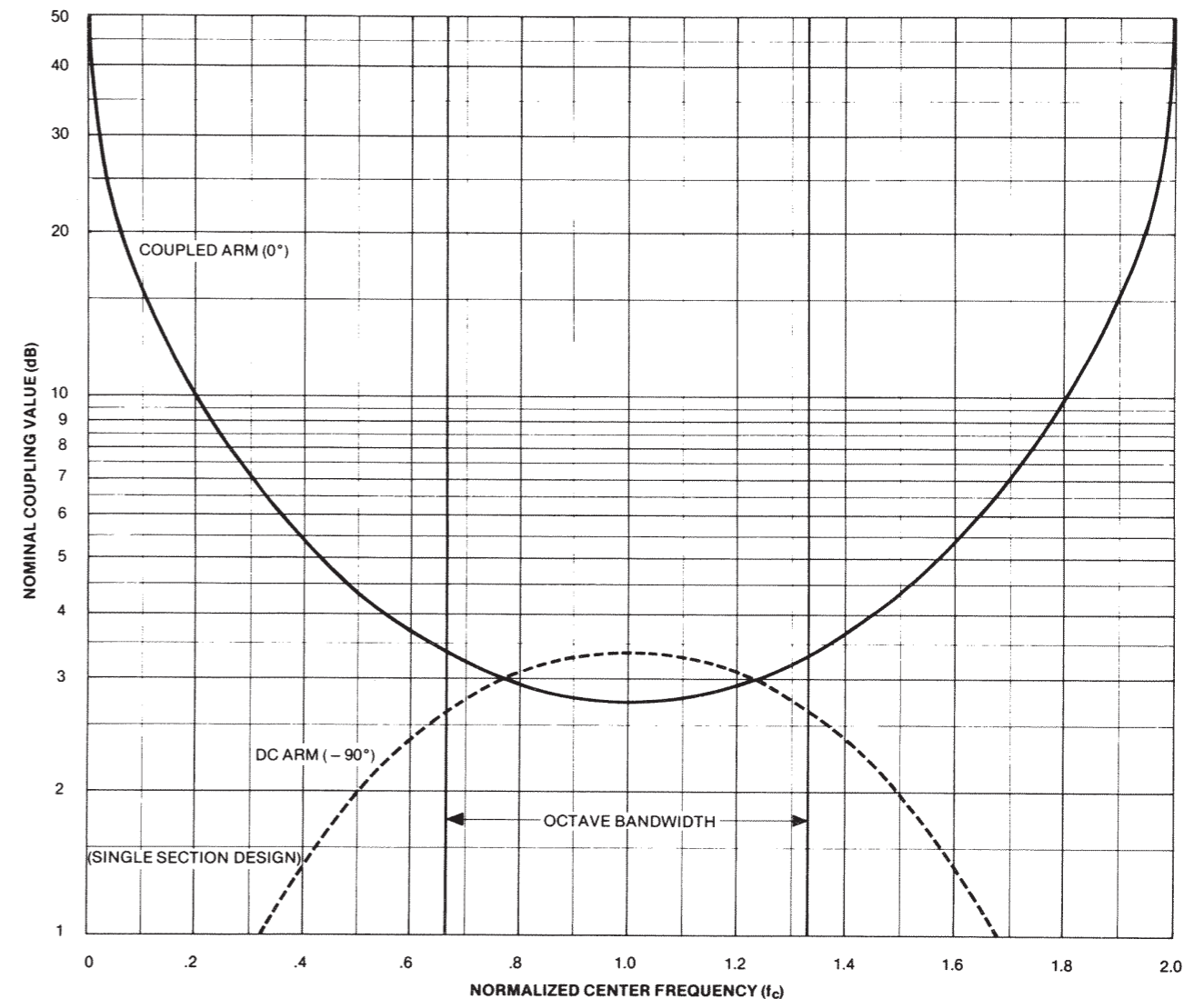


Figure 2 is similar to Figure 1 except that it details the frequency response of the *coupled arm only* for couplers of various coupling values.

Example 2: What is the expected roll-off at 5 GHz for a Model 10616-6 directional coupler?

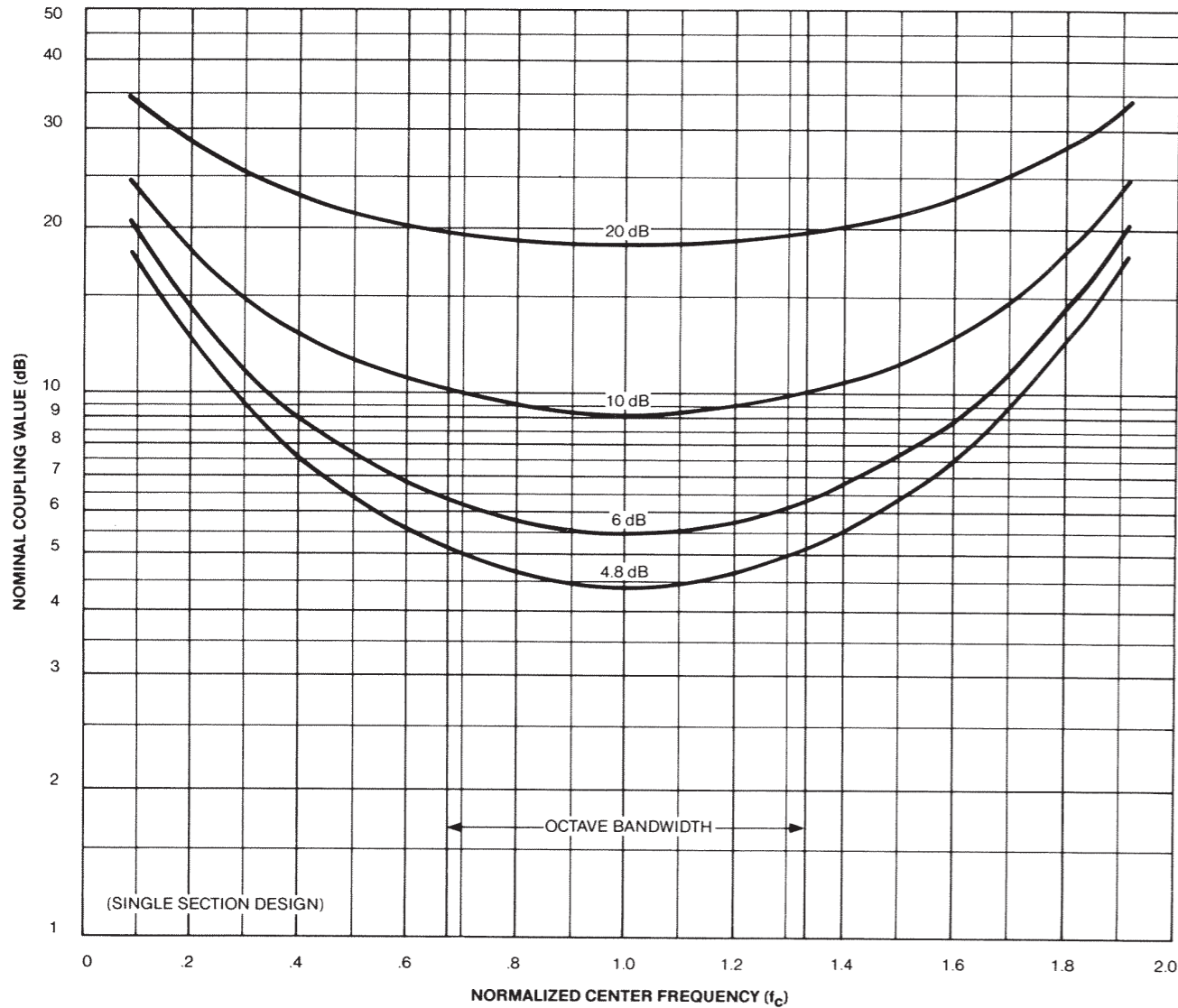
First: calculate f_c for the 10616-6:

$$f_c = \frac{f_{LO} + f_{HI}}{2} = \frac{2 \text{ GHz} + 4 \text{ GHz}}{2} = 3 \text{ GHz}$$

Second; normalize 5 GHz to $f_c \frac{5}{3} = 1.666$

Third; read the coupling value from the -6 dB curve at $f_c + 1.666$: approx. -10.2 dB

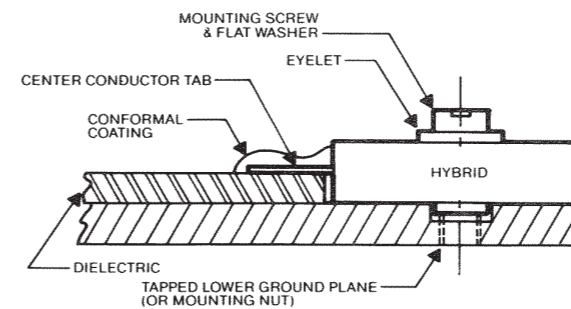
Figure 2 - Extended Band Coupling Data for Directional Couplers



Installation Details for Caseless Couplers and Combiner-Dividers

Anaren's caseless couplers *must* be installed with the label up for good case to ground plane contact. Caseless couplers can be installed in microstrip or stripline transmission media. Most units are designed for circuits using .030 inch dielectric material. Note that the ground plane mounting surface must be counterbored to clear the eyelet protrusion on the caseless coupler as shown in Figure 1.

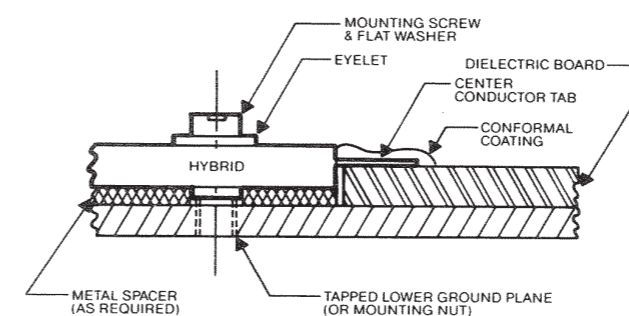
Figure 1 - Basic Mounting, Side View



This counterbore assures that the coupler is well grounded to provide the extremely low inductance ground paths necessary for good high frequency performance. It also promotes heat dissipation in high power applications and ensures flush contact of the coupler conductor tabs to the mating microstrip conductors.

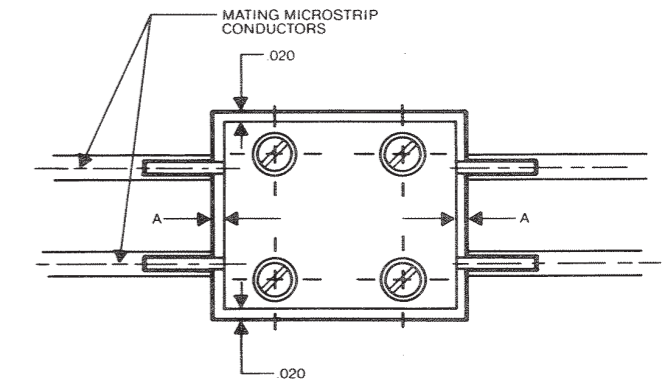
Figure 2 shows the use of a metal spacer to provide good electrical ground contact the and flush tab contact when the dielectric board is more than one-half the hybrid thickness.

Figure 2 - Mounting with Spacer, Side View



In normal installation, an area is cut-out of the dielectric board to accommodate the coupler as shown in figure 3.

Figure 3 - Basic Mounting, Top View



To permit proper tab alignment to the board's microstrip conductors, approximately .020 inch clearance is allowed on each side of the coupler.

The clearance dimension "A" on the tab sides of the coupler should be minimized to limit the inductance caused by conductor tab spanning an air gap. An "A" dimension of .020 inch is acceptable up to 150 MHz, .010 inch up to 1 GHz and .005 inch up to 2 GHz. Above 2 GHz this dimension becomes very critical and every effort must be made to minimize it.

Screws are normally used to fasten the coupler to the system ground plane. This ground plane may be tapped or it may be drilled with clearance holes for a mounting nut.

Conductor tabs may be attached to the microstrip conductor by soldering, conductive epoxy, welding or any other low contact resistance attaching method.

High Power Considerations

For use in application at or near their rated power, Conformal coating on the tab to coupler interface is required to eliminate arcing and voltage breakdown caused by this sharp transition region. Conformal coating the tabs also is required in high humidity and high altitude application.

Heatsinking, other than normal mounting is not normally required. However, when operating at high power, any effort to improve heat dissipation will minimize the insertion loss due to copper resistance increasing as temperature increases.

General

Mixers are used to convert a signal from one frequency to another. This is done by combining the original RF signal with a local oscillator signal (LO) in a non-linear device such as a Schottky-barrier diode.

The diode output spectrum includes:

- the original inputs, LO and RF
- all higher order harmonics mLO and nRF (where m, n are integers)
- the two primary sidebands, LO ± RF (m, n = 1)
- all higher order products of mLO ± nRF (where m, n are integers)
- a dc output level

The desired output frequency, commonly called the intermediate frequency (IF), can be either the lower (LO-RF) or upper (LO + RF) sideband. When a mixer is used as a down-converter, the lower sideband is the sideband of interest. (Unless specifically noted, we will use the term "mixer" synonymously with down-convertors.)

A microwave *balanced* mixer makes use of the 3 dB hybrid to divide and recombine the RF and LO inputs to two mixing diodes. The 3 dB hybrid can be either the 90° or 180° type. Each has certain advantages that will be covered later. The critical requirement is that the LO and RF signals be distributed uniformly (balanced) to each mixer diode.

Figure 1 is a typical balanced mixer block diagram. The mixer diodes are reversed relative to each other; the desired frequency (IF) components of each diode are then in-phase while the dc outputs are positive and negative, respectively.

The two diode outputs are summed in a tee where the dc terms cancel and only the desired IF component exits at the IF port.

Mixer Types Compared

While Anaren's 3 dB, 90° and 180° type mixers are in widespread use and quite effective, Anaren also supplies two other basic mixer types. These are the double-balanced mixer and the Ortho-Quad® (quadrature fed dual) mixer. None of the four mixer types is optimum for all parameters. The relative advantages and disadvantages of each type are summarized in Table 1. Careful use of the table will allow the selection of the optimum mixer type for a particular application. A more detailed discussion of the mixer parameters follows the table.

Figure 1 - Simplified Block Diagram of 3 dB Hybrid Balanced Mixer

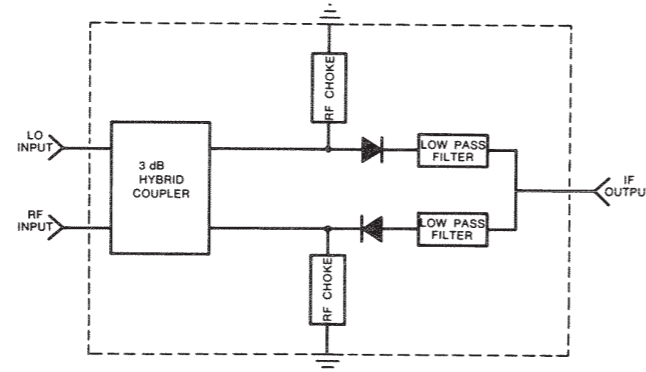


Table 1 - Anaren's 3 Basic Mixer Types — Performance Comparison

Mixer Type	Typical* Anaren Model No.	No. of Diodes ⁽¹⁾	VSWR ⁽²⁾	Conversion Loss ⁽³⁾	LO/RF Isolation ⁽⁴⁾	Bias	Spurious Rejection ⁽⁵⁾ m-n = 1	Harmonic Suppression ⁽⁶⁾	Intercept Point ⁽⁷⁾ (dBm)	Dynamic Range	IF Bandwidth	Image Focusing Port ⁽¹⁰⁾
90° Hybrid	70116 7H0116	2	Good Good	Lowest Lowest	Poor Poor	No Yes	Poor Fair	Poor Fair	+15 +30 ⁽⁸⁾	High Highest	Wide Wide	LO LO
180° Hybrid**	7B0055 70580	2	Poor Poor	Low Low	Good Good	Yes Yes	Fair Fair	Good Good	+15 +30 ⁽⁸⁾	High Highest	Wide Wide	RF RF
Double-Balanced	73125	4	Poor	Low	Very Good	No	Good	Very Good	+18	High	Extremely Wide ⁽⁹⁾	RF
Ortho-Quad®	74125	4	Poor	Low	Excellent	No	Good	Very Good	+18	High	Extremely Wide ⁽⁹⁾	RF
	7A0126	4	Good	Low	Very Good	No	Good	Fair	+18	High	Wide	Internal Load

NOTES:

- (1) 2-diode types require +7 dBm LO power for best performance; 4-diode types require +10 dBm LO power.
- (2) VSWR: Poor: 2.5:1 typ
Good: 1.3:1 typ
- (3) Conversion Loss: Lowest: 5 - 7 dB typ
Low: 7 - 9 dB typ
Poor: 10 dB typ
Good: 20 dB typ
Very Good: 25-30 dB typ
Best: 35-40 dB typ
- (4) LO/RF Isolation: Poor: 10 dB typ
Good: 20 dB typ
Very Good: 25-30 dB typ
Best: 35-40 dB typ
- (5) mxn Spurious Rejection: where |m-n| = 1: i.e., 1x2, 2x1, 2x3, 3x2, etc.
Poor: partial rejection of most |m-n| = 1 spurs
Fair: partial rejection of most |m-n| = 1 spurs (bias adjust will suppress some spurs even further)
Good: potentially rejects all |m-n| = 1 spurs
- (6) Harmonic Suppression: Poor: partial rejection of LO/RF even harmonics (bias adjust will suppress some harmonics even further)
Fair: partial rejection of LO/RF even harmonics (bias adjust will suppress some harmonics even further)
Good: can reject all LO even harmonics
Very Good: can reject all LO and RF even harmonics
- (7) Intercept Point: Typical third order intercept point is 6 to 9 dB above the LO power.
- (8) This intercept point can only be achieved by using the optimum load line biasing technique (see page 000) and increasing the LO power to approximately +23 dBm.
- (9) The IF bandwidth for the 73000 series of balanced mixers overlaps the RF range of the units. Bandwidths from DC to 4 GHz are available.
- (10) Image Focusing: defines where image signal energy is focused, LO port, RF port, or to internal termination. Where this image signal is focused can affect mixer performance in phase and amplitude tracking systems. (See page 000 for additional information.)

*Typical models shown are L-band or S-band units.

**Due to improved performance to be found in Anaren's double-balanced mixer series 73120 and 74120, 180° balanced mixers are no longer available as a separate line. However, they are discussed in this application section as part of the evaluation of the four basic mixer types.

VSWR

The VSWR specifies the degree of impedance match between the mixer LO and RF ports and the 50 ohm system in which it is used.

One of the most desirable characteristics of the 90° hybrid mixer is its excellent VSWR over the full performance range of the hybrid. When a signal is fed into either input, any reflections from the similar mixer diodes will combine at the other input, providing a low VSWR at either port. The input reflection coefficient for a 90° hybrid mixer having diode reflection coefficients, p_1 , p_2 is given by:

$$\rho_{\text{(mixer, 90°)}} = \frac{p_1 - p_2}{2}$$

If $p_1 = p_2$ (if the diodes are balanced), whatever their value, the input remains matched.

If the mixer uses a 180° hybrid, any reflections from the similar mixer diodes will be focused back to the input port. Unless the diodes look like a very good match, the input VSWR will be poor. The input reflection coefficient for a 180° hybrid mixer having diode reflection coefficients p_1 , p_2 is given by:

$$\rho_{\text{(mixer, 180°)}} = \frac{p_1 + p_2}{2}$$

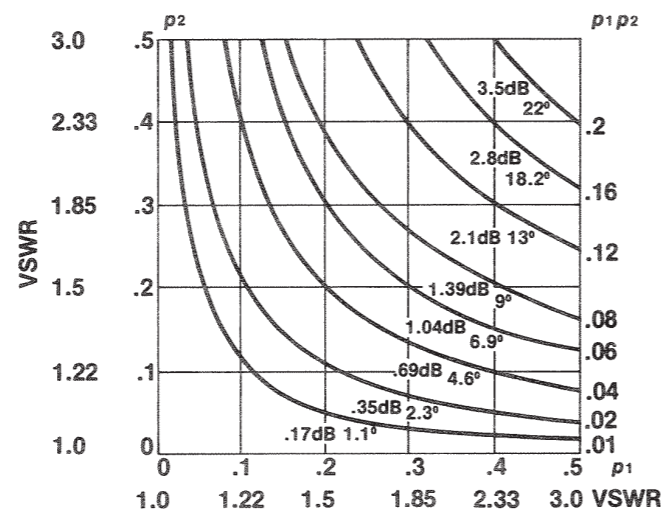
Diode impedance is a function of LO power; therefore VSWR will be affected by LO drive level for this mixer. If the diode impedances are equal, the input VSWR equals the return loss for one diode.

An Ortho-Quad® mixer has the same good VSWR characteristics as the 90° hybrid mixer since it uses 90° hybrids as the coupling mechanism to the diodes.

A double-balanced mixer exhibits poor VSWR characteristics. It uses 180° hybrids as the coupling networks to its diodes and therefore depends on good diode match to provide good input VSWR. In addition, the LO VSWR is frequently degraded even further by the necessity for extracting the IF signal from the LO coupling network. VSWR's of 3:1 or greater are not uncommon for double-balanced mixers.

Low VSWR can be especially important if the mixers are to be used in phase and amplitude tracking receiver systems.⁽¹⁾ The biggest cause of amplitude and phase ripple in a tracking receiver system is the error paths set up by the mismatch of one component beating with the mismatch of another component. Figure 2 shows the phase and amplitude ripple possible from two mismatches on a 50 ohm line. Consider, for example, the errors possible if an antenna and a mixer have a mismatch. If a VSWR of 2.33:1 ($p = 0.4$) is assumed for both components, Figure 2 shows it is possible to have peak-to-peak phase errors of 18.2 degrees and peak-to-peak amplitude errors of 2.8 dB. When it is realized that most microwave *double-balanced* mixers have a VSWR of 3:1 or greater, the typical 1.4:1 VSWR advantage of the Anaren 90° hybrid or Ortho-Quad® mixers becomes apparent.

Figure 2- Amplitude and Phase Ripple Due to Mismatch Errors.



LO/RF Leakage

The LO/RF isolation is a measure of the LO leakage at the RF port of the mixer.

The 90° hybrid mixer has poor isolation characteristics because LO/RF isolation is dependent upon diode match. Any LO energy not absorbed by the diodes is directed to the RF port. The LO/RF isolation for a 90° hybrid mixer having diode reflection coefficients p_1 , p_2 is given by:

$$\text{Isolation (dB)} = 20 \log_{10} \left(\frac{2}{p_1 + p_2} \right)$$

If the diode impedances are equal, the isolation equals the return loss for one diode. Since diode impedance is a function of LO power, the isolation will be sensitive to LO drive.

A 180° hybrid mixer has good isolation characteristics; dependent only on the diode balance regardless of their impedance values. The LO/RF isolation for a 180° hybrid mixer having diode reflection coefficients p_1 , p_2 is given by:

$$\text{Isolation (dB)} = 20 \log_{10} \left(\frac{2}{p_1 - p_2} \right)$$

LO power will not affect isolation if the diodes continue to track each other.

The Ortho-Quad® will have good LO/RF isolation regardless of LO power because a unique, patented phasing network directs any unused LO energy to an internal termination; it will never show up at the RF port as LO/RF leakage. The good LO/RF isolation is independent of LO power level. The Ortho-Quad® is the only one of the four basic type mixers that will provide, simultaneously, good VSWR and good isolation regardless of LO drive level.

The double-balanced mixer has the same good LO/RF isolation characteristics as the 180° hybrid balanced mixer because it uses 180° hybrids as the coupling networks to its diodes. As long as the diodes track each other, the LO/RF isolation will be good and will remain independent of LO power.

For many receiving applications the *amount* of LO power leaking out the RF port is important since it will ultimately be reradiated out of the antennas. A *biased* mixer can be very useful in such applications because LO power and resultant reradiation can be significantly lowered while still maintaining good conversion loss. In fact, using biased 90° balanced mixers may actually result in lower radiated energy from the antenna and better overall performance than when using many double-balanced mixers. Double-balanced mixers at first would appear to offer better results because of their higher LO/RF isolation specs, but the following comparison will serve to illustrate why this may not be the case:

	BIASED 90° BALANCED MIXER (Model 7H0118)	TYPICAL DOUBLE-BALANCED MIXER (Same Frequency as Model 7H0118)
Conversion Loss:	8.0 dB max (0 dBm LO) 8.5 dB max (-4 dBm LO)	9.0 dB max.
LO Power:	0 dBm at 1.8 mA bias -4 dBm at 1 mA bias	LO Power: +10 dBm (no bias option)
LO/RF Isolation:	10 dB typical (6 dB min)	LO/RF Isolation: 17 dB typical*
LO Leakage at RF Port:	-10 dBm (0 dBm LO) -14 dBm (-4 dBm LO)	LO Leakage at RF Port: -7 dBm (+10 dBm LO)
LO, RF VSWR:	1.65 typ. 2.0 max.	LO, RF VSWR: 3.0 typ. 4.0 max.*

*Many double-balanced mixers have no published worst case spec.

The Anaren 7H0118 radiated 7 dB *less* LO power at the antenna terminal than the double-balanced mixer. This improved leakage performance is even more impressive when the rest of the specifications are examined. When compared to the typical double-balanced mixer, the Anaren biased, 90° hybrid mixer has:

1. Lower LO/RF leakage levels.
2. Equal or better conversion loss.
3. 10 to 14 dB *less* LO drive required.
4. Much lower VSWR.

Conversion Loss and Noise Figure

Conversion loss and noise figure are two of the most important and closely-related mixer parameters. The primary requirement for a mixer is to provide maximum IF output power with the minimum RF input power while generating the least amount of noise. Minimum losses in the RF, LO coupling networks, high quality Schottky-barrier (hot carrier) coupling networks to the diodes, broadband diode matching and optimum local oscillator drive, all contribute to the good conversion loss and low noise figure of Anaren's mixers.

Conversion loss of the mixer is a measure of the power at the IF frequency relative to the power at the RF input frequency. It is a function of the mixer alone.

Mixer noise figure is commonly stated at a particular IF frequency when measured in a system containing an IF amplifier following the mixer. This IF amplifier contributes to the measured noise figure. The mixer diodes also can contribute a small amount of noise energy to the noise figure. The measured noise figure (NF_0) in decibels is related to the mixer conversion loss [L_C], the IF amplifier noise figure (F_{IF}), and the mixer diode noise-temperature ratio (T) by:

$$NF_0 = L_C + 10 \log_{10} (F_{IF} + T - 1)$$

where L_C is mixer conversion loss in dB
 F_{IF} is the noise factor (a numeric ratio) of the IF amplifier
T is the effective diode noise-temperature ratio.

T can be as low as 0.85 for modern high-quality hot carrier diodes but a more typical value is 1.0. The relationship between measured noise figure and conversion loss then simplifies to

$$NF_0 = L_C + NF_{IF} \quad (2)$$

where NF_{IF} is IF preamplifier noise figure in dB.

When $T = 1$ the mixers' single-sideband noise figure is the same as its conversion loss. Equation (2) then shows that the overall noise figure is obtained by adding the noise figure of the IF preamplifier directly to the mixer conversion loss.

It is instructive to observe what happens to the overall noise figure when $T = 0.85$. By equation (1):

$$NF_0 = L_C + 10 \log_{10} (F_{IF} + 0.85 - 1)$$

When NF_{IF} is equal to 1.5 dB:

$$\begin{aligned} NF_0 &= L_C + (1.413 - 0.15) \\ &= L_C + 1.02 \text{ dB} \end{aligned}$$

The combined preamplifier/diode noise contribution is only 1.02 dB, 0.48 dB *less* than that produced by the preamplifier alone.

All noise figure measurements relating to Anaren mixers are based on single sideband operation using a 30 or 60 MHz IF preamplifier having a NF_{IF} of 1.5 dB.

Bias Option

In many instances the optimum LO power is not available for best conversion loss. The conversion loss of an unbiased mixer degrades rapidly as the LO power decreases. This is due chiefly to diode mismatch at the RF and IF frequencies. The diode mismatch can be minimized and the conversion loss dramatically improved by biasing the diode with a dc current.

Anaren provides biased 90° hybrid mixers and biased 180° hybrid mixers as standard catalog items. Figure 3 is a block diagram for a 90° biased mixer and Figure 4 shows how conversion loss and optimum bias current typically vary with changing LO power. These biased 90° mixers use a single bias terminal with no internal current limiting resistor.

Figure 3 - Simplified Block Diagram of 90° Hybrid Biased Mixer.

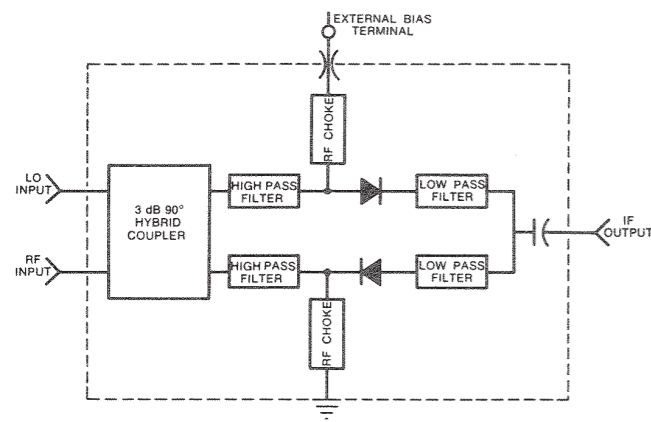
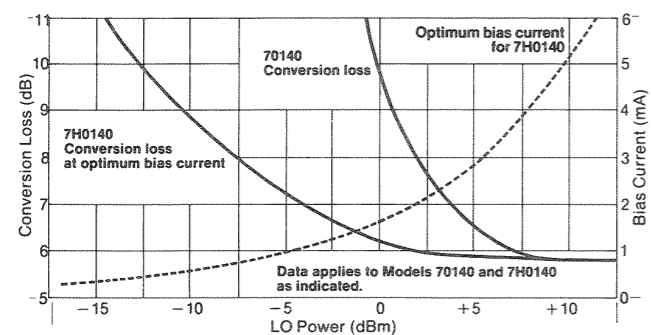


Figure 4 - Conversion Loss and Bias Current versus LO Power for 90° Hybrid Biased Mixer.



The 180° hybrid biased mixers use two bias terminals and most use internal current limiting resistors. Figure 5 is the block diagram for a 180° biased mixer. Figure 6 shows how conversion loss and optimum bias voltage typically vary as the LO power is changed. Note that, unlike the 90° biased mixer, bias voltage must be applied at all times for proper operation of the 180° biased mixer; even when normal LO power (+ 7 dBm) is applied. This is because the only dc return for the diode current is through the large (typically 3.3 K ohm) internal current-limiting resistors.

Figure 5 - Simplified Block Diagram of 180° Hybrid Biased Mixer

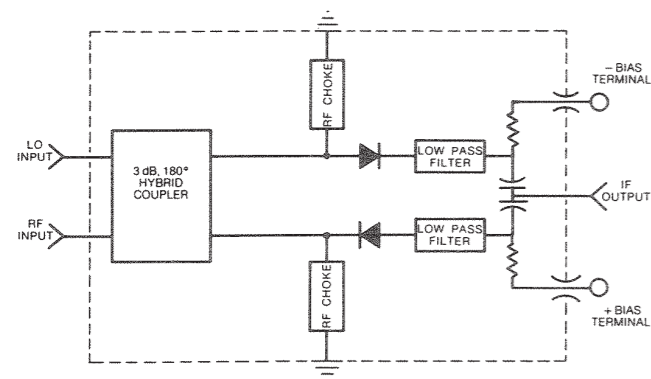
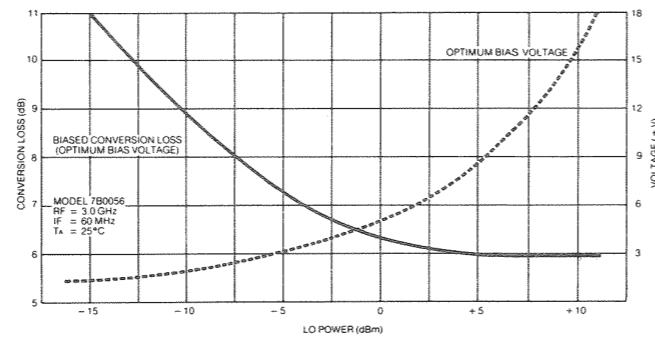


Figure 6 - Conversion Loss and Bias Current vs. LO Power for 180° Hybrid Biased Mixer



It is convenient to have current limiting resistors built into a mixer so that all one has to do is apply the correct bias voltages to the bias terminals. However, it turns out that having direct access to the diodes dc bias point allows a number of bias techniques to be used. One of these techniques, the optimum load line approach, allows the designer to optimize conversion loss and other mixer parameters over a wide LO dynamic range.

These bias techniques were first developed for use with Anaren's 90° hybrid balanced mixers and are available for use with the standard catalog models. Other mixer types can be supplied with similar bias options, on special order, but the discussion which follows will be directed toward the standard catalog line of 90° biased mixers.

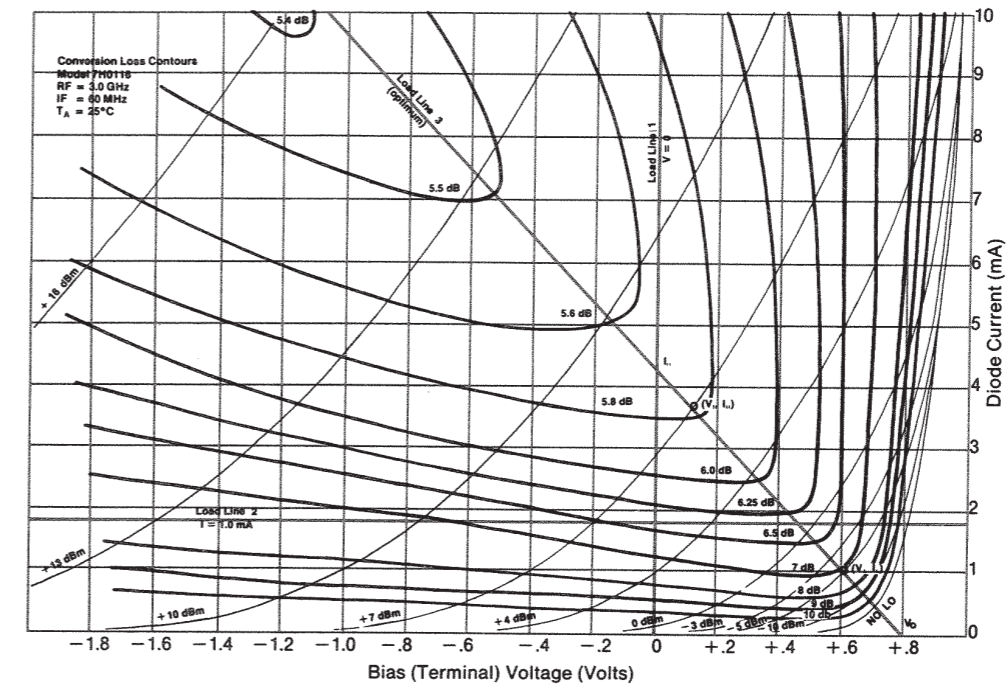
Bias Techniques

Conversion loss, VSWR and spurious response characteristics of a mixer depend upon the impedance presented to the diodes, not only at the RF and IF frequencies, but over the entire spectrum present in a Taylor's expansion of the diode current⁽²⁾. For biased mixer operation the dc impedance presented to the diode is most important. A family of I-V characteristics can be measured and plotted as a function of applied LO power with conversion loss, RF VSWR and spurious response contours then plotted over the I-V curves. Various load lines* can then be plotted revealing mixer performance under various bias and LO conditions.

Figure 7 shows the I-V characteristics and conversion loss contours for a typical mixer and illustrates the three types of load lines most useful for the majority of mixer applications. The first type is the unbiased diode (zero load resistance: voltage = constant = 0) which covers the majority of mixers in use today. The second type is the constant current load line (I = constant) which has been commonly used where insufficient LO power is available. The third case is a new approach⁽¹⁾ which optimizes both conversion loss and RF VSWR over a wide LO dynamic range through the use of an optimum load line.

*Where there is a resistance load in the diode's circuit, the voltage acting on the diode is a function of this external resistance network and any external bias voltage applied. This function can be expressed as an equation and may be represented by what is commonly known as a load line on the diode I-V characteristics. Because the load is a pure resistance it will obey Ohm's Law, and the relationship between current and voltage will be a straight line. Zero load resistance is indicated by a vertical load line, while a horizontal line indicates infinite resistance.

Figure 7 - Conversion Loss Contours



The simplest biasing technique (Figure 8a) is the constant current load line chosen to optimize conversion loss at a lower than normal LO power. A series resistor R_s is chosen according to the formula

$$R_s = \frac{V_b - V_d}{I_b}$$

where

- I_b = desired bias current (amps) from Figure 4
- V_b = supply voltage (volts)
- V_d = total diode voltage drop (volts)

V_d varies with LO power but is between 0.2 volts and 0.8 volts for LO powers between + 3 dBm and - 10 dBm.

Example: Assume a + 6V supply and desired operation at 0 dBm LO power;

$$\begin{aligned} \text{then } R_s &= \frac{6V - 0.5V}{1.8 \times 10^{-3} A} \\ &= \frac{5.5V}{1.8 \times 10^{-3} A} \end{aligned}$$

and $R_s = 3.06 K$ ohms

A 3.1 K Ohm resistor in series with a + 6V supply would, therefore, bias the mixer correctly for 0 dBm LO power.

The constant current load line works best for situations where the LO power variation can be limited to about ± 2 dB.

The optimum load line bias technique can optimize conversion loss (also VSWR and spurious) performance even if the LO power varies as much as 40 dB. Once a particular mixer has been characterized, implementing the required load line is straightforward.

The bias circuit required is a series and shunt resistor network connected as shown in Figure 8b.

The series resistor R_1 is chosen such that

$$R_1 = \frac{V_b}{I_0}$$

Figure 8a - Constant Current Bias

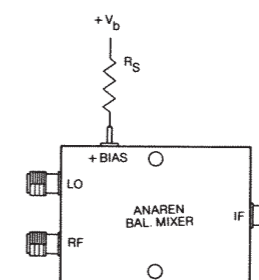
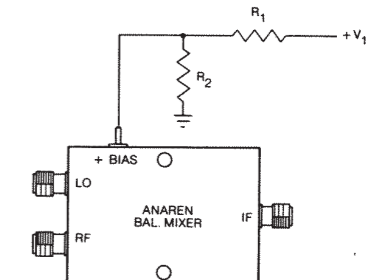


Figure 8b - Optimum Load Line Bias



where V_b = supply voltage (volts)

I_0 = is the dc current value at the intersection of the proper load line and current ($V = 0$) axis of Figure 7.

The shunt resistor R_2 is chosen by

$$R_2 = \frac{V_0 R_1}{V_b - V_0}$$

where V_0 = the voltage value (volts) at the intersection of the proper load line and the voltage ($I = 0$) axis of Figure 7.

Each Anaren biased mixer is individually characterized by measuring two current and voltage points on the optimum load line. These values are supplied on each mixer test data sheet in the form shown by Figure 9.

Figure 9

LO @ +7 dBm	LO @ -5 dBm
V _H = ___VOLTS	V _L = ___VOLTS
I _H = ___MA	I _L = ___MA

One of the measured points (V_H, I_H) is measured at +7 dBm LO power and the other point current and voltage axes, as LO power. The current intercept (I₀) and voltage intercept (V₀) for the required resistor calculations can then be found graphically by extending the optimum load line through the two measured points to the (V_L, I_L) is measured at -5 dBm illustrated in Figure 7.

Alternately, I₀ and V₀ could be calculated directly by using:

$$V_0 = V_L + \frac{I_L}{m}$$

$$I_0 = mV_0$$

where $m = \frac{I_H - I_L}{V_L - V_H}$ = slope of the optimum load line

Example: Assume a +6V supply and calculate the required values for R₁ and R₂ for optimum load line bias technique of Figure 8b. From Figure 7 or test data information (Figure 9) supplied with mixer:

$$V_H = 0.12V \quad V_L = 0.61V$$

$$I_H = 3.6mA \quad I_L = 0.95mA$$

$$\text{then } m = \frac{(3.6 - 0.95) \times 10^{-3}}{(0.61 - 0.12)}$$

$$= \frac{2.65 \times 10^{-3}}{0.49} = 5.41 \times 10^{-3}$$

$$\text{and } V_0 = 0.61 + \frac{0.95 \times 10^{-3}}{5.41 \times 10^{-3}} = 0.61 + .176 = .786V$$

$$I_0 = 5.41 \times 10^{-3} (.786) = 4.25 \times 10^{-3}A$$

Therefore:

$$R_1 = \frac{6.0V}{4.25 \times 10^{-3}A} = 1.412 \times 10^3 \text{ ohms}$$

$$R_2 = \frac{.786(1.412 \times 10^3)}{6.0 - .786} = \frac{1.110 \times 10^3}{5.214} = 213 \text{ ohms}$$

$$\text{Use } R_1 = 1.5 \text{ K ohms}$$

$$R_2 = 220 \text{ ohms}$$

The two-resistor bias network just described minimizes the mixer conversion loss over an extended LO dynamic range. It also turns out that spurious and two-tone intermodulation performance of these mixers can be improved by operating the diodes at high LO powers while the bias network maintains optimum conversion loss.

Both the constant-current and optimum load line bias techniques should be temperature compensated if

performance is to be maintained over wide temperature variations. If temperature compensation is not used, the constant current load line is more tolerant of temperature variations, especially for mixer operation at low LO power.

These mixers having the bias option differ from some types of biased mixers because they can also be used with no external bias. This is accomplished by directly grounding the bias terminal (zero load resistance) and applying sufficient LO power. As shown in Figure 4, an LO drive of +7 dBm is typically required for optimum performance.

Figure 3 shows how the bias circuitry is implemented in the mixer. The bias terminal is an EMI low-pass (pi-network) filter. It does not protect against low frequency (less than 1 MHz) noise or voltage surges. The bias supply should, therefore, be reasonably well regulated and filtered for optimum mixer performance and diode protection.

Intermodulation Performance

Strictly speaking, all mixer outputs other than the desired sideband (LO - RF = IF) are "spurious" responses. However, the spurious responses that will be considered in this section are the two major types of distortion products—single-tone (harmonic) intermodulation and two-tone intermodulation.

A mixer diode, due to its I-V curvature, is an efficient harmonic generator and will produce the entire spectrum of mixing terms present in the Taylor's expansion of diode current. All of these terms are of lower amplitude than the desired IF output but can be reduced even further by various techniques. A *single-ended* mixer filters out many of the higher-order terms with a frequency selective decoupling network behind the diode. *Balanced* mixers depend on the phasing properties of their LO and RF coupling networks, (3 dB, 90° or 180° hybrids) for added spurious suppression. Most *double-balanced* mixers, by virtue of their 4-diode network and symmetry of their LO and RF coupling networks, achieve additional suppression without need for frequency selective filters.

Harmonic Intermodulation

Single-tone harmonic intermodulation products result from the mixer local oscillator and its harmonics beating with the RF input signal and its harmonics. They are of the form mLO ± nRF and are usually classified by their "order". For example, when the third harmonic (m = 3) of the LO beats with the second harmonic of the RF (n = 2) the resulting intermodulation product is a fifth-order term (m + n = 5). This term is also commonly called a "three-by-two" (3x2).

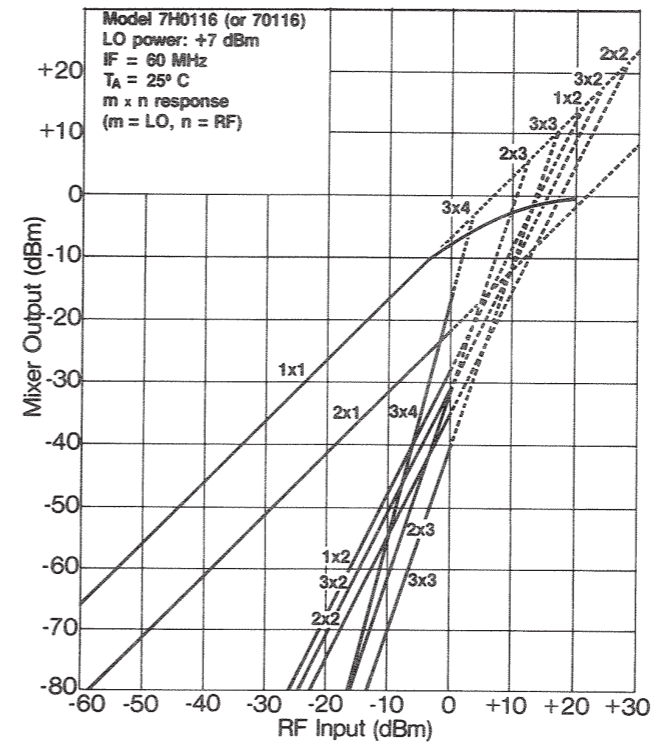
Suppression of single-tone intermodulation products by a balanced mixer* depends primarily upon good mixer balance. The more uniform the distribution of RF and LO power to the diodes, and the more closely matched the diode characteristics, the better the mixer balance.

*Compared to an unfiltered, single-ended mixer.

Suppression of single-tone (harmonic) intermodulation products is dependent upon the RF and LO phase codes at the diode junctions. If the RF and LO harmonics are properly phased, complete suppression of some harmonic intermodulation terms is possible. For example, all four basic mixer types, theoretically, completely suppress the 2x2, 4x4, and other even m x n harmonics. (Conversely, none of the mixers suppress the 3x3, 5x5 or other odd m x n harmonics).

The 90° hybrid balanced mixer has a phase code that provides at least 3 dB additional suppression for all harmonics of the LO and RF inputs, save the 2x4, 4x2, 3x3 and 5x5. It also, theoretically, completely suppresses the 2x2, 4x4, 3x1, 1x3, 3x5 and 5x3 terms. [In this discussion of intermodulation performance we will limit ourselves to 5x5 terms or lower (m, n ≤ 5).] Figure 10 shows typical single-tone intermodulation response for a 90° mixer.

Figure 10 - Single-Tone Intermodulation Response



The Ortho-Quad® mixer provides identical performance to the 90° mixer except there is as much as 15 dB additional suppression for all the harmonics of the RF input.

The 180° hybrid mixer's suppression characteristics depend upon whether the sum (Σ) or difference (Δ) port of the hybrid is selected as the LO port. When the LO signal is applied to the Δ port, all even harmonics of the LO signal are suppressed. (If the LO is applied to the Σ port, second-order intermodulation is suppressed.)

The double-balanced mixer theoretically can provide complete suppression of all even harmonics of the LO and RF signals. Specification sheets for low frequency (< 100 MHz) double-balanced mixers typically provide

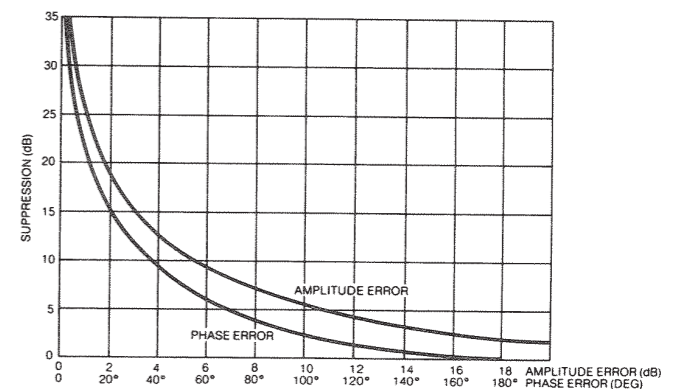
harmonic intermodulation charts for m x n responses which show suppressions as high as 90 dB. Our experience with microwave balanced and double-balanced mixers indicates the microwave system designer should be very cautious about extrapolating this low frequency data to microwave frequencies.

At frequencies of 100 MHz or less it is possible to achieve extremely broadband coupling networks that provide phase and amplitude balances of ± 1 degree and ± 0.1 dB at the input frequencies and their harmonics. This performance is required to obtain harmonic suppression greater than 50 or 60 dB at -10 dBm input levels. Specifications of ± 5° and ± 0.3 dB for phase and amplitude balance are typical for microwave LO and RF coupling networks.

Because phase errors are multiplied by the order of the RF and LO harmonic, it is possible to have very large phase errors that will reduce the actual harmonic suppression. As an example: the 2x2 (mxn) suppression for all mixers is theoretically infinite, but a calculation shows the typical microwave balun could possibly have m(5°) + n(5°) = 2(5°) + 2(5°) = 20° phase error.

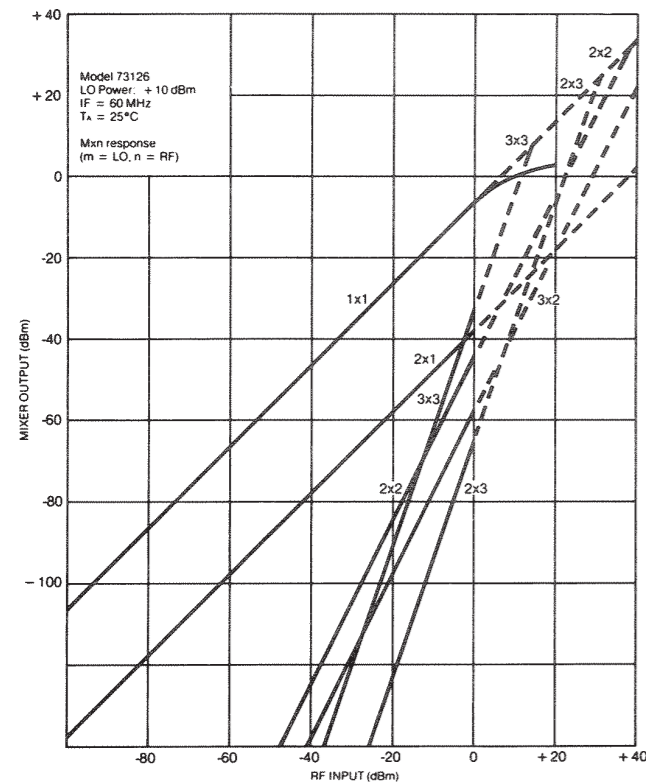
Figure 11, showing the theoretical suppression for various values of phase and amplitude error, gives a maximum suppression value of 15 dB for 20° phase error. At some other point in the band there may be zero phase error, if the balun errors cancel. At that point the suppression would approach infinity (or more realistically, be limited by the balun amplitude balance and/or the diode balance). Our experience has shown the amount of actual suppression to vary by as much as ± 15 dB depending on the exact frequency of operation and the particular order of intermodulation.

Figure 11 - Suppression vs. Phase and Amplitude Error



The double-balanced mixer will consistently provide the best |m-n| = 1 suppression, however. These terms (4x5, 5x4, 3x4, 4x3, etc.) are important because they, along with the 2x2 and 3x3 terms, lie closest to the desired response. Figure 12 shows typical single-tone intermodulation response for a double-balanced mixer.

Figure 12 - Single-Tone Intermodulation Response

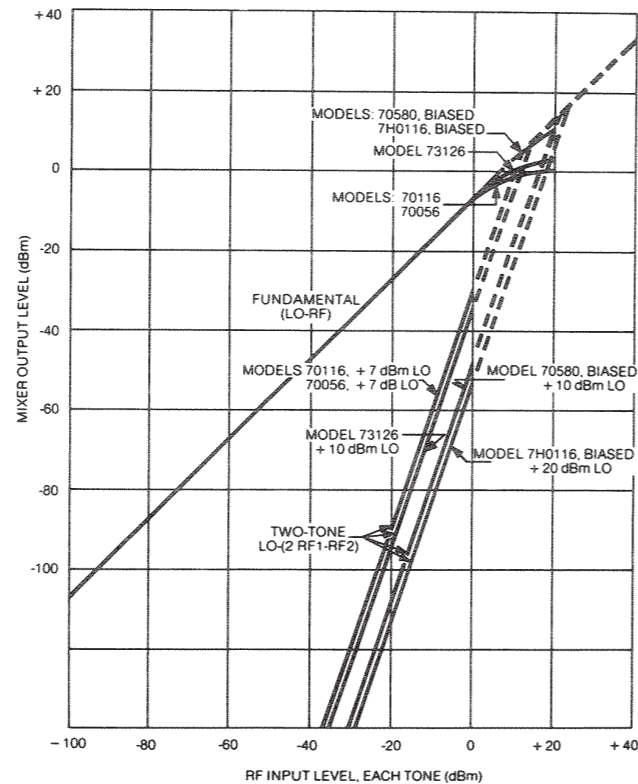


Two-tone Intermodulation/Intercept point

Two-tone intermodulation distortion is the result of two signals being applied to the mixer RF input at the same time. These signals may generate harmonics, mix with each other, then beat with the mixer local oscillator according to the expressions $(2RF_1 \pm RF_2) \pm LO = IF$ or $(RF_1 \pm 2RF_2) \pm LO = IF$. These are the expressions for the *third-order* two-tone intermodulation products. They are usually of primary interest because of their relatively large magnitude and because they are difficult to filter from the desired mixer output.

A convenient method of determining the two-tone third-order performance of a mixer is the "third-order intercept" approach. It makes use of the intersection of the fundamental and third-order responses on a log-log (or dB/dB) scale. A plot of each response will be a straight line with a slope corresponding to the order of the RF response. (The 1x1 fundamental is a first-order response, a 3x2 is a second-order response, a 2x3 is a third-order response, etc.) The third-order, two-tones will have a slope of 3 when plotted on a dB/dB scale. Figure 13 is a plot of the fundamental and third-order responses for some typical mixers. The third-order intercept for the biased Model 7H0116 mixer occurs at an RF *input* level of + 15 dBm. Note this is a theoretical point, graphically obtained by extending the measured third-order and fundamental responses until

Figure 13 - Fundamental and Two-Tone, Third-Order Response



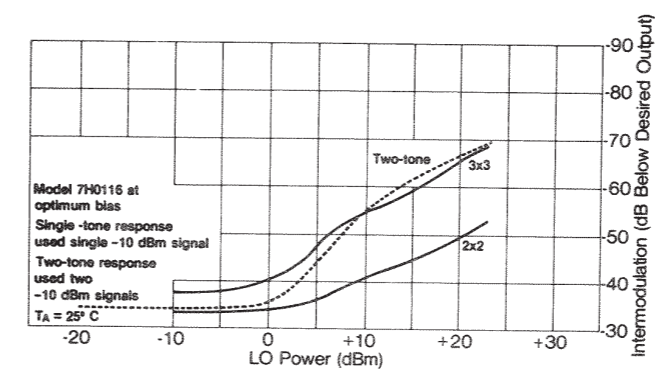
they intercept. Once the intercept point is known the third-order response at any input level can be calculated: with a slope of 3, a 1 dB change in the input level will produce a 3 dB change in the third-order output. Various mixers can be compared for third-order suppression if their intercept points are known—the higher the intercept point, the better the suppression.

Improvement with Bias

Note in Figure 13, the third-order performance of most of the unbiased mixers, regardless of what type they are, is nearly identical. No mixers (balanced or double-balanced, of any type) provide any additional two-tone suppression compared to a single-ended mixer. Two-tone suppression is a function of diode I-V characteristics.

Improved rejection of both single-tone (harmonic) and two-tone intermodulation *can* be improved with the use of high mixer LO power and/or high bias voltage as shown in Figure 14. The intercept point will increase approximately dB for dB, with LO power, if the mixer is properly biased. (Note in Figure 13, the higher intercept point for the biased Model 7H0116 compared to its unbiased version, Model 70116.) Lepoff and Cowley⁽²⁾ have shown this intermodulation improvement to be due to the diode characteristic's departure from the theoretical expression for diode current.

Figure 14 - Intermodulation vs. LO Power



Intermodulation is caused by non-zero values for fourth-order and higher terms in the power series expansion of the diode current-voltage function. For diode voltages near 1 volt they found that the measured diode current drops below the theoretical curve. This meant that the higher-power (intermodulation producing) terms in the power series expansion were smaller at those voltages than they were at lower levels. Therefore, intermodulation rejection could be improved by operating the diode at a higher bias voltage than the *usual zero bias*.

In a balanced mixer in which the two diodes can be operated at different bias voltages (as the Anaren 180° hybrid biased mixers having two bias terminals) some of the higher power terms of one diode's current function can actually be made to cancel the corresponding terms in the other diode's current function. This technique has been used with mixers operating in the 2.2-2.3 GHz telemetry band to obtain greater than 100 dB rejection of spurious components. If the bias voltage is increased still further, the diode current saturates and the second-order (mixing) term decreases in magnitude. There is an optimum bias voltage which minimizes intermodulation yet still provides good conversion loss.

Other high-level mixer designs⁽³⁾ use series diodes or series resistors to achieve the bias effect necessary for good intermodulation performance. These additional elements add complexity, cost, and increased conversion loss and are restricted to optimum performance for high level signals. The Anaren *optimum load line* bias technique allows the lowest conversion loss and the highest intercept point, regardless of signal or LO drive. The LO power can be raised to the level required for best two-tone suppression; without suffering the conversion loss penalty, associated with high LO drive, of mixers not using the load line technique. A special, high-cost, high-level mixer for best two-tone performance is not required. Figure 15 shows the intermodulation performance obtained using the optimum load line bias technique described on page 000. Figure 16 shows performance

Figure 15 - Conversion Loss (at Optimum Bias) & Intermodulation vs. LO Power

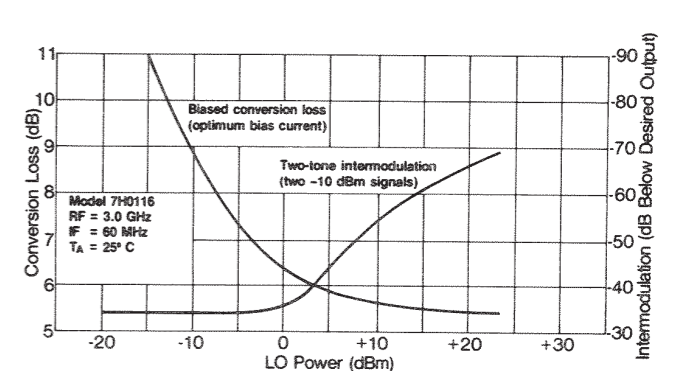
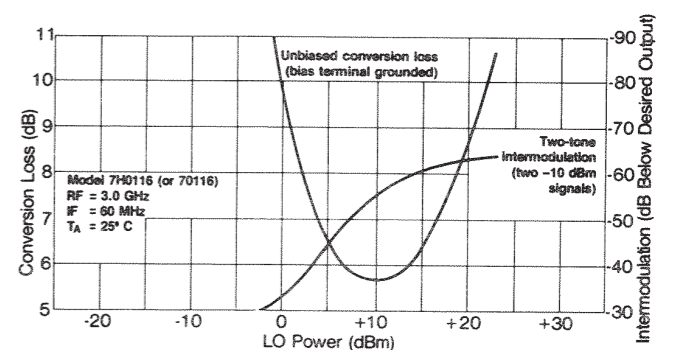


Figure 16 - Conversion Loss (No Bias) & Intermodulation vs. LO Power



when using a non-biased mixer. Comparison of the two figures demonstrates the advantage of using the optimum bias capability. At an LO power of + 23 dBm it provides about 69 dB of intermodulation suppression and a mixer conversion loss of about 5.5 dB. At the same high LO power a normal unbiased mixer provides about 63 dB suppression but the conversion loss has increased to 10.6 dB.

Image Focusing Port

In some mixer requirements, it is important that the internally generated image signal (2LO-RF) be focused where it will not interfere with generation of the desired IF output. One of the sources of phase and amplitude ripple produced by a mixer is the internally generated image signal leaking from the RF port. This signal can be reflected back into the mixer by other component mismatches of the system, mix with the LO and convert to the IF frequency as an error component. The image signal leaking from the LO port does not cause the same problem because it is suppressed by the mixer's common-mode rejection (all four basic mixer types feature good common-mode rejection.)

The 180° mixer and the double-balanced mixer focus the image at the RF ports and the 90° mixer focuses it to the LO port. The Ortho-Quad® mixer does not let the image signal come out either the LO or RF ports. It, and other potentially troublesome harmonic terms, are focused to an internal load. For additional information on other phase and amplitude error considerations see page 116.

IF Bandwidth

The 90° mixer, the 180° mixer and the Ortho-Quad® mixer frequency selective decoupling networks behind the diodes. These networks suppress higher-order spurious components, increase the LO/IF and RF/IF isolation, and minimize the mixer conversion loss at low IF frequencies. A plot of relative conversion loss versus IF frequency for the above 3 mixer types would show the IF response rolling off at approximately 6 dB/octave, and the -3 dB response point at approximately .2 RFL, where RFL is the lower RF band edge. All unbiased units have an IF response that extends down to dc with no conversion loss degradation. Biased units normally contain a dc blocking capacitor(s) in series with the IF output. This limits the low frequency -3 dB response to about 5 MHz.

The double-balanced mixer is available in two versions. One version, in the standard mixer packages, has frequency selective filters at the IF port as described above. The second version, in a miniature package, has an extremely wide IF bandwidth. The IF response extends from dc up into the RF passband because it is extracted with a phasing technique rather than by filtering. These high IF mixers can be extremely useful. Large segments of the RF passband can be downconverted and processed instantaneously using a fixed-frequency (non-scanning) LO. This means a much simpler LO system and elimination of the image and 2x2 and 3x3 spurious response. If the double-balanced mixer is used as a bi-phase (BPSK) modulator, the wide IF band allows very high data rate modulation.

Dynamic Range

Simply defined, dynamic range of a balanced mixer is the power range over which the device can be used. The absolute maximum useful range is limited on the low end by the minimum detectable signal (MDS) and at the high end by mixer saturation level. (The saturation level occurs at an input power level approximately equal to the LO power level less the conversion loss of the mixer).

For most applications however, the dynamic range of interest is usually the "spurious free dynamic range". The upper limit on this dynamic range is set by the maximum input level that generates third-order intermodulation products just equal to the mixer output noise level.

An expression⁽⁴⁾, using the intercept point (IP) for spurious free dynamic range (R_{SF}) is:

$$R_{SF} \text{ (in dB)} = 2/3 [IP - L_c - MDS]$$

Where L_c is mixer conversion loss (dB). MDS is 3 dB above thermal noise:

$$MDS = -111 \text{ dBm/MHz} + 10 \log_{10} B$$

Where B is the bandwidth in MHz and -111 dBm is 3 dB above thermal noise in a 1 MHz bandwidth.

Example: An optimally biased Model 7H0116 has an intercept point of + 25 dBm. If an IF bandwidth of 10 MHz is chosen, the spurious free dynamic range is:

$$2/3 [+ 25 - 5.5 + 101] = 2/3 [+ 120.5] \text{ or } 80 \text{ dB.}$$

Applications of Balanced and Double-Balanced Mixers

Downconverter

The preceding pages have been concerned with performance of the four basic mixer types when used as downconverters. These basic mixer types can be used singly and/or combined with other components to form Image Rejection mixers. Quadrature IF mixers, etc. These downconversion devices will be discussed later.

Upconverter (Balanced Modulator)

In upconverter or balanced modulator applications the lowest frequency signal is used as an input and applied to the IF port. *Balanced modulation* usually implies a double-sideband, suppressed carrier, output signal with the modulation sidebands located close to the carrier. *Upconversion* usually means that the LO (pump) signal is widely separated from the desired sideband outputs.

For either application, the balanced modulator accepts an RF input and a modulation input (usually called the IF) and produces an output consisting of the upper (RF + IF) and lower (RF - IF) sidebands. The original RF input (carrier) is normally suppressed at the output.

For double-sideband, suppressed carrier applications, the RF input is normally a low-level (-10 dBm typical) signal while the IF input is a low-frequency, modulating signal. The modulating signal is used as the high level switching signal and is usually + 7 to + 10 dBm. The RF output consists of the upper and lower sidebands centered about the suppression RF carrier. The degree of carrier suppression is directly related to the RF input/RF output isolation of the modulator. This carrier suppression may vary from 6 to 40 dB depending on the type of modulator and the frequency involved.

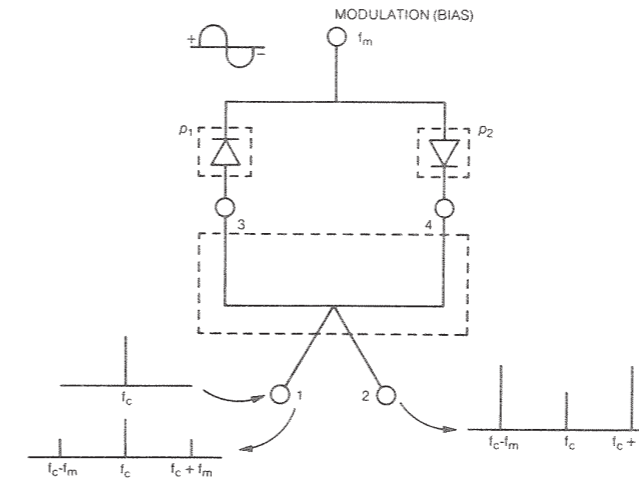
The 90° hybrid mixer and the Ortho-Quad® mixer are *not* used as modulators because their LO and RF coupling networks use 90° hybrids. The 90° hybrid mixer, if used as a balanced modulator, suppresses the sidebands but does not suppress the carrier. The Ortho-Quad® mixer suppresses both the carrier and the sidebands.

The 180° hybrid coupling networks, used in the 180° mixers and the double-balanced mixers, offer the right phasing characteristics so they can be used either as mixers (downconverters) or as modulators (upconverters). The balanced modulator using a single 180° hybrid will be described for simplicity but the double-balanced mixer (used as a modulator) works on the same basic principle. The difference is that separate 180° RF and LO hybrids (baluns) drive a balanced diode quad in a full-wave configuration, for the double-balanced modulator.

Balanced Mixer/Modulator Using Single Hybrids

A balanced mixer/modulator can be constructed by placing two mixer diodes with reverse polarity behind a 180° hybrid and combining the IF in a tee as shown in Figure 17.

Figure 17 - Balanced Modulator Using 180° Hybrid



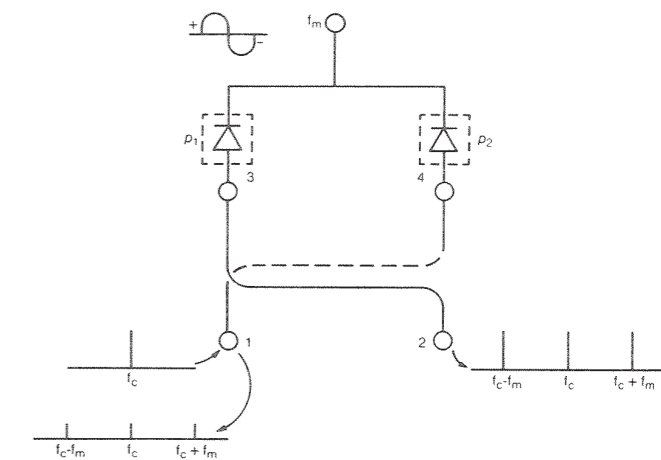
The incident RF carrier sees like reflection coefficients at the diodes and reflects back to the input port. The modulating (biasing) signal in the IF port produces opposite polarity reflection coefficients at the sum and difference frequencies and these modulated signals come out the remaining port.

Assuming perfect isolation for the hybrid, the amount of carrier suppression depends primarily on the similarity of the diodes—if they have equal reflection coefficients all the residual carrier is reflected back to the input port and none shows up at the output. This residual carrier shows up as VSWR at the input port, however. In effect, a balanced modulator using a 180° hybrid trades carrier suppression for VSWR.

Both 180° hybrid, and double-balanced, mixer/modulators provide good carrier suppression and have poor VSWR. The double-balanced mixer provides better carrier suppression because it has higher LO/RF isolation. It also offers more harmonic suppression because of its full-wave, double-balanced, drive. The most serious problems occur because of the poor mixer VSWR. When the mixer ports are not terminated in well-matched loads, reflections can cause severe amplitude and phase distortion due to the VSWR beats. The LO and IF ports are particularly sensitive to reactive terminations, which can cause conversion loss variation of ±3 dB and spurious response variations of ±20 dB.⁽⁵⁾

A balanced modulator using a 90° hybrid can be constructed as shown in Figure 18, by placing two mixer diodes with the *same* polarity behind the hybrid. However, this modulator, used alone, provides no carrier suppression. Because both diodes are inserted with the same polarity, the carrier and the modulation sidebands see like reflection coefficients. For a 90° hybrid this means that no energy reflects back to the input (therefore, good VSWR). There is poor carrier suppression because the carrier shows up at port 2 at a comparable amplitude to the sidebands.

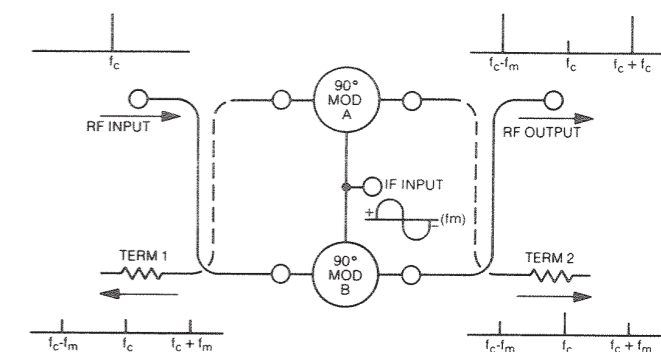
Figure 18 - Balanced Modulator Using 90° Hybrid



A High Performance Balanced Modulator

In order to get good carrier suppression and good VSWR simultaneously, Anaren uses the special patented circuit of Figure 19 (which is a balanced modulator version of the Ortho-Quad® balanced mixers).

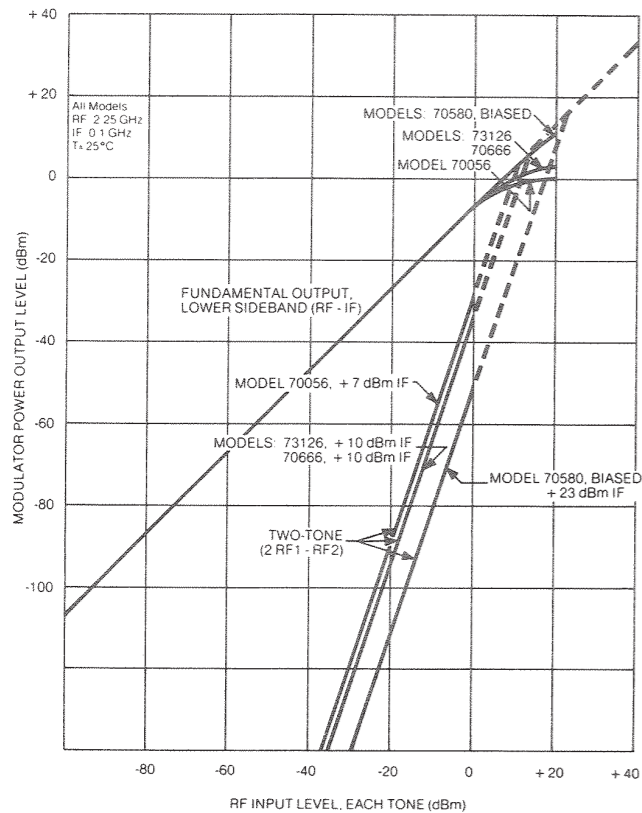
Figure 19 - 70660 Series Balanced Modulator



As previously noted, the 90° balanced modulators (A, B) of Figure 19 have no carrier suppression of their own, and the unsuppressed carrier shows up at the same port as the modulated signal. However, the carrier and the modulated sidebands have different *phase* relationships. This makes it possible to separate the carrier from the sidebands by using RF phasing networks. The RF phasing properties of the INPUT and OUTPUT 90° hybrid direct the unsuppressed carriers to termination 2 where they are absorbed. The modulated signals, having a different phase code, are focused to the RF output port. Termination 1 absorbs the residual carriers from A and B and provides the good VSWR. The result is the 70660 Series balanced modulator; providing good carrier suppression and good VSWR, simultaneously.

Figure 20 shows typical power up-conversion and two-tone, third-order performance for the 180° balanced, double-balanced, and 70660 series modulators. Note the intercept points for all these mixers are identical, except for the biased Model 70580 that uses the optimum load line technique to achieve good two-tone performance at high low power.

Figure 20 - Power Upconversion and Two-Tone, Third-Order Response

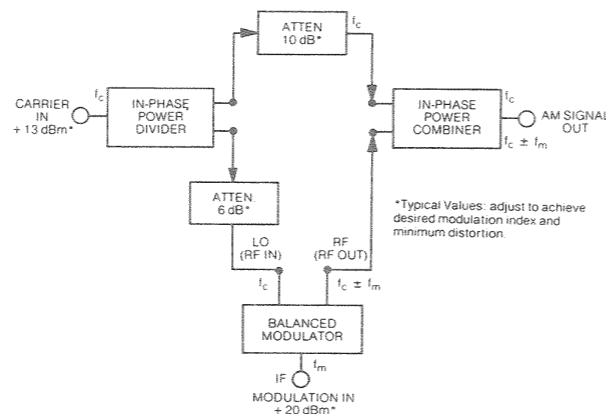


AM Modulator

The balanced modulator can easily be converted to an amplitude modulator by reinserting the required amount of carrier at the output of the mixer. One method of re-establishing the carrier is unbalancing the modulator by applying a dc bias current along with the modulation signal to the IF port. This decreases the RF input/RF output isolation, letting more of the original carrier leak through to the output.

A second approach offers lower distortion and better control of the modulation index by reinserting the carrier after the modulator. This approach is illustrated in Figure 21. The 70660 Series balanced modulators offer the best VSWR at all ports, independent of drive levels. This minimizes the output distortion.

Figure 21 - AM Modulation Using Balanced Modulator



Pulse Modulator

The balanced modulator is used as a pulse modulator by applying the carrier signal to the LO (or RF IN) port and the modulating pulse (either positive or negative) to the IF port. The pulsed output is then taken from the RF (RF OUT) port. The normal pulse requirements are 0 to 20 mA. The IF port will typically switch in less than one nanosecond and will support a pulse of indefinite length. Very clean pulse bursts, with minimal carrier feedthrough are provided for RF levels between 0 and +10 dBm.

Again, the 70660 Series offers the best performance for most applications, because of its very low VSWR and high LO/RF (RF IN/RF OUT) isolation.

Bi-Phase Modulator

Bi-phase modulation is similar to pulse modulation—reversing the IF pulse polarity will switch the RF output phase by 180°. (A bi-polar drive of +10 mA is typically required.)

For those applications where the accuracy of the 0°, 180° phase and insertion loss states is critical, the modulator having the best LO/RF (RF IN/RF OUT) isolation and the best VSWR will provide the best results. The 70660 Series will typically provide phase accuracy of ±2 degrees and insertion loss tracking of ±0.2 dB for bandwidths up to 2 GHz. The absolute insertion loss is typically 3 dB.

For BPSK systems requiring extremely high data rates, the 73000 series of double-balanced mixers offers bi-phase data rated up to 4 gigabits/sec.

Current-Controlled Attenuator/Switch

Balanced modulators can be used as wide-range, current-controlled attenuators or high on-off ratio switches. The isolation between the LO and RF (or RF IN, RF OUT) ports is controlled by the amount of dc current flowing through the IF port. The control current polarity is irrelevant. The maximum attenuation (“OFF” state) is equal to the LO/RF (RF IN/RF OUT) isolation. The minimum attenuation at 10-20 mA of control current is typically 2-3 dB.

The VSWR at the RF ports will vary with the control current for the 180° and double-balanced mixers. The VSWR for the 70660 Series modulator will remain low and independent of control current.

Figure 22 - LO to RF Attenuation vs. IF Current

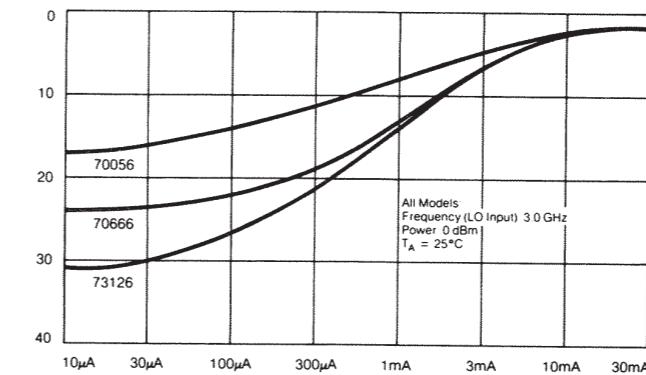


Figure 22 shows typical attenuation vs. control current for the balanced modulators.

NOTE: For all applications requiring bias current, avoid damage to the modulator diodes by *always* driving the IF port with a current-limited source.

Phase Detector

All four basic *mixer* types are useful as microwave phase discriminators. (The 70660 Series of balanced modulators is not designed for use as a phase detector). When identical frequencies are fed to the mixer LO and RF ports, a dc output proportional to the phase difference between the two signals will appear at the IF port.

The 90° hybrid mixer produces an output voltage proportional to the *sine* of the phase difference between the two identical input frequencies:

$$V_{outDC} = K_1 \text{SINE} (\theta_L - \theta_R)$$

Where K_1 depends on the input power and diode characteristics.

$$(\theta_L - \theta_R) = \text{phase difference of the two inputs.}$$

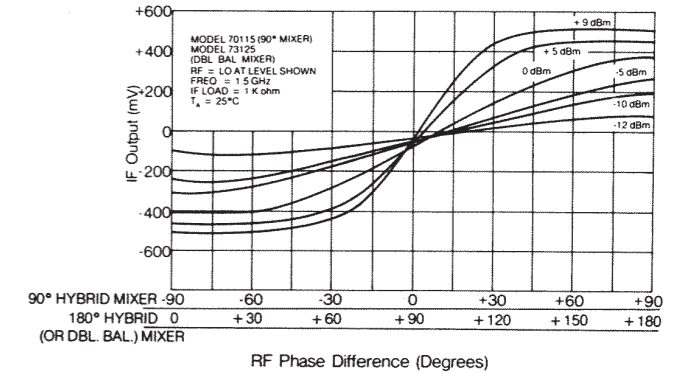
A typical value of K_1 , at 0 dBm input power (-3 dBm per diode) is 500 mV/mW. This is the voltage sensitivity when loaded into 1 K ohm.

The 180° hybrid mixer, and the double-balanced mixer, produces a dc output proportional to the *cosine* of the phase difference between the two identical input frequencies:

$$V_{outDC} = K_1 \text{COSINE} (\theta_L - \theta_R)$$

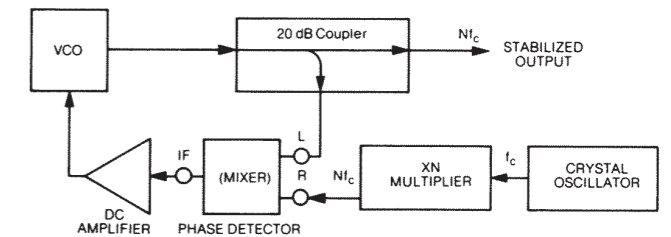
Figure 23 shows IF output voltage as a function of the phase difference of the two inputs. The 90° hybrid mixer produces a dc null when the input signal phases are equal. The 180° hybrid, and double-balanced, mixers produce a maximum negative output when the input signal phases are equal.

Figure 23 - Phase Detector Performance



A typical application for a phase detector is in a phase-locked loop. The block diagram shown in Figure 24 shows a phase detector being used as the error sensor for a phase locked source.

Figure 24 - Block Diagram of Phase-Stabilized Frequency Source



Frequency Discriminator

A phase detector can be converted to a frequency discriminator by adding a power divider and a delay line as shown in Figure 25.

The unknown RF signal is divided to a reference and a delay path. The differential delay (T) creates a phase difference (θ) between the two signals which is a linear function of frequency (f) and is given by

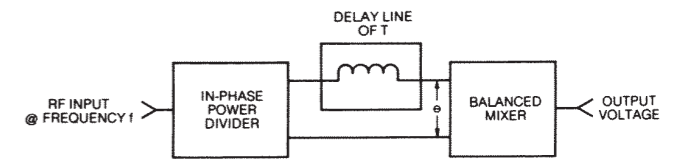
$$\theta = 2\pi fT$$

or

$$\theta = 2\pi f \left(\frac{l}{C} \right)$$

where l = length of the delay line
 C = velocity of propagation

Figure 25 - Frequency Discriminator



The 90° hybrid mixer, and the Ortho-Quad® mixer, produce an output voltage proportional to

$$V_{out} = kP \sin \theta$$

The 180° hybrid mixer, and the double-balanced mixer, produce an output voltage proportional to

$$V_{out} = kP \cos \theta$$

k is a constant related primarily to insertion loss and diode sensitivity. P is the RF input signal power.

If the RF input is 0 dBm, K is typically 500 mV/mW when the output is loaded into 1 K ohm.

The output voltage of the 90° hybrid mixer, and Ortho-Quad® mixer, has zero crossings when $\theta = 0, \pi, 2\pi$, etc. For example, when

$$f = \frac{n}{2T} = \frac{nc}{2l}$$

where n = 0, 1, 2, 3, etc.

The output voltage of the 180° hybrid mixer, and double-balanced mixer, has zero crossings when

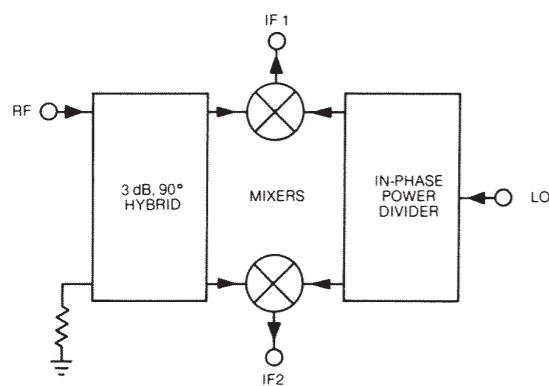
$$\theta = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \text{ etc.}$$

Near the zero crossing, sine θ and cosine θ are almost linear functions of θ , so the output voltage is nearly linear with frequency (within ± 30 degrees of the zero crossings the deviation from linearity is less than $\pm 5\%$). The slope of the output voltage curve is a function of input power and the discriminator must be preceded with a hard limiter to remove the power/frequency ambiguity.

Quadrature IF Mixers

The Quadrature IF Mixer (QIFM) provides two equal amplitude IF outputs that are in phase quadrature. It consists, basically, of two balanced mixers and two hybrids. Figure 26 is a block diagram.

Figure 26 - Block Diagram of a Quadrature IF Mixer



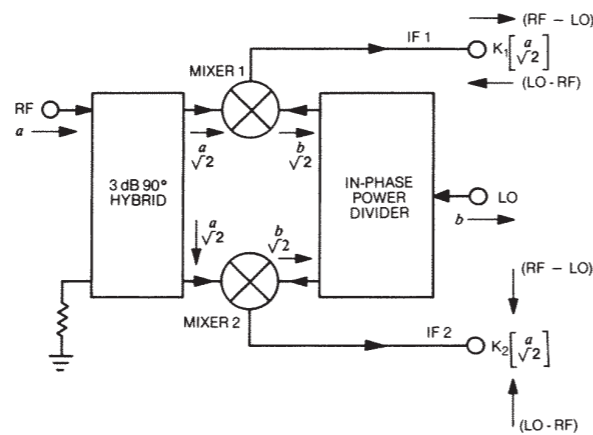
Operation

The LO is introduced to the two mixers in-phase and the RF is introduced through a quadrature hybrid. This introduces a 90° phase difference between the RF and LO signals applied to the mixers, and results in two IF outputs of equal magnitude but in phase quadrature. One IF output leads or lags the other depending on whether the RF frequency is greater or less than the LO frequency. If the LO signal is a fixed frequency, the desired IF output can be produced by an RF signal above or below the LO frequency:

$$RF = LO \pm IF$$

The operation of a QIFM can be understood by following the signal voltage vectors in Figure 27.

Figure 27 - Simplified Vector Operation of Quadrature IF Mixer



With a high level LO signal, b, (typically greater than 0 dBm), an RF input, a, will produce IF outputs equal to: $k_1 (\frac{a}{\sqrt{2}})$ and $k_2 (\frac{a}{\sqrt{2}})$ where k_1 and k_2 are proportional to the conversion losses in mixers 1 and 2. The vectors show the relative phase of the IF outputs for the upper (RF - LO) and lower (LO - RF) sideband responses.

When the RF frequency is below the LO frequency, the IF response (LO - RF) from mixer 1 lags the output of mixer 2 by 90°. When the RF is above the LO, the IF response (RF - LO) leads the output of mixer 2 by 90°.

Another way of looking at the operation of the QIFM is to realize that the two IF outputs are proportional to $a \sin \theta$ and $a \cos \theta$, respectively. θ is the difference phase between signals a and b. Note that θ can be a fixed angle if the two frequencies are identical, or is time varying at the difference frequency ($\Delta \omega t = IF$). Since the IF outputs are proportional to $\sin(a-b)t$ and $\cos(a-b)t$ respectively, and since $\sin(-\theta) = -\sin \theta$ and $\cos(-\theta) = \cos \theta$, one output changes phase by 180° relative to the other when $a > b$ or $a < b$.

The two IF voltages, a sin θ and a cos θ , are the in-phase (I) and quadrature (Q) components of the correlation of the RF and LO signals. The correlation time is the inverse bandwidth of the IF outputs. The QIFM is identical in design and application to the correlator (phase discriminator) provided one of the QIFM inputs, a or b, is strong enough to act as an LO. (The correlator uses dc biased diodes, which enables it to operate with both a and b at very low levels.)

Intermodulation Performance

The mixers shown in Figure 26 could be any of the four mixer types: 90° balanced, 180° balanced, ORTHO-QUAD® or double-balanced. The intermodulation performance of the QIFM is the same as the intermodulation performance of the type of mixer used. (See pages 101-104 for a discussion of intermodulation performance for the four mixer types.) Anaren uses the 90° balanced or the ORTHO-QUAD® in its QIFM designs because they provide better phase and amplitude balance at the IF ports than either the 180° balanced or double-balanced.

Applications

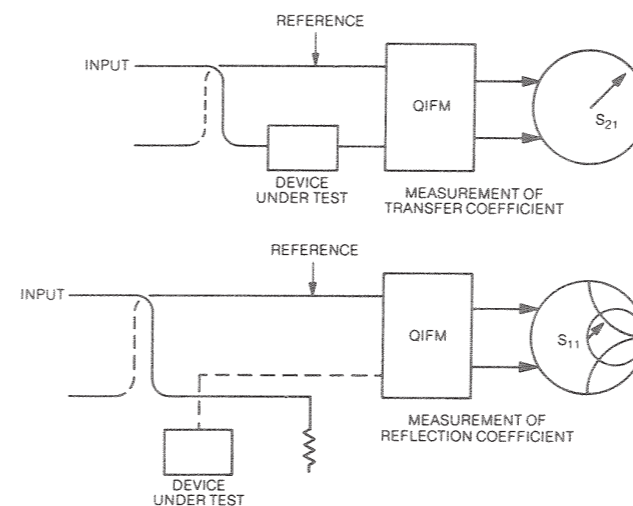
Doppler Systems

This network is used for many applications. The earliest was probably to discriminate between approaching and receding doppler targets. This application is described in detail by Skolnik⁽⁶⁾. For an approaching target, the received frequency is greater than the LO and vice versa for a receding target. The relative phases of the received doppler signals (IF) are used to discriminate between the two situations. This technique is used for motion detector, "burglar" alarm, and radar altimeter applications, to name a few.

Network Analyzer

When the LO and RF signals are at the same frequency, the IF outputs are still proportional to a sin θ and b cos respectively, where θ is the phase difference between the RF and the LO signals. The device can therefore be used as a vector voltmeter, when connected to an X-Y oscilloscope, as shown in Figure 28.

Figure 28 - Quadrature IF Mixer Used as Network Analyzer



With the voltage a cos θ applied to the X-axis of the oscilloscope and the voltage a sin θ applied to the Y-axis, a pulsed RF signal appears as a strobe whose length is proportional to the RF voltage a and whose angle is θ . This makes the device useful as a test instrument to measure transmission and reflection coefficients — a network analyzer.

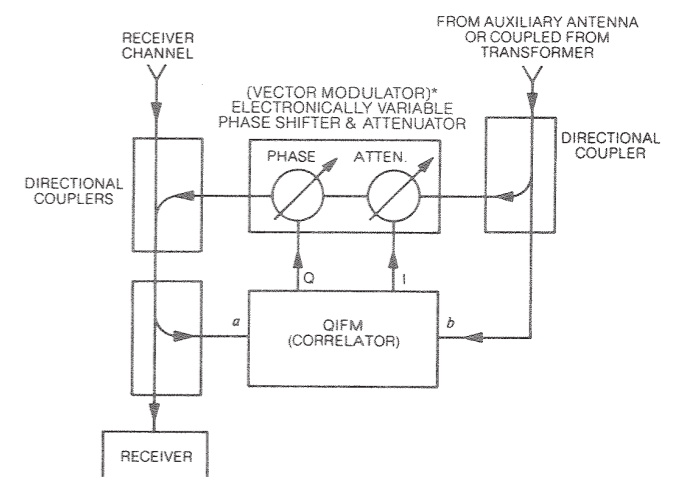
Adaptive Canceller

The QIFM can be applied as a correlator and used in the adaptive cancellation of two microwave signals.

A typical example of a problem that requires adaptive cancellation is where a transmitter and receiver are operating in close proximity, such as a jammer and a surveillance receiver. Transmitter leakage to the receiver via the antennas usually is sufficiently strong so as to blind the receiver during transmission. Another example is that of a hostile jammer blinding a receiver through its sidelobes.

To combat such situations, short of turning off the receiver, a scheme such as indicated in Figure 29 can result in a significant reduction of the interference at the receiver, while still maintaining look-through at the outside world.

Figure 29 - Adaptive Canceller



*See page 125 for details.

The essentials of the scheme are that we pick off a strong sample of the interfering signal, (either by means of a coupler in the first case, or by means of an auxiliary omnidirectional antenna in the second case), and add this sample to the signal being received by the receiver. By adjusting the amplitude and phase of the added signal we can arrange that it exactly cancels the interfering signal in the receiver channel. Since the relative amplitude and phase of the interfering signal will vary owing to relative motion of the antennas, vibration, frequency changes, etc., we are required to continuously adjust the phase and amplitude of the cancelling signal to maintain the nulled condition at the receiver. This is achieved by means of a quadrature IF mixer as shown.

A sample of the combined signal finally reaching the receiver is correlated with a sample of the jammer signal. Provided the jammer signal is strong enough to act as an LO, the outputs of the mixer are:

$$a \cos \theta$$

and

$$a \sin \theta$$

where a is the voltage entering the receiver, and θ is the difference phase between the two signals being correlated. Note that θ can be a fixed angle if the two frequencies are identical, or is time varying at the difference frequency ($\Delta \omega t$). Filtering these outputs with a low-pass filter (e.g. 1 KHz cut-off) insures that only signals that are extremely close in frequency give an output. The two error signals are thus the in-phase (I) and quadrature (Q) components of the correlation of the RF signals over a time period equal to the inverse bandwidth of the filter (1 msec. in the case of a 1 KHz cut-off).

If the two RF signals do not correlate, then both $a \sin \theta$ and $a \cos \theta$ are zero. That is, the interfering signal has been cancelled at the receiver. The two error signals I and Q drive the variable attenuator/phase shifter (Vector Modulator) in a null seeking mode to insure a continuing null at the receiver. This adaptive scheme will affect the desired signal at the receiver by less than 1 dB.

Digital (PSK) Demodulator

The QIFM can also be used to demodulate a QPSK digital phase format and recover the two data streams. The QPSK input is applied to the RF port while the regenerated carrier is applied to the LO port. The demodulated data streams are then available at IF ports 1 and 2. Figure 30 shows a basic modulator/demodulator system block diagram. The QPSK modulator is the Quadrature Modulator specified on page 61 and explained on pages 114-115.

Figure 30 - Block Diagram of QPSK Modulator/Demodulator System

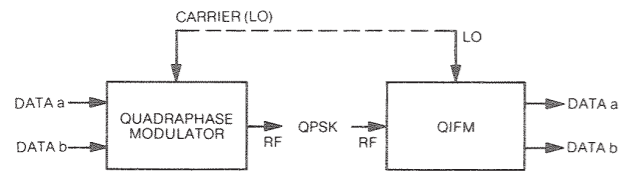


Image Rejection Mixers

From the previous section we know that a quadrature IF mixer can discriminate between the IF outputs produced when the RF frequency is above or below the LO frequency. This fact allows the realization of an Image Rejection Mixer (IRM). The IRM directs each IF output to a specific IF port and suppresses the undesired (image) IF response.

Operation

The desired IF frequency can be produced by an RF signal either higher or lower than the LO frequency by a frequency difference equal to the IF frequency:

$$RF = LO \pm IF$$

Normally, only one of these sidebands is desired and is designated the "real" IF output; the other is termed the "image". The choice of the upper or lower sideband as the "real" response is an arbitrary design decision.

From Figure 27 we know that the IF outputs of the mixers provide voltage vectors $k_1 (\frac{a}{\sqrt{2}})$, with phase dependent on the sideband. If we select the lower sideband ($LO - RF$) as the "real" response and apply the corresponding IF frequency, the vectors will ideally sum to only one IF (real) port and cancel at the other (image) port. See Figure 31.

Figure 31 - Simplified Vector Operation of Image Rejection Mixer

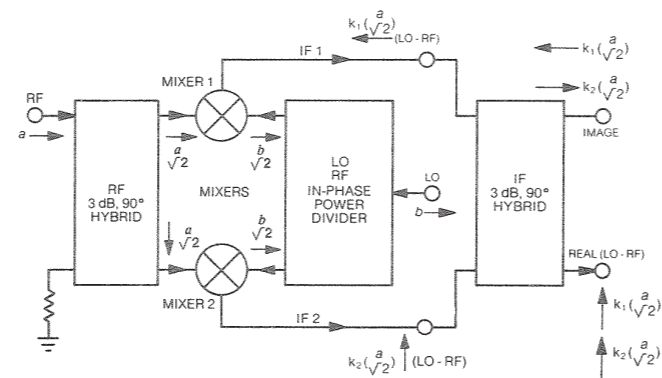
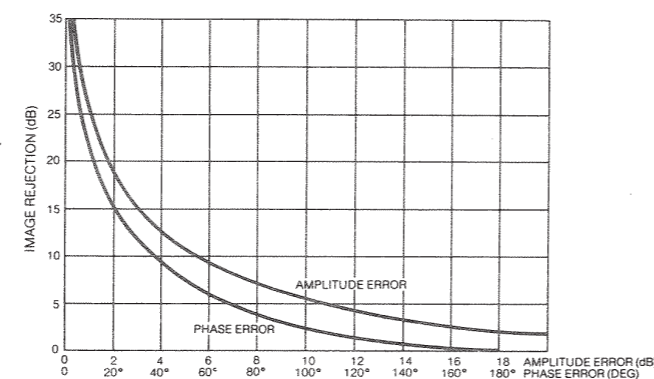


Image Rejection

If $k_1 \neq k_2$, or if the vectors are not in quadrature, they will not completely sum at the real port and cancel at the image port. Image rejection is the ratio of the image signal to the real signal at the real IF port. Good image rejection requires close control of the phase and amplitude of the signal vectors. Phase and amplitude errors occur primarily in the RF portions of the IRM network but can also occur when the mixer outputs are summed by the IF hybrid. Figure 32 is a chart showing how image rejection is affected by phase and amplitude errors. When $k_1 = k_2$, and there is no phase error, the output voltage at the real port is equal to $k_1 a$; the only loss is due to the mixer losses (k_1, k_2).

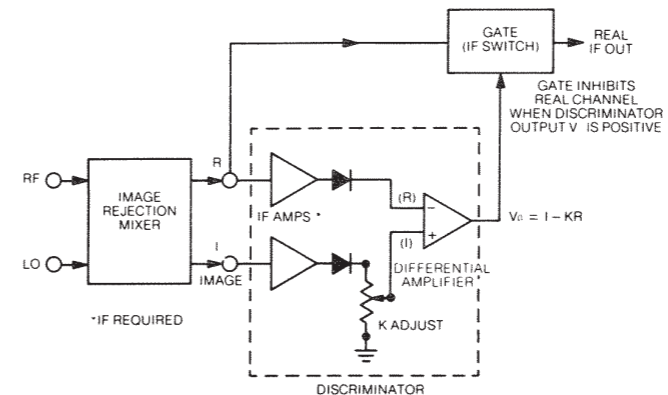
Figure 32 - Image Rejection vs. Phase and Amplitude Error



Complete Image Rejection Using Gating Techniques

Figure 32 shows that it takes only ± 0.5 dB of amplitude imbalance to reduce the image rejection to 25 dB (assuming perfect phase balance.) Typically, 20 dB of image rejection can consistently be obtained over octave bands. This may not be enough rejection for the applications in which image rejection mixers are normally used. Typical applications for these mixers are in wideband, sweeping LO receivers or spectrum analyzers. In both cases, the required dynamic range of the equipment may exceed 80 dB. The 20 dB image rejection is, therefore, not a very practical number for this application. However, once we have discriminated between the real and image responses to this degree, a simple gating scheme, such as illustrated in Figure 33 will give the additional rejection required.

Figure 33 - Gating Technique for Complete Image Suppression



The IF signals from the real (R) and image (I) ports are detected and fed to the inputs of a differential amplifier with an output: $V_0 = I - KR$ where k is an adjustable constant. When the I channel output is greater than the R channel output, the differential amplifier produces a positive output (V_0) which activates the IF switch (gate) and produces no IF output. If the R channel output is greater than the I channel, the amplifier output is negative, the IF gate is not activated, and the real IF is allowed to pass. If the constant k is adjusted to a value of 0.1, then the real channel IF output is inhibited when the real signal does not exceed the image by at least 10 dB. This insures that random signals in the image channel do not inhibit the real channel IF output. This technique does more than suppress the image signal — many intermodulation products can be eliminated by the scheme.

Intermodulation Products

Anaren's image rejection mixers use the 90° balanced, and the ORTHO-QUAD®, mixers because they provide the best amplitude and phase balance and, therefore, the best image rejection. The intermodulation performance of the unaided IRM is therefore the same as these two mixer types. Using a gating scheme similar to the one in Figure 33 used for image suppression, also allows suppression of many other intermodulation products.

Referring to Figure 31, we see that the LO signals appearing at the mixer inputs are in phase with each

other. Thus, harmonics of the LO signals are also in phase with each other (the relative phase of the n^{th} harmonic is n times the relative phase of the fundamental). The RF fundamentals, however, are 90° relative to each other. Thus the second, third and fourth harmonics are 180°, 270°, and 360° (0°) respectively.

The second and fourth harmonics of the RF, mixing with any harmonic of the LO (including the fundamental), produce mixer outputs which are not in phase quadrature, but are 180° and 0° respectively. When these signals are summed in the IF quadrature hybrid, they appear equally at the real (R) and image (I) ports. Since there is no difference between I and R, a positive V_0 is obtained, eliminating all these products. (In practice, R and I vary by a few dB, but normally not by the 10 dB threshold required to inhibit the output.) This gating scheme, when properly implemented, can eliminate the 1x2, 2x2, 3x2, 4x2, 1x4, 2x4, 3x4, and 4x4 intermodulation products. A more sophisticated gating scheme is reviewed in detail on page 173.

Bias Options

The catalog's biased IRM's allow performance under "starved" LO conditions. Biased IRM's using the optimum load line technique (see pages 99-103) can be supplied on special order and can provide optimum conversion loss and best intermodulation performance.

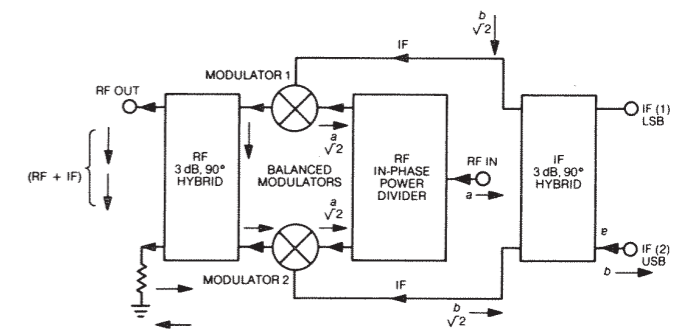
Single Sideband Modulators

A single sideband modulator (SSBM) accepts an RF (carrier) input and an IF input, and produces either the upper ($RF + IF$) or lower ($RF - IF$) sideband with the carrier and unwanted sideband suppressed. This is accomplished using the phase cancellation method of single sideband modulation.

Operation

This single sideband modulator consists of two balanced modulators and two hybrids, arranged as shown in Figure 34 (The block diagram is identical to the image rejection mixer shown in Figure 31, except that the balanced mixers must be balanced modulators.)

Figure 34 - Simplified Vector Operation of Single Sideband Modulator



Although not shown by the vectors in Figure 34, the output of each modulator is a *double sideband* signal, the phase states changing at the IF (modulation) rate. When these double sideband signals are fed to the output quadrature hybrid, one sideband will sum to the RF out port with the other sideband suppressed. By changing the modulating signal from IF1 to IF2, either the lower or upper RF sideband can be selected. Thus it is possible to do sideband selection by IF switching between IF1 and IF2.

The vectors in Figure 34 follow just the upper (RF + IF) sidebands. The upper sideband sums to the RF output port when IF input 2 is driven. If input 1 was driven, the upper sideband would sum to the termination of the RF output hybrid, and the lower sideband (RF - IF) would be available at the RF out port.

Sideband and Carrier Suppression

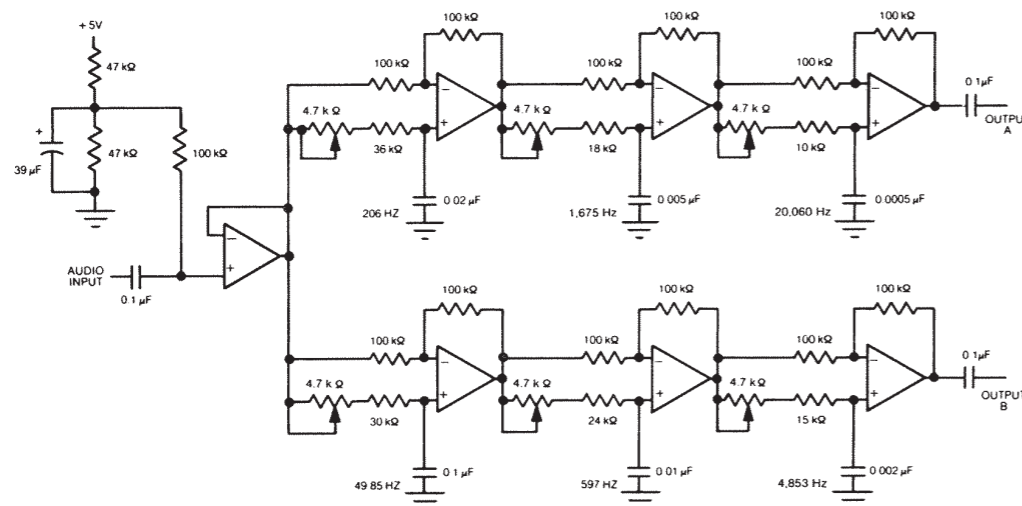
The amount of unwanted sideband suppression depends on the vectors at the RF hybrid being phase and amplitude balanced, just as the image rejection mixer. (Figure 32 can be used to determine unwanted sideband suppression. As a function of phase and amplitude balance; relabel the vertical axis "sideband suppression.")

The degree of carrier suppression is directly related to the RF input/RF output isolation of the type of balanced modulator used. Anaren uses the balanced modulator versions of the ORTHO-QUAD® mixers as described on pages 106-108. These balanced modulators provide good isolation with the phase and amplitude balance necessary for good unwanted sideband suppression.

Applications

The SSBM is used whenever it is desired to generate a carrier signal having only one sideband. It could be used as the heart of a single sideband transmitter, for example. The more common use, however, is to offset a carrier by a precise frequency increment. The SSBM can offset a carrier either up (RF + IF) or down (RF -

Figure 35 - Quadrature Drive Outputs from Single Input



OP AMPS ARE LM324 QUADS
+ 5V TO PIN 4 EACH LM324, GND TO PIN 11

IF) by simply changing IF input connections. The accuracy of the offset will be equal to the frequency stability of the modulation (IF) source.

Low-frequency Modulation

The modulation frequency is limited only by the availability of a quadrature drive to the balanced modulators. Anaren supplies standard IF options from 20 MHz to 320 MHz. These options use an internal octave-band hybrid to provide the quadrature modulator drive.

For modulation frequencies below 20 MHz Anaren offers the "—DC" suffixed models that have the modulator inputs brought directly to the IF ports. The customer must supply his own quadrature drive for these models. Lumped component (ferrite toroid) hybrids are available from a number of manufacturers and can be externally connected to the "—DC" IF ports. These devices will extend the IF modulation capability of the "—DC" versions down to about 1 MHz. Below this frequency either digital drive or phase-shift techniques are required.

Figure 36 (page 114) shows a phase-shift method for developing a quadrature drive from 100 Hz to 10 kHz. Any methods used must be able to deliver the equivalent of +10 dBm, or approximately 10 mA across 50 ohms, to the IF ports.

Intermodulation

The IF inputs are normally the high level signals. Their harmonics produce single-tone harmonic intermodulation products that limit the output power dynamic range available from the SSBM. Typically the RF ±3 IF response is only suppressed by 10 to 15 dB. However, the RF ±3 IF response can be improved significantly by making the RF carrier input the higher level signal and the modulation (IF) the lower level signal. This must be considered with care because transposing the power levels will effectively degrade the carrier suppression since this is related to the RF IN/RF OUT isolation. In the case where the modulator has very high RF IN/RF OUT isolation the higher level carrier should present no problem.

Quadrature Modulators

The quadrature (four-phase) modulator is designed for high data-rate digital communication systems. It can be used either in the biphasic (BPSK) mode or the quadrature (QPSK) mode.

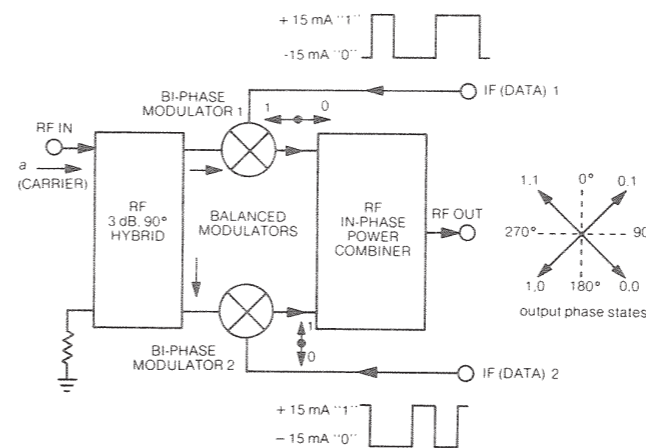
For BPSK operation the input carrier is modulated by *identical* data inputs at modulation (IF) ports 1 and 2 (the ports can be simply "teed" together). The data input normally consists of a two-level, bi-polar pulse code. The output carrier phase, relative to the input carrier, is phase shifted by 0 or 180° depending on the properties of the data inputs.

For QPSK operation the input carrier is modulated by two independent data channels at IF ports 1 and 2. Each data channel consists of a two-level, bi-polar pulse code. The output carrier phase, relative to the input carrier, is phase shifted 0, 90°, 180° or 270° depending on the properties of the data inputs.

Operation

Figure 36 shows the simplified vector and operation and block diagram of the quadrature modulator. (The block diagram is identical to the single sideband modulator except there is no IF hybrid.)

Figure 36 - Simplified Vector Operation of Quadrature (QPSK) Modulator



The heart of the circuit is the balanced modulator, used as bi-phase modulator (see page 125). The unmodulated carrier signal *a* is split into two carrier components, one 90° out of phase with respect to the other. One data input is used to modulate the 0° to 180° phases of the carrier (modulator 1); the other data input modulates the 90° to 270° phases of the carrier

(modulator 2). The modulator outputs are then combined by an in-phase power divider (combiner) to produce the four phases, 0°, 90°, 180°, and 270°.

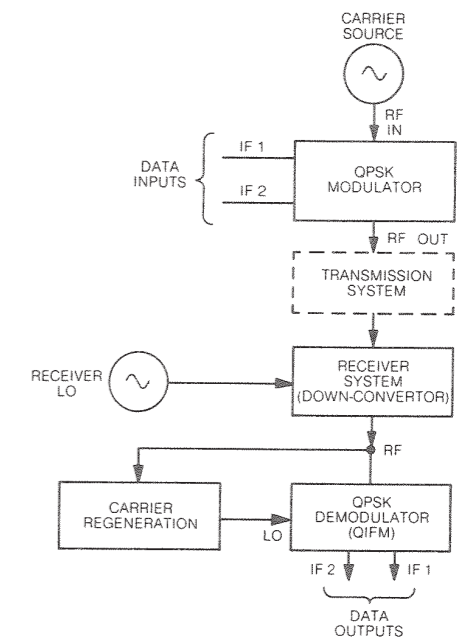
Applications

Digital communication systems are becoming more widely used because of their ability to transmit information over long distances without deterioration, since digital signals, unlike analog signals, can be accurately regenerated. Digital phase modulation (phase shift keying, PSK) allows only discrete phase angles, rather than continuous functions that occur with analog phase modulation. This instantaneous phase difference of the output carrier with respect to the input carrier determines the "digit" being transmitted.

PSK Transmission Systems

Figure 37 shows the elements of a typical QPSK transmission system. PSK systems usually have 2 discrete phase states with two-phase (biphase, BPSK), and four-phase (quadrature, QPSK) being most common. BPSK generally carries one data stream and QPSK carries two data streams. These phase states are as widely separated as possible to reduce the noise sensitivity.

Figure 37 - Elements of Typical QPSK Digital Transmission System



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Toll Free: (800) 411-6596
Europe: +44 2392-232392
Asia: +86-512-62876400

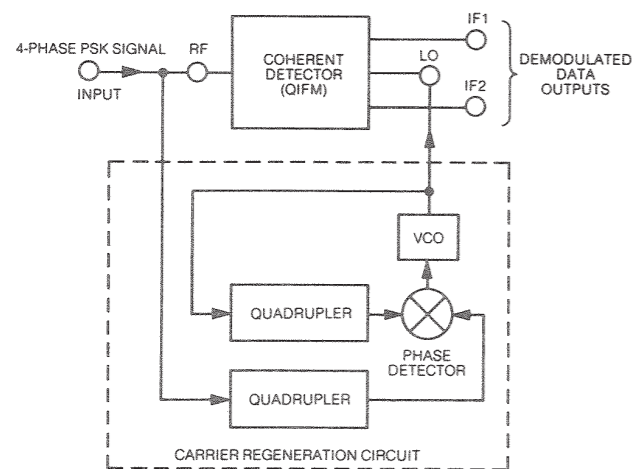
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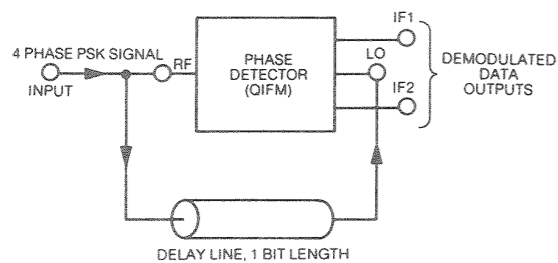
With PSK phase angles of 0° and 180°, 90° and 270°, there is theoretically a perfect carrier null. In order to detect this PSK signal at the demodulator the receiver must therefore regenerate the carrier to use as a coherent phase reference. This can be done by passing the BPSK signal through a frequency doubler and deriving a signal with 0° and 360° phase states. This is now a constant phase signal and it can be filtered and its frequency divided by two, thereby regenerating the original carrier frequency. Or, it can be used as an input to a phase comparator for controlling a phase-locked reference oscillator. The same method is used for regenerating the QPSK carrier except a frequency quadrupler is used. Figure 38 is a block diagram illustrating the coherent detection type of QPSK demodulator.

Figure 38 - Coherent Detection Type QPSK Demodulator



Another, simpler, type of QPSK demodulator is shown in Figure 39. It is called a differentially coherent or, delay, detector. The delay detector is most suitable for low-cost demodulators.

Figure 39 - Delay Detection Type QPSK Demodulator



The delay line is used as a memory for the preceding bit and provides a phase reference for the next symbol. Carrier phase changes from bit to bit are, therefore, detected without the need for establishing the fixed phase-lock reference of the carrier regeneration schemes. Either demodulator type uses the QIFM as the demodulating elements.

Quadrature Modulator Performance

Typical performance specifications for the Model 260015 Quadrature Modulator are as follows:

IF (Data) Signal Levels:

Logic 1: +15 mA
Logic 0: -15 mA

Data Rate: 0 to 100 mB/s (NRZ Format)

Biphase Modulation:

Input Logic Level (IF Ports 1 and 2)	Relative Phase (Degrees)
1	$-(0 + \theta_0) \pm 5^\circ$
0	$-(180^\circ + \theta_0) \pm 5^\circ$

Note: θ_0 is the zero reference phase angle defined as input/output phase shift measured with a logic 1 level present at both IF ports.

Quadrature Modulation:

Input Logic Level	IF Port 1	IF Port 2	Relative Phase (Degrees)
1	1	1	$-(0 + \theta_0) \pm 5^\circ$
1	1	0	$-(270 + \theta_0) \pm 5^\circ$
0	0	0	$-(180 + \theta_0) \pm 5^\circ$
0	0	1	$-(90 + \theta_0) \pm 5^\circ$

Note: θ_0 is defined as 0° for biphase modulation.

Input RF power Level: 0 dB (max)
Insertion Loss: 7 dB (typ.)
RF VSWR: 1.5 (typ.)
Isolation: IF to IF Ports: 25 dB (min)
IF to Output Ports: 25 dB (min)

The BPSK signal can be demodulated with any balanced or double balanced mixer covering the modulator RF range.

The QPSK signal can be demodulated with a quadrature IF mixer (QIFM) covering the modulator RF range.

Note that QPSK can give you two independent data channels without multiplexing; biphase only one.

References:

- (1) C.W. Gerst, "New Mixer Designs Boost D/F Performance," *Microwaves*, Vol. 12, No. 10, Oct. 1973. (Reprinted on next page.)
- (2) J.H. Lepoff and A.M. Cowley, "Improved Intermodulation Rejection in Mixers," *IEEE Transactions on Microwave Theory and Techniques* Vol. MTT-14, No. 12, Dec. 1966.
- (3) D. Cheadle, "Selecting Mixers for Best Intermodulation Performance *Microwaves*, Vol. 12, No. 11, Nov. 1973.
- (4) R.I. Disman, "Dynamic Range Performance of Microwave Transistor Amplifiers," *Microwave Journal*, Vol. 16, No. 8, Aug. 1971.
- (5) P. Will, "Reactive Loads - The Big Mixer Menace," *Microwaves*, Vol. 10, No. 4, April 1971.
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Mixer Designs for Phase/Amplitude tracking Subassemblies

The principal requirements being imposed on modern electronic warfare receivers today are wide-frequency coverage, spurious free dynamic range, small size and weight, and for direction-finding functions, extreme accuracies in phase and amplitude characteristics. Previously, broadband DF systems relied upon very accurate RF beam forming networks. As bandwidths have gone to multi-octave coverage, however, it has been necessary to down-convert the RF received signal and to perform beam forming functions at IF frequencies. The translation from RF to an IF frequency must be done, however, while preserving the RF phase codes. This approach has placed considerable stress on the mixer requirements. Specifically, those mixer specifications which are most critical for wide-band ECM receiving systems are:

- Biasing of the mixer—this bears on the LO dynamic range and spurious performance.
- Rejection of spurious signals—this is important when related to system false alarm and dynamic-range requirements.
- LO is RF isolation—important to reradiated LO power requirements.
- VSWR—influences phase and amplitude tracking.
- Number of diodes used—this has a direct bearing on the LO power requirements.
- Focusing of image signal energy—critical to phase and amplitude tracking requirements.

The last requirement on the internally generated image signal, (produced by mixing of the LO second harmonic with the RF input (2 LO-RF), introduces systems phase error. The image power must, therefore, be focused so it doesn't interfere with the generation of the desired IF output.

In order to get mixers to meet these requirements, proper selection of the dc load line is critical.

Most mixers are designed to operate at a constant bias voltage. However, through the use of a relatively simple resistive bias network, it is possible to establish an optimum dc load line, where diode conversion loss and VSWR can be optimized over an extended local oscillator dynamic range. In addition, spurious and intermodulation performance of a diode can be improved through the operation of the diode at high LO power levels while maintaining optimum conversion loss.

Four Mixer Types Analyzed

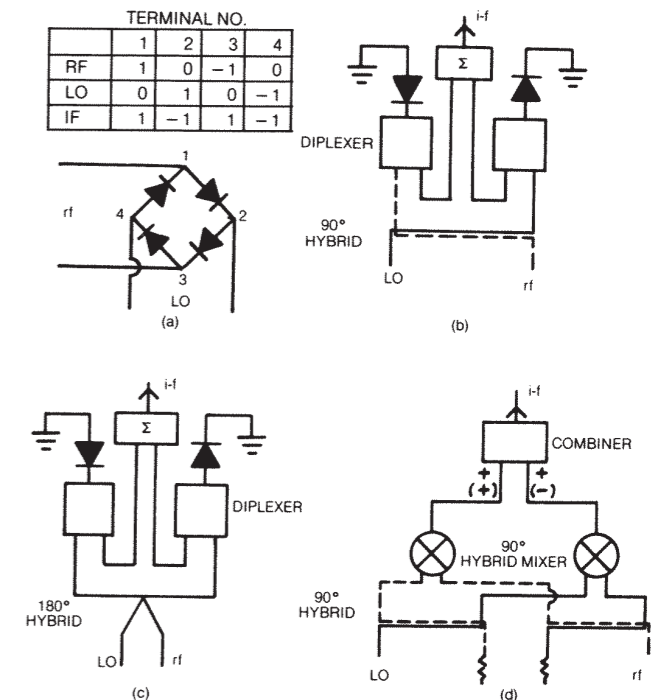
Figure 1 describes four basic mixer types that meet the aforementioned mixer requirements in varying degrees. For the double-balanced mixer in Fig. 1a, a fundamental diode quad is shown. Also shown is a sequence of phase codes or excitation required at each junction.

There are several circuit approaches available for achieving the proper RF and LO excitation and extracting the proper IF signal phase in a double-balanced mixer.

The ORTHO-QUAD^{RM} (quadrature-fed dual mixer), Fig. 1d, is a relatively new approach. In practice, a pair of mixers—either balanced or double-balanced types—are fed in phase quadrature. Only the quadrature-fed dual mixer with a pair of 90° hybrid mixers is considered here.

Table 1 gives a comparison of relative performance of these four mixer types based on the criteria established earlier. Ease of biasing is a direct function of circuit complexity. The 90-degree hybrid mixer and the 180-degree hybrid mixer, Fig. 1b and 1c are the easiest mixers to bias. All the mixers reject 2 x 2 spurious, none reject 3 x 3 spurious or two-tone intermodulation but no one mixer is optimum for all parameters.

Figure 1 - Four mixers considered are (a) double-balanced mixer; (b) 90-degree hybrid mixer; (c) 180-degree hybrid mixer; and (d) Ortho-Quad[®] (quadrature-fed dual mixer). Phase excitations for the double-balanced mixer are shown.



Combining Into a Mixer Subassembly

Let us now see which of these mixer types is most suited for an ECM tracking system. In a phase and amplitude tracking receiving system, mixers can be arranged such as shown in Fig. 2. With this system, the phase and amplitude code which appears at the various RF ports is translated to the same phase and amplitude code at the corresponding IF ports. Note that the LO and BITE signal are injected through a single port.

The systems engineer can do broadband monopulse direction finding, or build up relatively large synthetic arrays using interferometric techniques with subassemblies of this type. The IF frequency of such systems can range from 60 MHz to 1 GHz or even extend into S-band.

A typical frequency breakdown of a broadband system, taking into account antenna bandwidths, LO power available, and high frequency conversion loss as a function of bandwidth, is a system broken into three bands—the lower band from 0.5-2 GHz, the middle band covering 2-12 GHz and the upper band covering 12-18 GHz. It is possible with today's technology to cover either 2-18 GHz, or even 0.5-1.8 GHz in a single system, but as the overall bandwidth becomes larger and larger, the conversion loss at 18 GHz begins to suffer.

Figure 2 - A phase and amplitude tracking mixer subassembly integrates several mixers, each of which must preserve the RF phase codes applied.

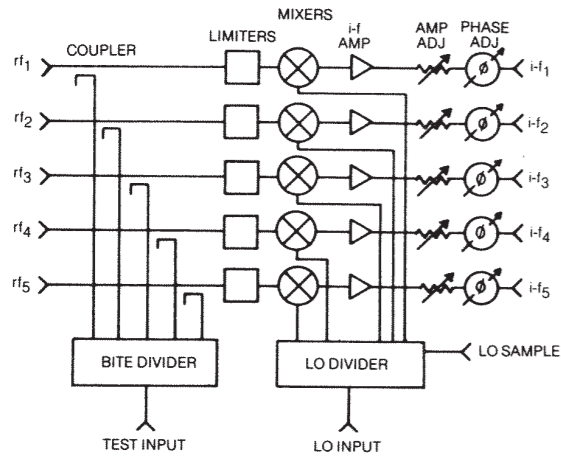


Table 1

	No. of Diodes	VSWR	LO-RF Isolation	Image Focusing Port	Bias ability	Spurious Rejection m-n = 1
90° Hybrid	2	Good	Poor	LO	1	Poor
180° Hybrid	2	Poor	Good	RF	1	Poor
Double-Balanced	4	Poor	Good	RF	3	Good
Ortho-Quad® (Q.F.D.M.)	4	Good	Good	Int. Load	2	Good

- a. VSWR: Poor: 2.5:1 typical
Good: 1.5:1 typical
- b. LO-RF Isolation: Poor: 6 dB typical
Good: 20 dB typical
- c. Image Focusing: Defines where image signal energy is focused, LO port, RF port, or internally terminated.

It is highly desirable, and almost imperative, that in a wideband multi-channel phase and amplitude tracking system of this type, the LO be operated on the same side of the RF for all real signals. That is, throughout the band, the real signal has to be consistently characterized as LO above the RF frequency or vice-versa. For discussion purposes, let us assume that the LO frequency is always above the RF frequency for the real channel. The phase of the nth IF channel is equal to the phase of the nth LO channel, minus the phase of the nth RF channel to the mixer,

$$\phi^n \text{ IF} = \phi^n \text{ LO} - \phi^n \text{ RF}$$

Ideally, the insertion phase from each RF input port to each mixer should be identical, and likewise, the insertion phase from the single LO terminal to each of the mixers should track. But in the case of a broadband multi-channel subassembly, such as in Fig. 2, the insertion phase from the LO input to a single mixer can be as large as 4 to 5 thousand degrees, and on the RF side, the insertion phase can be as great as two thousand degrees. Errors in the insertion phase produced by either inhomogeneities in the propagation constant (by a very small percentage) or slight constructional line length differences will produce time-delay errors. A time-delay error produces a phase error which varies linearly with frequency.

Let us now consider a 12 to 18 GHz system where this time-delay error causes a phase error of 1 degree per GHz, Fig. 3. For the real signal, the phase error is equal to 12 degrees at 12 GHz and increases linearly to 18 degrees at 18 GHz. At the image frequency, that is where the LO is below the RF, the phase error is simply reversed in sign. This error could be taken out in one of the three places; a time-delay change in the RF channel, a time-delay change in the LO channel or an IF phase shift. Time delay corrections take out the phase error at all LO frequencies and for both real and image RF frequencies. The problem with this approach is that in real life, a variable time delay will be accompanied by a VSWR addition. This VSWR, if it were the only one in the system, would not be a problem, but this mismatch will beat with the already existing VSWR's of the other components and will produce sinusoidal phase and amplitude error patterns as a function of frequency. Such errors are large enough to mask the good done by the time-delay correction.

A phase-shift at the IF port; however, will not affect the performance of the RF and LO paths as far as VSWR beats with frequency are concerned. It thus can

- d. Bias ability: Rated from 1 through 3
1. Easiest to bias
2. More difficult to bias
3. Most difficult to bias
- 3. m x n spurious rejection: Where |m-n| = 1
ie, 1x2, 2x1, 2x3, 3x2, etc.
Poor: Only partial rejection of |m-n| = 1 spurs
Good: Potentially rejects all |m-n| = 1 spurs

produce a reduction of phase error to zero at one LO frequency (real signal). In the case of the real and image frequency errors in Fig. 3, an IF phase shift of 15 degrees at the IF terminal will produce the phase plots shown in dashed lines. The real channel peak error has been reduced from 18 degrees to 3 degrees. In this case, the image channel peak error has been increased from 18 degrees to 33 degrees. This increase is immaterial if the LO is run consistently on the same side of the RF with only the real channel information being processed.

The biggest cause of amplitude and phase ripple in a subassembly (Fig. 2) is the error paths set up by the mismatch of one component beating the mismatch of another component. The flow diagram of Fig. 4 describes the phase and amplitude ripple of these mismatches:

$$\phi_{pp} = 2 \sin^{-1} \Gamma_1 \Gamma_2 \quad (2)$$

$$A_{pp} = 20 \log \frac{1 + \Gamma_1 \Gamma_2}{1 - \Gamma_1 \Gamma_2} \quad (3)$$

Figure 5 shows the phase and amplitude ripple possible from two mismatches on a 50-ohm line.

There are many possible combinations of error paths due to mismatches of an array of components making up a subassembly. Consider, for example, a hypothetical case where all components in Fig. 2 have a perfect match except the limiter and the RF port of the mixer. If a VSWR of 2.33:1 ($\Gamma = 0.4$) is assumed for both of these mismatches, then from fig. 5, it is possible to have peak-to-peak phase errors of 18.2 degrees and peak-to-peak amplitude errors of 2.8 dB ($\Gamma_1 \Gamma_2 = 0.16$).

Another source of phase and amplitude ripple which can be traced to a mixer is the internally generated image signal leaking from the RF port. This signal can be reflected back into the mixer by the mismatches of other components in the system, mix with the LO and convert to an IF frequency as an error component. Image generation of -12 dB relative to the RF input signal offers the same error path potential as the VSWR of 1.66:1. This image signal leaking from the LO port does not have the same error potential because it is suppressed by common mode rejection.

Figure 3 - Time-delay errors cause a phase error which increases linearly with frequency.

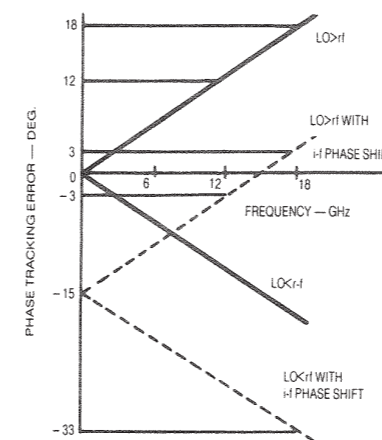


Figure 4 - Flow-graph generation of the transmission coefficient shows cumulative efforts of two mismatches separated by a length of transmission line.

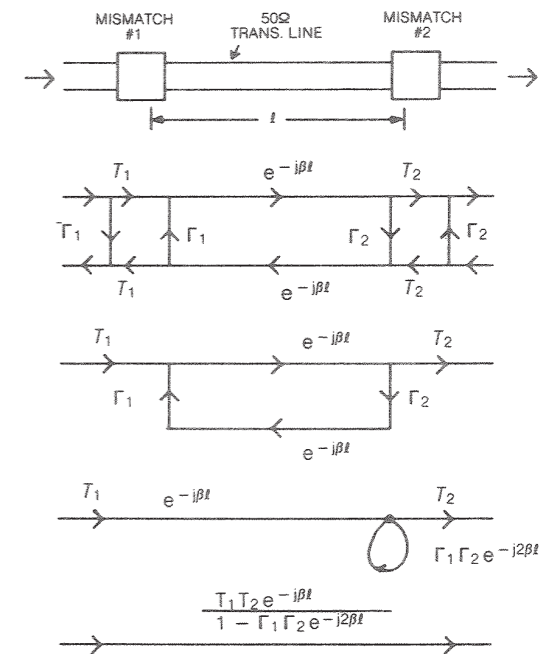
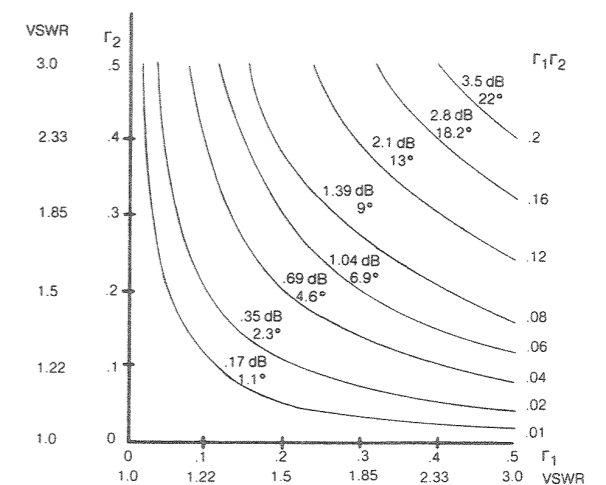


Figure 5 - Two mismatches widely separated by a matched transmission line produce widely varying peak-to-peak amplitude and phase ripple.



Isolation Important

As far as phase and amplitude tracking are concerned, the three parameters that are most important in a mixer are low RF VSWR, low LO VSWR, and image generation at the RF port. These restrictions rule out the double-balanced mixer, Fig. 1a, and the 180 degree hybrid mixer, Fig. 1c, as contenders for a broadband phase and amplitude tracking system. Both the 90 degree hybrid mixer, Fig. 1b and the Ortho-Quad® (quadrature-fed dual mixers), Fig. 1d, have good return loss and do not allow the image signal to come out the RF port. Cross-channel isolation is also very important if significant amplitude imbalance is expected at the RF ports.

It should exceed the greatest amplitude unbalance expected in the system by more than 25 dB to minimize the amplitude-to-phase cross talk. In a phase-only system, where the RF levels are all the same, cross-channel isolation will not produce significant errors.

There are four primary modes that can produce RF to IF cross-channel coupling, Fig. 6. First, is RF leaking through the first mixer across the LO divider and coming in on the LO port to mixer 2. It may then be down converted to the IF frequency at port IF₂. The cross-channel isolation is equal to the RF to LO isolation of the first mixer plus the isolation of the LO splitter at the RF frequency plus the common mode rejection of the second mixer.

The second type of leakage than can occur, Fig. 6b, is IF generated in the first mixer leaking to the LO port through the LO divider and coming in on the LO port of the second mixer. If this mode turns out to be prohibitive, it can be reduced by means of IF filtering on the LO divider.

A third mode of leakage, Fig. 6c, is the sum frequency (LO + RF) generated in the first mixer coming out the LO port, leaking through the LO divider and coming in on the LO port of the second mixer. It then mixes with two times the LO frequency in the second mixer and generates an error signal at the IF. The leakage path is generally not a problem unless the LO divider has no isolation at the sum frequency.

The fourth type of leakage is the image (2 LO - RF) generated in the first mixer leaking out the LO port across the LO divider and coming in on the LO port of the second mixer.

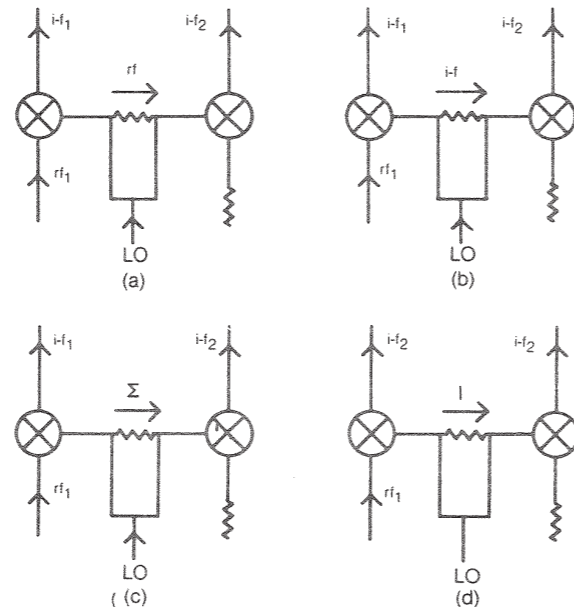
In practice, if the isolation of the LO power divider is maintained in-band and out-of-band, the primary sources of cross channel coupling are RF and image leakage across the LO divider.

The amount of LO power that is re-radiated from the RF terminals is important since it will be ultimately re-radiated out the antennas. The amount of LO power appearing at the RF ports of Fig. 2 is equal to the LO power required per mixer, minus the LO to RF isolation. Under starved LO conditions the typical LO power per mixer is 0 dBm. A 90 degree hybrid mixer affords about 10 dB of LO to RF isolation. The Ortho-Quad® (quadrature-fed dual) mixer provides approximately 25 dB of LO RF isolation. Hence, the LO power appearing at the RF port in Fig. 2 would be either minus 10 dBm or minus 25 dBm, depending upon the type of mixer used. Any further reduction must be made up with phase and amplitude tracking isolators between the RF ports and the antennas.

Mixer Parameters as a Function of LO Power

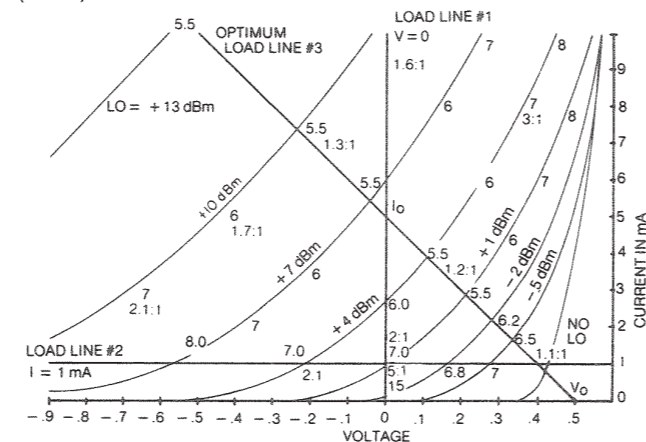
The conversion loss and spurious response of a diode depends on the impedance presented to the diode, not only at the RF and IF frequencies, but over the entire spectrum present in the Taylor's expansion of the diode current. In starved mixer operation, where insufficient local oscillator power is available and a mixer diode must be biased by a dc current the impedance presented to the diode at dc is most important.

Figure 6 - Four Possible Modes of RF to I-F Cross-channel coupling are (a) RF leakage; (b) IF leakage; (c) sum leakage ($\Sigma = LO + RF$) and (d) image leakage ($I = 2 LO - RF$).



The current-voltage characteristics of a hot-carrier diode varies as a function of LO power. This is due to rectification effects in the diode, Fig. 7. The circuit used to obtain these curves is also shown in Fig. 8. With a fixed LO power level applied, the dc voltage is varied, and the dc current through the diode measured. Consider now the response of the diode for three dc load lines, Fig. 7: Voltage = constant = 0 Current = constant = 1.0 mA. A linear load line through V = 0 at 5 mA and I = 0 at 0.5 V.

Figure 7 - Current Voltage Characteristics for a Schottky diode, HP 5082-2506, show diode non-linearities for various LO powers. Conversion loss figures are superimposed on the curves (black)—VSWR (color).



The first load line is for the unbiased diode—the case for the majority of mixers in use today. The second case is when the diode is biased for constant current. Here, the load line is optimized for very low LO power. The third case is a relatively new approach which optimizes both diode conversion loss and RF VSWR

over a wide local oscillator power dynamic range. This requires the use of an optimum dc load line and requires a biasing circuit as shown in Fig. 9.

If the available supply voltage is V_b , then the series resistor (R_1) is chosen such that:

$$R_1 = V_b / I_0 \quad (4)$$

where

I_0 is the dc current value at the intersection of the load line and current axis (Fig. 7).

The shunt resistance R_2 is then chosen to obtain the proper slope of the load line such that:

$$R_2 = V_0 / I \quad (5)$$

where

V_0 is the voltage value at the intersection of the load line and $I = 0$ axis of the diode.

Since there is no current through the diode at this point, the current I through R_2 is:

$$I = \frac{V_b - V_0}{R_1} \quad (6)$$

Combining Eq. (5) and (6), the shunt resistor value is then,

$$R_2 = \frac{V_0 R_1}{V_b - V_0} \quad (7)$$

Figure 8 - Circuit used to derive diode I-V characteristics in Fig. 7 also provides conversion loss.

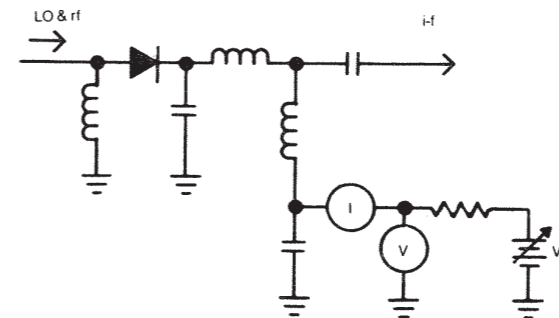
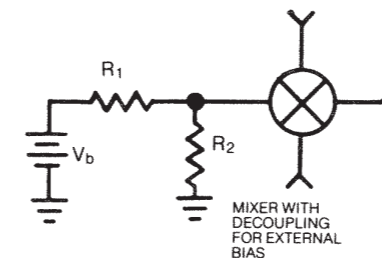


Figure 9 - This bias circuit is required to obtain the optimum dc loading of the mixer diodes.



To obtain the optimum load line of Fig. 7 with a bias supply of 10V; $V_0 = 0.5V$, $I_0 = 5$ mA then,

$$R_1 = \frac{10V}{5 \text{ mA}} = 2k \text{ ohm and}$$

$$R_2 = \frac{(0.5)(2k)}{10-0.5} = 105 \text{ ohms}$$

Figure 10 is a direct plot of conversion loss as a function of LO power for the three dc load line conditions. As can be seen the third load line condition provides the best possible conversion loss over a 35 dB LO dynamic range. The $V = 0$ load line optimizes conversion loss at approximately +10 dBm LO power and the $I = 1.0$ mA load line has an optimum conversion loss only for LO powers below -7 dBm.

Spurious and intermodulation suppression can also be superimposed on the I-V curve as a function of LO power. Fortunately, a load line can be chosen to optimize spurious suppression, conversion loss and VSWR simultaneously. Conversion loss and two-tone suppression [(2f₁ - f₂); f₁ and f₂ at -10 dBm] are plotted in Fig. 11. At high LO powers, (i.e., about +16 dBm) a load line other than $V = \text{constant} = 0$ can be used to improve two-tone suppression with no degradation in conversion loss. For example, the load line in Fig. 11 gives 60 dB two-tone suppression with 5.5 dB conversion loss at +16 dBm. Using the $V = 0$ load, however, the optimum conversion loss point has less than 50 dB two-tone suppression. If the LO power is increased to improve the two-tone suppression, the conversion loss degrades by 2.5 dB.

The $m \times n$ spurious suppression can also be superimposed on the current-voltage curves in Fig. 11 in the same manner as the two-tone suppression. Best spurious performance results with relatively high LO power and by selecting the proper load line.

Figure 10 - By optimizing the load line at which a mixer diode operates, the dynamic range of a mixer can be improved to 35 dB.

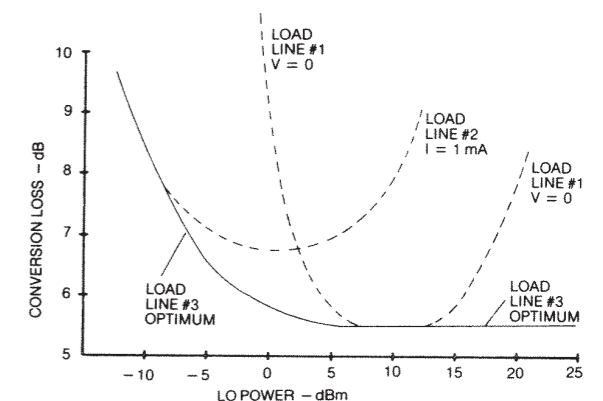
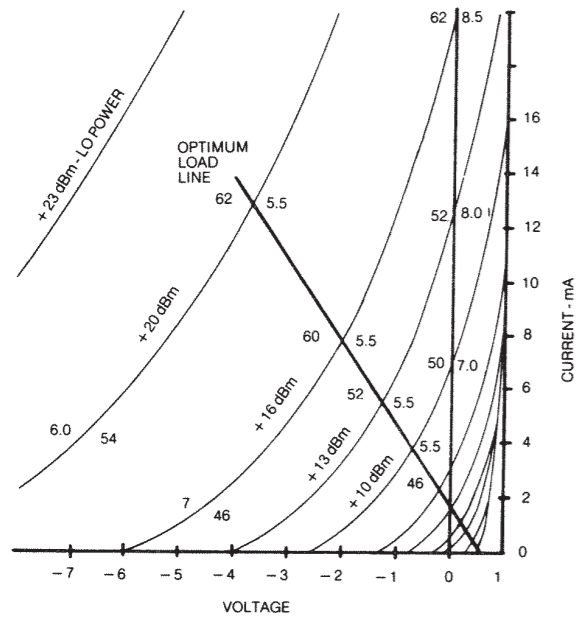


Figure 11 - Variations of conversion loss (black) and two-tone suppression (color) as a function of LO power are shown super-imposed on the I-V characteristics of a mixer.



Increase of Dynamic Range by Means of Gating

A starved LO situation, which is frequently encountered in broadband electronic warfare systems, can produce serious dynamic range problems. The spurious suppression of a mixer is seriously degraded as the LO power is reduced. For example, a choice of mixers will not help the particular situation depicted in Fig. 12, since all of the mixers of Fig. 1 suppress the 2x2 and none of them suppress the 3x3. A gating technique, however, can be used when severe spurious generation limits the dynamic range.

Figure 12 - Spurious 2x2 and 3x3 signals vary linearly with LO power.

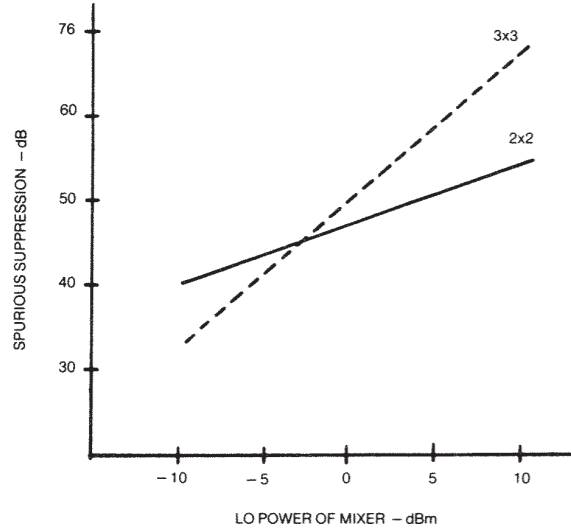


Figure 13 - Spurious chart indicates under what RF and LO conditions spurious signals occur. The rectangle represents limitations of a typical bandpass filter.

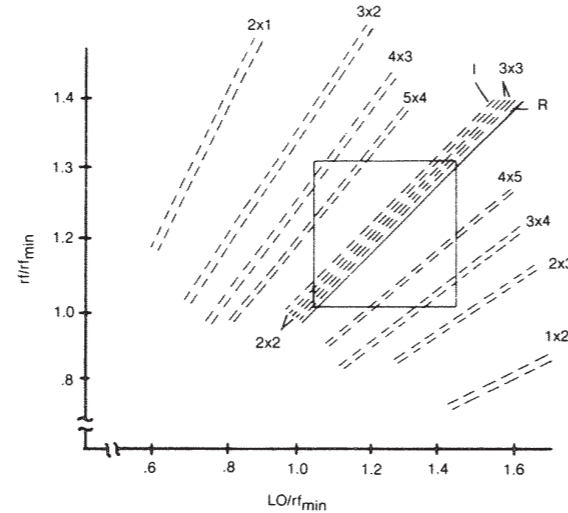
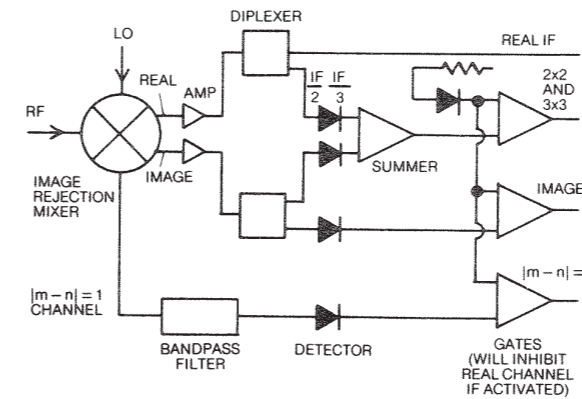


Fig. 13 is a spurious chart showing the relative RF and LO frequencies at which the various spurious signals occur. In this chart, both the RF and LO signals are normalized to the minimum RF frequency. In this case, it is assumed that the real signal will exist when the LO is above the RF. Fig. 13 assumes the IF frequency is equal to 4% of the minimum RF frequency. The LO and RF frequencies required to produce the m x nth spurious signals are:

$$mLO - nRF = +IF \quad (8)$$

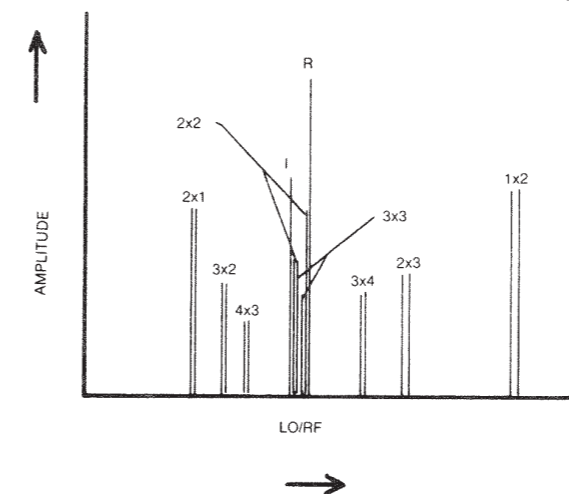
We can divide all these spurious signals into two categories; near in terms, that is RF close to the LO frequency, and far out terms, (i.e., where the RF is at least 20% removed from the LO frequency). The troublesome near-in terms are the image (which is at the same level as the real signal for a single mixer), and the 2x2 and 3x3. The troublesome far-out terms are the m x n spurs where |m-n| = 1. Gating techniques can utilize three separate gates. The first will inhibit the signal channel if an image is present, the second will inhibit the signal channel if either a 2x2 or 3x3 is present, and the third will inhibit the signal channel if signals such as the 3x2, 4x3, or |m-n| = 1 are present. The gating technique shown in Figure 14 centers around an image rejection mixer. The mixer itself has two input ports; the LO and RF. It has two IF outputs, the real channel and the image channel; in addition, it has one other output which will provide the difference frequency when the |m-n| = 1 spurs are present. This particular port has no image rejection; it will respond in the same manner for both the high side and low side spur.

Figure 14 - Gating circuits used in conjunction with an image-rejection mixer allows rejecting 2x2, 3x3 and m-n = 1 spurs.



Before discussing the gating circuitry further, consider what would come out the real port of an image rejection mixer after passing through a narrow band IF filter as the LO is swept over a wide frequency range for a fixed high level RF signal. The IF output as a function of LO frequency normalized to the RF frequency is plotted in Fig. 15. A similar plot of the image channel would yield a similar looking spectrum, except that the level of the real and image signals would be interchanged. The image gating takes the real and image channel and passes them through narrowband filters at the IF frequency. A comparison is made of the real to image level. If the image is greater than the real, the image gate is activated.

Figure 15 - This spectrum occurs with an image rejection mixer after passing through a narrowband IF filter as the LO is swept over a wide-frequency range.



The 2x2 spur is generated when the LO is above or below the RF signal by half of the IF frequency. The image rejection mixer is designed such that the IF response is flat from one-third of the IF frequency to the IF frequency. This means, when the 2x2 spur is produced at the IF frequency, there is a much stronger signal (stronger by the 2x2 suppression) at one-half the IF frequency. A diplexer is placed in the real channel to separate out one-half the IF frequency and one-third the IF frequency.

Theoretically, the 2x2 spurious should be at the same level for both the real and image channels. In practice, these two channels do not track closely. Differences as great as 10 dB can be seen in large production lots. To overcome this imbalance, the diplexer is placed in both the real and image channel and detectors are placed on both output and the video signals are added. This 2x2 and 3x3 detector will respond for RF signals that are removed from the LO frequency in the vicinity of one-third to one-half the IF frequency. If the response of the real channel is due to a 2x2 or 3x3 spurious, this spur channel detector output will be stronger than the real channel detector by the spur suppression. Relative amplitudes of these detectors can be adjusted and fed into the 2x2 or 3x3 gate. When the gate is activated, the system output is inhibited because of the possibility of a 2x2 or 3x3 spurious signal being present.

The third gate works on the spurious signals with wide LO to RF separation. For a given spurious, such as the 4x3 spur, the range of difference in frequencies between the LO and RF over which this spur can be generated is relatively small. The 3x2 and 2x3 spurs are generated in the vicinity of LO-RF = 0.5 of RF min. The 4x3 and 3x4 are generated in the vicinity of LO-RF = 0.33 RF min. The 4x3 and 3x4 are generated in the vicinity of LO-RF = 0.2 RF min. The high IF (|m-n| = 1) port of the mixer can be filtered for one or more of these spurious and followed by a detector. Pre-amplification should not be needed in front of the detector since these signals are higher than the real channel spurious by the amount of the spurious rejection. The output of this detector is then compared to the real channel detector. If the detector output of the |m-n| = 1 channel is greater than the real channel, this gate will be activated and the real channel will be inhibited because of the possibility of a spur whose absolute value of m-n is equal to 1.

These gating techniques have one serious drawback. A desired low-level real signal can be rejected in the presence of a high-level non-spurious signal occurring at an RF frequency where a spur would exist. The probability of this happening is proportional to the bandwidth of that particular detector. Therefore, the image gate presents the least serious problem. Next would be the 2x2 and 3x3 gate, and the most serious is the |m-n| = 1 channel.

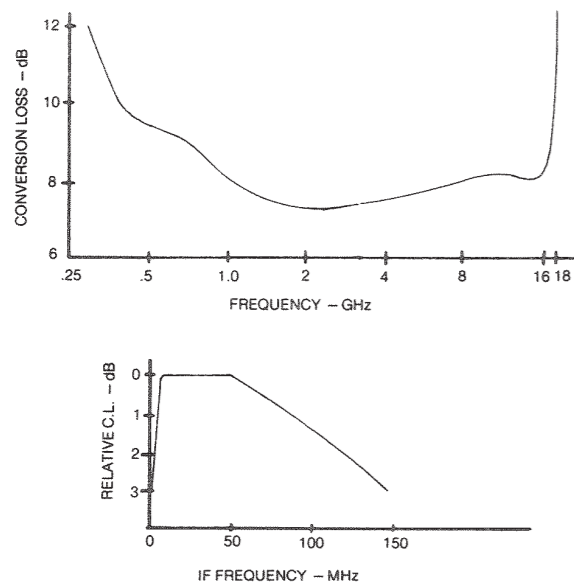
Future Trend—Wider Bandwidths

Two trends are emerging with EW receivers

- Mixers requiring more and more bandwidth
- Mixers with high IF frequency capability

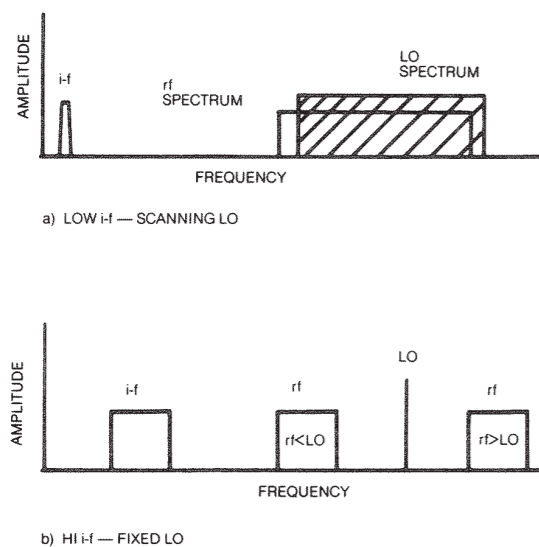
Recent developments in biasing of the 90-degree hybrid-coupler mixer have made possible bandwidths of six octaves in a single mixer, Fig. 16. The 3 dB point of the IF response is 150 MHz. since the mixer is biased, the minimum IF frequency is determined by the coupling capacitor. In this case, the minimum IF frequency is 1 Mhz. The typical RF and LO VSWR is 1.5:1, (hence, it is possible to use this mixer in phase and amplitude tracking systems). The typical LO to RF isolation is only 6 dB.

Figure 16 - A 90-degree hybrid mixer can be designed to cover six octaves or over a 60:1 bandwidth.



The second trend is in high IF mixers. A frequency spectrum comparison between the low IF scanned LO system and the high IF fixed LO system is made in Fig. 17. In a low IF system, the LO is swept through the RF band in a search mode such that IF is always in the center of the IF pass band. When this occurs, the RF frequency is equal to the LO frequency, minus the IF. Circuitry must be provided for rejecting images and 2x2 and 3x3 intermodulation products as well as 2x1 and 3x2 higher-order spurs. In the high IF system, the image and the 2x2 and 3x3 lower-order intermodulation products are not a problem. The LO is a fixed frequency and the IF is typically an octave wide. This means that an RF band—either below or above the LO frequency— can be covered but preselection is required to separate the RF band.

Figure 17 - This spectrum shows the differences between a low IF scanned LO system and a high IF fixed LO system.



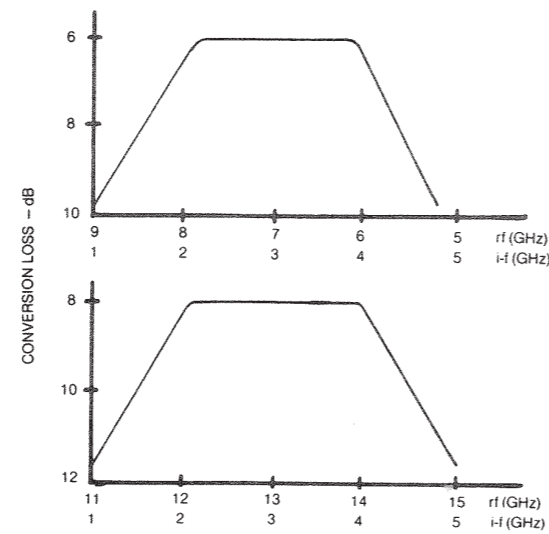
The two major advantages of a high IF system are

- Less complicated LO system
- Elimination of image and 2x2 and 3x3 spurious response.

The major disadvantage is a more complicated IF processor because of the increase of both absolute and percentage bandwidth.

The conversion loss of a mixer with a 10 GHz LO and 2-4 GHz IF is shown in Fig. 18.

Figure 18 - Conversion loss of a high IF mixer with an IF of 2-4 GHz and an LO of 10 GHz.

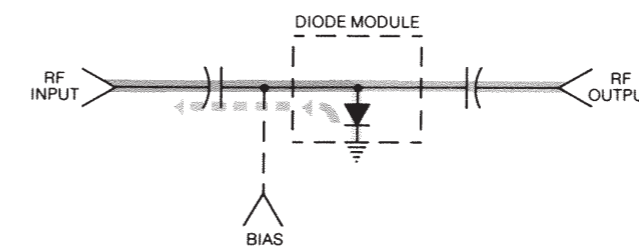


There are two basic types of PIN control devices, reflective and non-reflective. As the name implies, reflective attenuators reflect some portion of the input power back to the driving source; the amount reflected being a function of the attenuation level. Non-reflective (absorptive) attenuators absorb this reflected power in some manner so that it never appears at the input or output ports. Since any reflected power is a measure of VSWR, the absorptive attenuator offers better VSWR characteristics than the reflective device.

Reflective Attenuator

Fig. 1 is a simplified block diagram of a reflective attenuator.

Figure 1 - Reflective Attenuator



When the PIN diodes are zero-biased, or reverse-biased, they appear as open circuits which permit most of the RF input power to travel to the RF output port. Whenever, the diodes draw bias current, their RF resistance decreases and they absorb some of the RF input, but simultaneously reflect some back to the input

port. The remainder of the RF input passes on to the output port. At maximum bias current, when the diodes have very low RF resistance, most of the RF input will be reflected back to the input port resulting in a high input VSWR.

Absorptive Attenuators

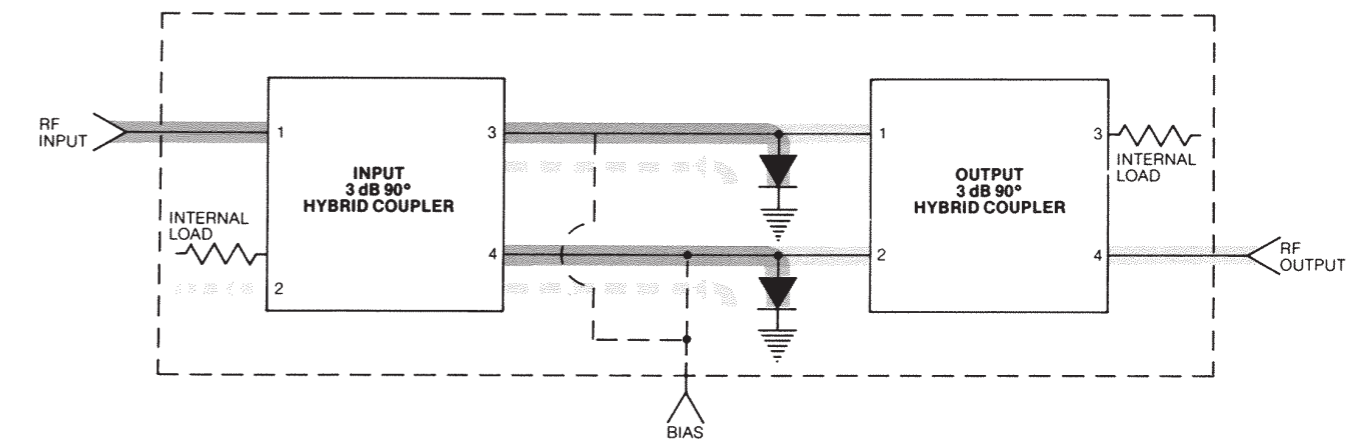
Fig. 2 is a simplified block diagram of a non-reflective (absorptive) attenuator. The VSWR of an absorptive unit remains good at any attenuation (bias) state because of the properties of the input and output hybrid couplers.

The input 3 dB 90° hybrid coupler divides the RF input at port 1 equally to ports 3 and 4. When the PIN diodes are zero-biased, or reverse-biased, they basically appear as open circuits which permits nearly all the RF input to travel to ports 1 and 2 of the output 3 dB 90° hybrid coupler. The output coupler combines these inputs to port 4, the RF output port.

Whenever the diodes draw bias current, their RF resistance decreases and they absorb a portion of the RF input while simultaneously reflecting some of the RF input back to ports 3 and 4 of the input coupler.

The remainder of the RF input is combined in the output coupler to the RF output port. That portion of the RF input, reflected by the diodes to the input coupler, is combined to port 2, which is terminated internally with a 50 ohm load. Thus, none of the reflected RF input appears at the RF input port even at maximum bias when the diodes have very low RF resistance.

Figure 2 - Simplified Block Diagram of 60360 Series Non-Reflective PIN Diode Attenuator



By Carl W. Gerst, Jr., Executive Vice President, Anaren Microwave, Inc. Reprinted from "Microwaves."

Power Handling

At a certain value of diode impedance, the diodes will be absorbing some maximum amount of power. This point occurs at approximately the 6 to 10 dB attenuation state of the attenuator and limits the maximum power handling of the attenuator. At lower attenuation (bias) settings the diodes pass most of the microwave energy along the transmission line to the output hybrid; at higher attenuation (bias) settings most of the energy is reflected back to the hybrid internal load and is dissipated there.

Maximum RF power ratings (burnout levels) are 2 watts CW at 25° C, linearly derated above 25° C to 1 watt at +95° C. Pulse power ratings (1 microsecond wide, 0.001 duty cycle) are 50 watts peak at 25° C, linearly derated above 25° C to 25 watts at +95° C. These "burnout" ratings are very conservative and are based on worst case analysis for heat sinking, attenuation level and rate of temperature rise (thermal shock).

There are other effects limiting power handling for the absorptive attenuators and attenuator/drivers. Before the maximum PIN diode burnout rating is exceeded, diode self rectification effects (frequency and power sensitive) can limit the power handling because of harmonic generation and accompanying distortion products.

Insertion Loss

With Anaren attenuators and attenuator/drivers, insertion loss is primarily a function of RF dispersive losses in the 90° input and output hybrids and PIN diode modules, and increases with increasing RF frequency.

Attenuator Flatness

Attenuator flatness is a function of input and output match, hybrid performance, and diode-module tracking. The input and output match is tightly controlled due to attenuator design, excellent hybrid performance and because the modules are Anaren designed and built. The combination these factors assures the exceptionally high degree of uniformity required for the attenuator specifications and applications.

Attenuation flatness is specified as ±2 dB maximum for attenuation settings up to 45 dB for L thru X band units. The typical data curves of attenuation versus frequency on pages 66-67 show, for lower attenuation values and/or narrower bandwidths, flatness is dramatically improved. A 20% BW at any attenuation setting will provide a typical flatness of ±0.25 dB. As the attenuation curves also show, the octave-band specifications are generally valid 10% out-of-band and the X band specifications are typical for 20% out-of-band performance.

Vector Modulator

Aside from the conventional applications of PIN attenuators such as modulators, switches, and levelers, the PIN attenuator can be connected in complex networks to provide a variety of functions. One such application is a Vector Modulator (Figure 5) which utilizes PIN attenuators, in-phase power dividers, 90° and 180° couplers. With the correct control signals, all value of phase and an amplitude (over 55 dB dynamic range) can be generated. In this application the control signals shown in Figure 5 control the vectors as illustrated in Figure 6. The control signals are analog and vary between 0 and +10V, +10 volts being the "absence of" the vector signal. For example, a vector of unity amplitude and relative phase of -90° would require +10 Volts on A-2, B-1 and A-1 and 0 volts on B-2.

Insertion loss through the vector modulator is approximately 12dB. Since the network utilizes PIN diodes it can be operated at relatively high input levels with low intermodulation levels. The Vector Modulators can be operated at a level of 100 mw (+20 dBm) input for harmonics 50 dB down.

Figure 5 - Vector Modulator

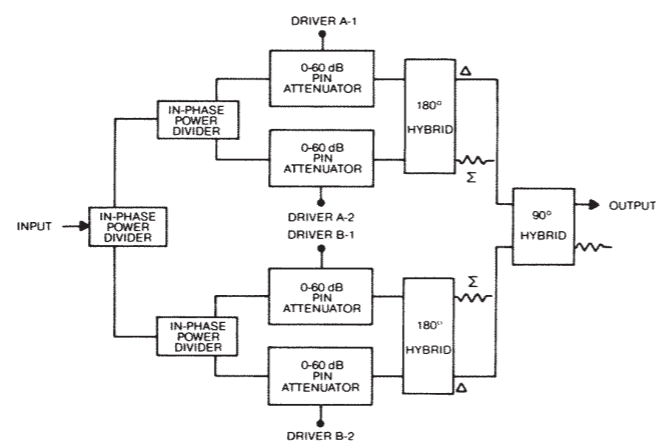
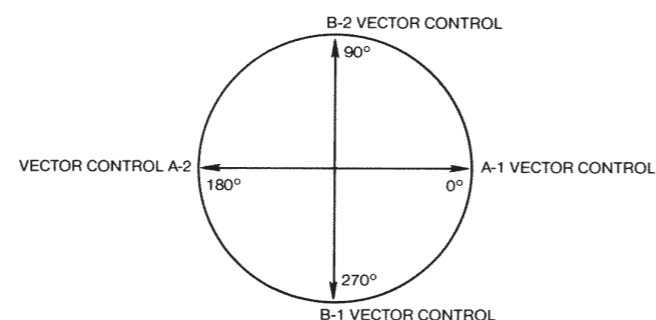


Figure 6 - Vector Modulation Control Diagram

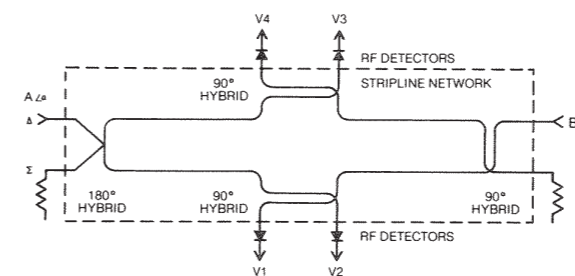


The Phase Discriminator (correlator) and Frequency Discriminator are similar devices. Both use a common principle; a unique phase difference between two RF signals is determined. The phase angle is measured (by interferometry) and, instantaneously, the required phase, frequency or amplitude signature of the RF signal is obtained.

Phase Discriminators

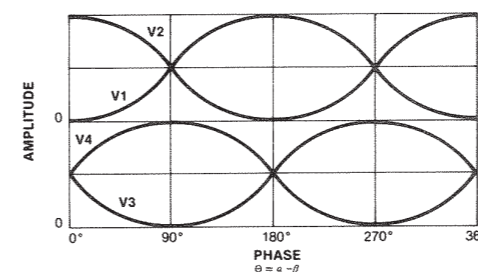
Consider first the phase discriminator (correlator) network shown in Figure 1.

Figure 1 - Phase Discriminator (Correlator) Network



The passive RF portion of this device is a two-channel processing network. Two RF input signals (A ∠ α and B ∠ β) are divided to the four output ports. The resultant outputs are square-law detected and have the amplitude and phase relationships shown in Figure 2.

Figure 2 - Instantaneous Video Amplitude Versus Phase

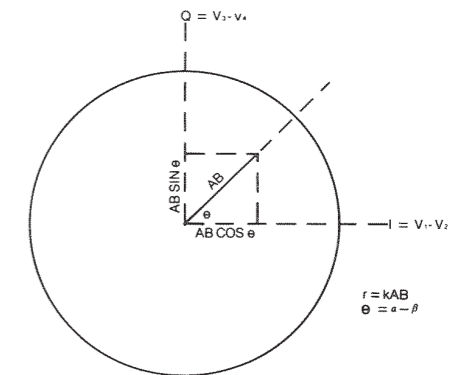


These video voltages are a function of the relative phase between inputs A and B (θ = α - β) and are proportional to:

$$\begin{aligned} V_1 &= (A^2 + B^2) + 2AB \cos \theta \\ V_2 &= (A^2 + B^2) - 2AB \cos \theta \\ V_3 &= (A^2 + B^2) + 2AB \sin \theta \\ V_4 &= (A^2 + B^2) - 2AB \sin \theta \end{aligned}$$

Connecting V1 and V2 to the +X and -X deflection plates of an oscilloscope, and connecting V3 and V4 to the +Y and -Y deflection plates, respectively, will produce a circular (polar) display. The radius of the display will be proportional to AB and the angular displacement proportional to θ, as indicated in Figure 3.

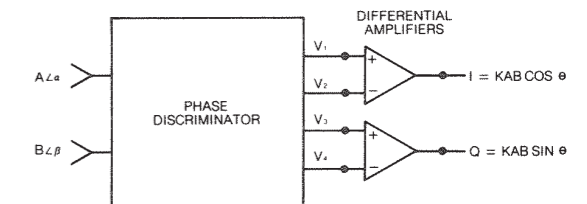
Figure 3 - Polar Discriminator Display



Alternatively, outputs V1 thru V4 can be combined in differential amplifiers as shown in Figure 4. These two resulting bipolar voltages are also the X-Y coordinates of a polar display and are of the form:

$$\begin{aligned} I &= kAB \cos \theta \\ Q &= kAB \sin \theta \end{aligned}$$

Figure 4 - Simplified Block Diagram Phase Discriminator/Video Amps.



These two video outputs are, in fact, the in-phase (I) and quadrature (Q) components of the correlation of the two RF signals over a time period corresponding to the video bandwidth (30 nanoseconds for 15 MHz video bandwidth). To increase the correlation time, simply reduce the video bandwidth.

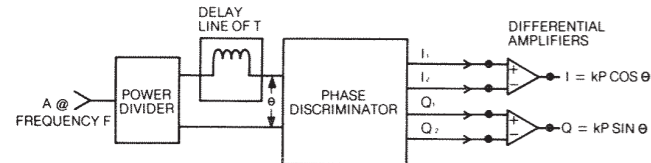
When I and Q are applied to the oscilloscope the beam is deflected from the center of the display. The vector radius is again proportional to AB (signal power) and the angle at which it occurs is θ (the relative phase angle between A and B). CW signals would produce a dot at the vector tip (in a completely dc coupled network). Pulsed signals will produce a strobe along the vector radius.

The phase discriminator (correlator) can serve as a common signal processing network for systems designed to monitor bearing, polarization and frequency of AM or FM radiated signals.

Frequency Discriminators

A frequency discriminator uses a phase discriminator and adds a power divider/delay line at the RF input as shown in Figure 5. The unknown RF signal A is divided to a reference and delay path. The differential delay (T) creates a phase difference (θ) between the two signals which is linear function of frequency (f) and is given by $\theta = 2 \pi f T$.

Figure 5 – Frequency Discriminator



The two signals are applied to the phase discriminator which provides four detected video voltages proportional to:

$$V_1 \equiv I_1 = \frac{kP}{2}(1 + \cos \theta) \quad V_3 \equiv Q_1 = \frac{kP}{2}(1 + \sin \theta)$$

$$V_2 \equiv I_2 = \frac{kP}{2}(1 - \cos \theta) \quad V_4 \equiv Q_2 = \frac{kP}{2}(1 - \sin \theta)$$

Where: P is the RF signal power level
k is a constant related primarily to delay line insertion loss

These output voltages are used in the same manner as described in the previous section on phase discriminators. All four outputs can be applied directly to an oscilloscope or they can be differenced in a pair of differential video amplifiers to produce bipolar voltages:

$$C = I_1 - I_2 = kP \cos \theta$$

$$S = Q_1 - Q_2 = kP \sin \theta$$

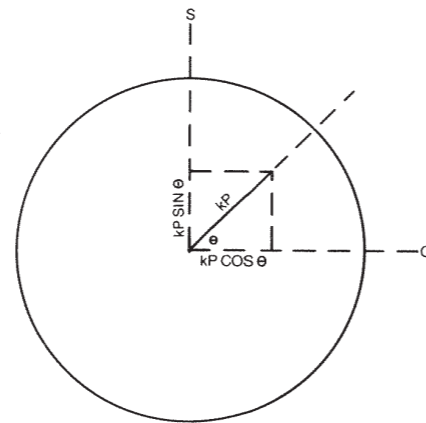
Either method would result in a display as shown in Figure 6. Again, the deflection radius (kP) is proportional to the power of the RF signal. For the frequency discriminator, however, the angle (θ) is now linearly proportional to the frequency of the RF signal. This proportionality constant depends on the differential delay required and determines the length of the delay line.

The frequency discriminator display is obviously ambiguous if required to operate over more than 360°. The delay time is therefore selected so that varying the frequency from start (F min) to stop (F max) yields approximately 275°–330° rotation on the oscilloscope display. The unambiguous bandwidth for a discriminator with a differential delay, T, is given by:

$$\Delta f = \frac{1}{T}$$

For example, an S-band discriminator designed to work from 2 to 4 GHz typically would require a differential delay of about 0.39 nanoseconds. This would provide an unambiguous bandwidth of 2.56 GHz, with the phase angle θ varying from 281 degrees at 2 GHz to 562 degrees at 4 GHz.

Figure 6 – Polar Display of Discriminator Video Outputs



The phase/frequency relationship is theoretically linear. However, owing to construction tolerances, a practical discriminator exhibits a phase linearity error. Depending on the operating band, at any given frequency, the actual phase angle produced may be in error by as much as plus or minus 12 degrees. For any given discriminator, this is a reproducible error. That is, the same angle will always be produced for the same frequency. The actual phase/frequency function is thus:

$$\theta = 2 \pi f T \pm \epsilon$$

where ϵ is the phase linearity error.

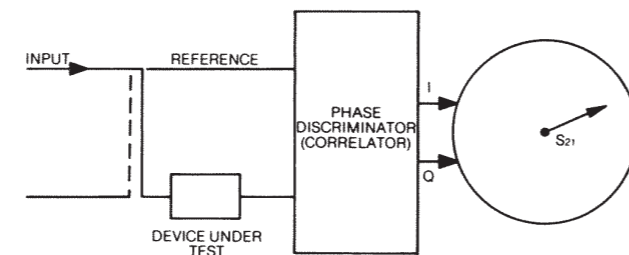
Application Information

Test & Measurement Networks:

Measurement of Transfer Characteristics

The transfer characteristics of a device can be rapidly and accurately determined over wide bandwidths with a correlator connected as shown in Fig. 7.

Figure 7 – Connection Of Correlator For Determination Of Transfer Characteristics



The reference signal is adjusted to equal 1 L^0 on the CRT display. The polar display is then proportional to the transfer characteristics of the device under test.

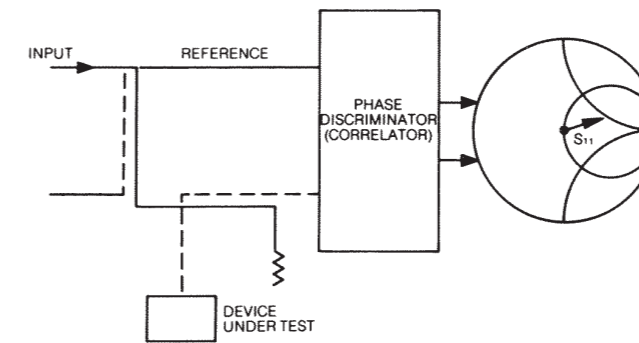
This testing technique is particularly useful for measuring the transfer characteristics of phase-shifters and microwave transistors.

The vector display can be continuously monitored as successful states of the phase-shifter are switched into the circuit; microwave transistors can readily be tested for both gain and insertion phase over wide bandwidths.

Smith Chart Plotter

A correlator connected as shown in Fig. 8 will provide a fast, accurate Smith Chart display of the input impedance of a device under test.

Figure 8 – Connection Of Correlator For Display Of Input Impedance.



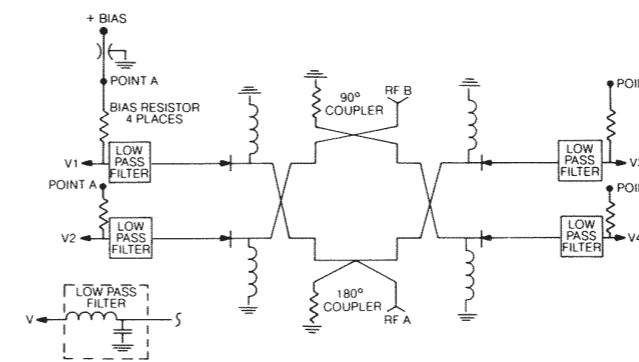
As indicated, an additional coupler is required to obtain a signal proportional the reflection component. With a Smith Chart plot on the face of the CRT the input impedance of the device being tested can be read directly.

If a leveled sweep source is used, the octave bandwidth of the correlator makes it possible to quickly match devices over wide bandwidths.

Video Interface Considerations

Anaren phase discriminators Series 20750, which do not include video amplifiers, use Schottky Barrier diodes as detectors. Because of the voltage potential necessary, to bring the Schottky Barrier detectors into conduction an external bias voltage (+5V) is used to forward bias the detectors. This bias level is set for optimum tangential sensitivity and linearity and is established by four fixed resistors inside the discriminators. (Figure 9)

Figure 9 – Phase Discriminator Series 20750



Due to the voltage drop across the detectors caused by the external bias, there is a dc offset voltage present on the video output terminals. This offset voltage value is a function of the diode VF characteristics and may be between 200 mV and 450 mV DC.

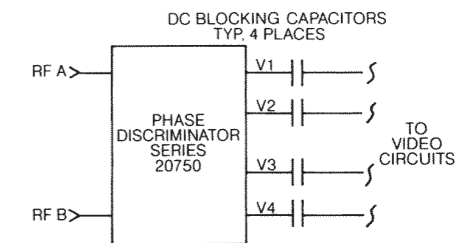
Certain precautions must be taken when connecting the video outputs of the 20750 series discriminators to external circuits:

1. The connecting circuit must be of sufficient high dc resistance (greater than 500K ohms) so that it does not shunt all or part of the detector bias current. If the connecting circuits dc resistance is not high enough the discriminator will not perform to specification. However, this will not affect the reliability of the discriminator. The discriminator will function correctly when reconnected to a high dc resistance video circuit.

There are various methods that can be used to interface the discriminators video outputs. Two are listed below:

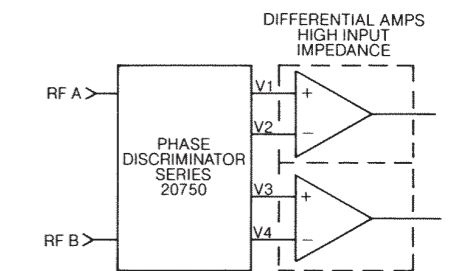
- (a) Install series blocking capacitors in the video circuits. This will affect the low frequency response of the video signal but will prevent bias shunting to the video load. (Figure 10) The Anaren discriminator series 2A0750 uses this method. They have integrated ac coupled video amplifiers which interface with the video detectors.

Figure 10 - Installation of Series Blocking Capacitors



- (b) Connecting the detector outputs to a differential amplifier having a high input impedance (greater than 500K ohms) The detector offset voltage appears as a common mode voltage to the differential amplifiers and the zero signal output should be near zero. Slight offsets due to circuit imbalances can be trimmed out. (Figure 11)

Figure 11 - Connecting Outputs to High Input Impedance



2. Precautions should be taken to prevent static discharge damage to the discriminators. The RF detector diodes used in the Anaren discriminators are protected against applications of reverse bias voltages but are static sensitive. These detectors may be permanently damaged by careless handling. Antistatic handling procedures must be used.

Hybrids Coupler, no case Selection Matrix

90° Hybrids, no case									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Port Impedance (Ω)	Return Loss (VSWR)	Insertion Loss (dB)	Amplitude Balance (+/- dB)	Phase Balance (+/- °)	Isolation (dB)
10230-3	0.03 - 0.076	800	2.1 x 2	50	1.4:1	0.5	0.8	2	15
10270-3	0.03 - 0.076	200	2.65 x 2.65	50	1.2:1	0.45	0.8	2	20
1A0230-3	0.054 - 0.088	700	2.1 x 2	50	1.2:1	0.45	0.5	2	20
10261-3	0.0625 - 0.125	200	1.83 x 2.01	50	1.2:1	0.35	0.5	2	20
1D0261-3	0.07 - 0.11	200	1.83 x 2.01	50	1.2:1	0.3	0.3	2	20
1A0280-3	0.09 - 0.18	200	1.83 x 2.01	50	1.2	0.3	0.5	2	20
1H0280-3	0.09 - 0.18	200	2.2 x 0.8	50	1.2	0.3	0.5	2	18
1J0280-3	0.1 - 0.16	500	2.2 x 0.8	50	1.2	0.3	0.3	2	20
1A0920-3	0.1 - 0.5	200	5 x 2.5	50	1.35	0.9	0.85	2.5	13
RFP-4243	0.12 - 0.23	200	2.2 x 0.8	50	1.25	0.3	0.5	2	20
10262-3	0.125 - 0.25	300	1.43 x 1.5	50	1.2	0.3	0.5	2	20
RFP-4053	0.13 - 0.18	200	2.2 x 0.8	50	1.25	0.3	0.4	2	20
1H0262-3	0.16 - 0.23	400	1.43 x 1.5	50	1.2	0.3	0.3	2	20
10260-3	0.225 - 0.4	250	1.25 x 1.25	50	1.2:1	0.3	0.5	2	20
1A0260-3	0.225 - 0.4	250	1.09 x 1.22	50	1.2	0.3	0.5	2	20
1B0260-3	0.225 - 0.4	250	2 x 0.5	50	1.2	0.3	0.5	2	20
1R0260-3	0.225 - 0.4	250	1.62 x 0.56	50	1.2	0.3	0.5	2	20
10263-3	0.25 - 0.5	200	1.25 x 1.25	50	1.2	0.3	0.5	2	20
1H0263-3	0.25 - 0.5	200	1.62 x 0.56	50	1.2	0.3	0.5	2	20
RFP-4047	0.3 - 0.5	200	1.35 x 0.5	50	1.2	0.3	0.4	2	21
1D0263-3	0.3 - 0.55	200	1.25 x 1.25	50	1.2	0.3	0.5	2	20
1R0263-3	0.4 - 0.52	100	2 x 0.5	50	1.2	0.3	0.25	2	20
1B0263-3	0.4 - 0.7	200	2 x 0.5	50	1.2	0.3	0.5	2	20
1H0264-3	0.44 - 0.88	200	1 x 1	50	1.2	0.3	0.5	2	20
10264-3	0.5 - 1.0	200	1 x 0.87	50	1.2	0.3	0.5	2	20
1B0264-3	0.5 - 1.0	200	1.35 x 0.5	50	1.2	0.3	0.5	2	20
10330-3	0.7 - 1.4	150	0.81 x 0.81	50	1.25	0.3	0.5	2	18
RFP-4015	0.8 - 1.0	400	1.5 x 0.5	50	1.25	0.3	0.3	1.5	20
1Y0265-3	0.8 - 2.1		1.35 x 0.5	50	1.3	0.35	0.9	2.5	17
1B0220-3	0.8 - 2.5	55	2.2 x 0.8	50	1.5	0.25	0.5	3	12
1A0220-3	0.8 - 4.2	55	2.2 x 0.8	50	1.43	0.45	0.7	3	16
1B0890-3	0.85 - 1.45	150	1.35 x 0.5	50	1.25	0.3	0.5	2	20
10890-3	0.95 - 1.225	150	1.35 x 0.5	50	1.25	0.3	0.3	2	18
1L0265-3	1.0 - 1.4	150	1.35 x 0.5	50	1.25	0.3	0.3	2	20
10265-3	1.0 - 2.0	100	0.81 x 0.81	50	1.25	0.3	0.5	2	18
1B0265-3	1.0 - 2.0	100	1.35 x 0.5	50	1.25	0.3	0.5	2	18
1C0220-3	1.0 - 4.2	55	2.2 x 0.8	50	1.36	0.45	0.6	4	16.5
1K0265-3	1.3 - 1.7	100	1.35 x 0.5	50	1.25	0.3	0.3	2.5	20
1E0320-3	1.3 - 2.6	100	0.81 x 0.81	50	1.3	0.35	0.5	2.5	18
1G0265-3	1.35 - 1.85		0.81 x 0.81	50	1.25	0.3	0.5	2	22
1B0320-3	1.7 - 2.5	100	1.35 x 0.5	50	1.3	0.35	0.5	2	18
1B0266-3	1.7 - 3.4	80	1.2 x 0.4	50	1.3	0.35	0.5	2.5	17
10266-3	2.0 - 4.0	60	1.2 x 0.4	50	1.3	0.35	0.5	2.5	17
1C0266-3	2.0 - 4.0	60	1.35 x 0.51	50	1.3	0.35	0.5	3	17
1D0266-3	2.0 - 4.2		1.35 x 0.51	50	1.35	0.035	0.7	3	16
11270-3	2.0 - 6.0	50	1.62 x 0.56	50	1.5	0.8	0.8	3.5	15
1A0266-3	2.1 - 4.2	60	1.2 x 0.4	50	1.3	0.35	0.5	2.5	18

Hybrids Coupler, no case Selection Matrix

90° Hybrids, Hi-pwr, no case									
Part Number	Frequency GHz	Power (W)	Size inches/ (mm)	Port Impedance (Ω)	Return Loss (VSWR)	Insertion Loss (dB)	Amplitude Balance (dB)	Phase Balance (°)	Isolation (dB)
1Z0261-3	0.088 - 0.108	400	2.65 x 2.65	50	1.15	0.25	0.4	2	23
1Z0280-3	0.1 - 0.16	700	2.65 x 2.65	50	1.15	0.25	0.4	2	23
1Z0262-3	0.16 - 0.23	560	4.5 x 0.8	50	1.15	0.25	0.3	2	23
1Z0263-3	0.2 - 0.4	420	4.5 x 0.8	50	1.15	0.25	0.5	2	20
1H0360-3	0.225 - 0.4	420	4.5 x 0.8	50	1.15	0.25	0.4	2	23
1Z0364-3	0.44 - 0.88	280	1.43 x 1.5	50	1.15	0.25	0.5	2	23



Model 10230-3

Hybrid Couplers
3 dB, 90°



Applications

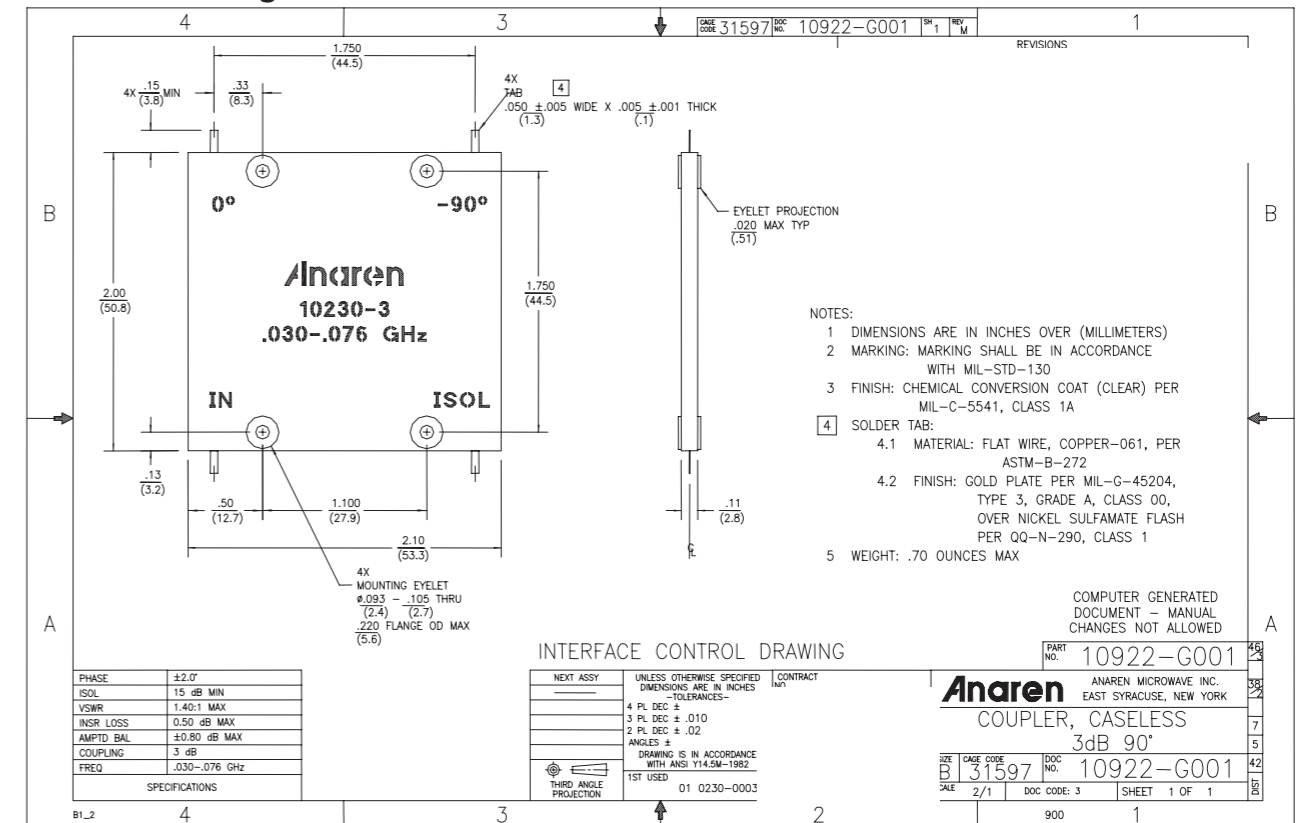
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.03 - 0.076 GHz
- Welded Tab mount
- Reliable Performance
- Handles 800 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Asia: +86-512-62876400

Model 10270-3



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.03 – 0.076 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements



Model 1A0230-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

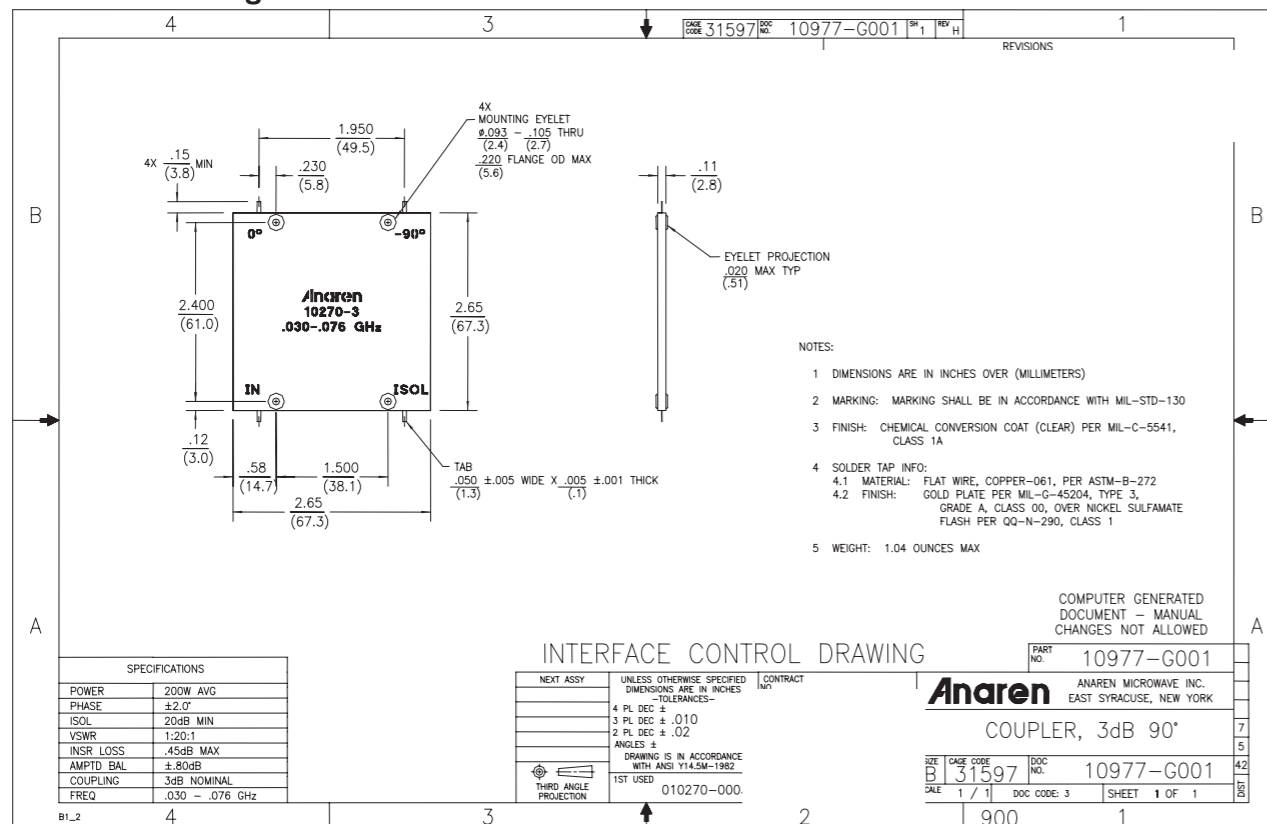
Features

- 0.054 – 0.088 GHz
- Welded Tab mount
- Reliable Performance
- Handles 700 Watts
- Meets MIL-E-5400 Class 3 Requirements



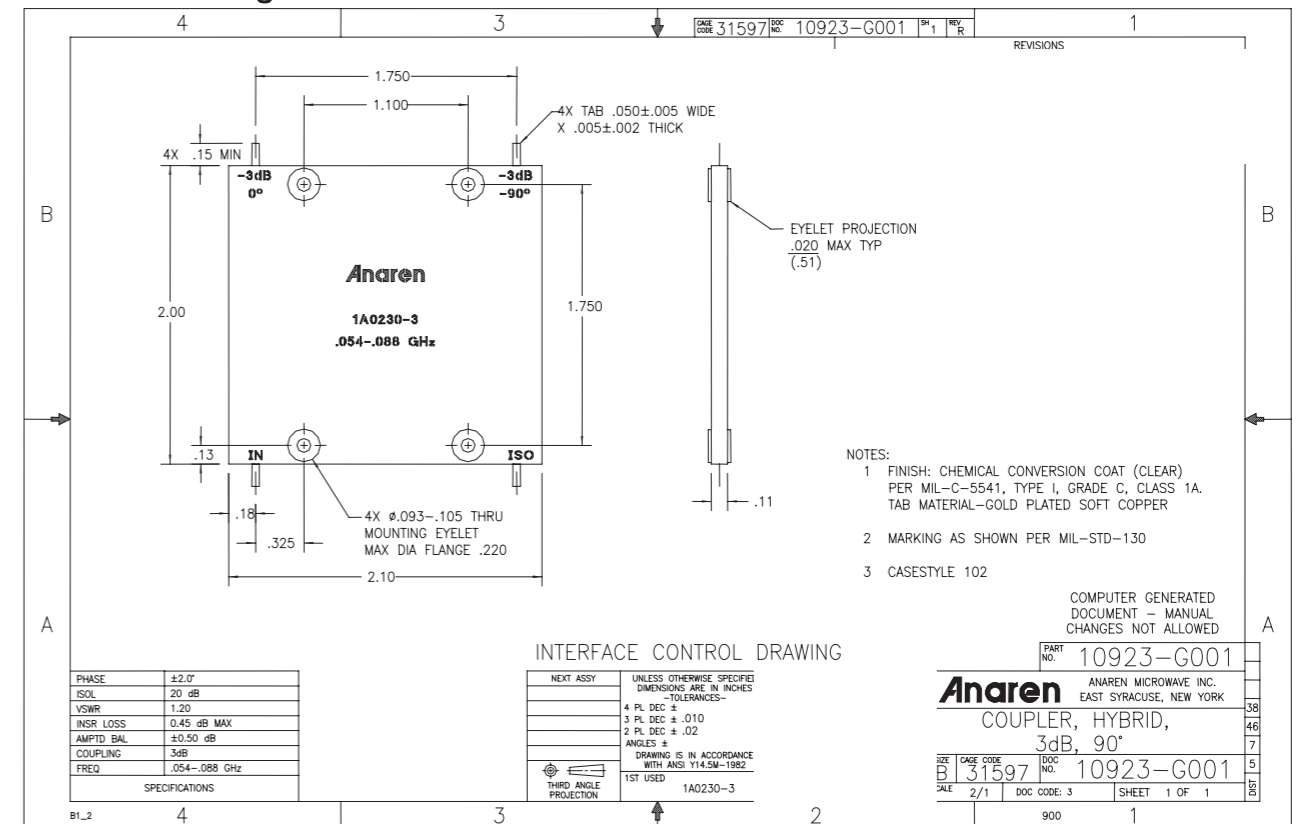
NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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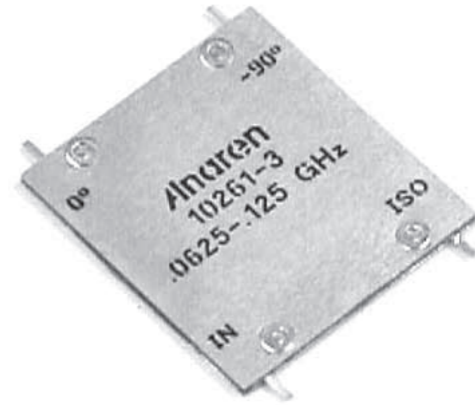
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Asia: +86-512-62876400

Hybrid Couplers

3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

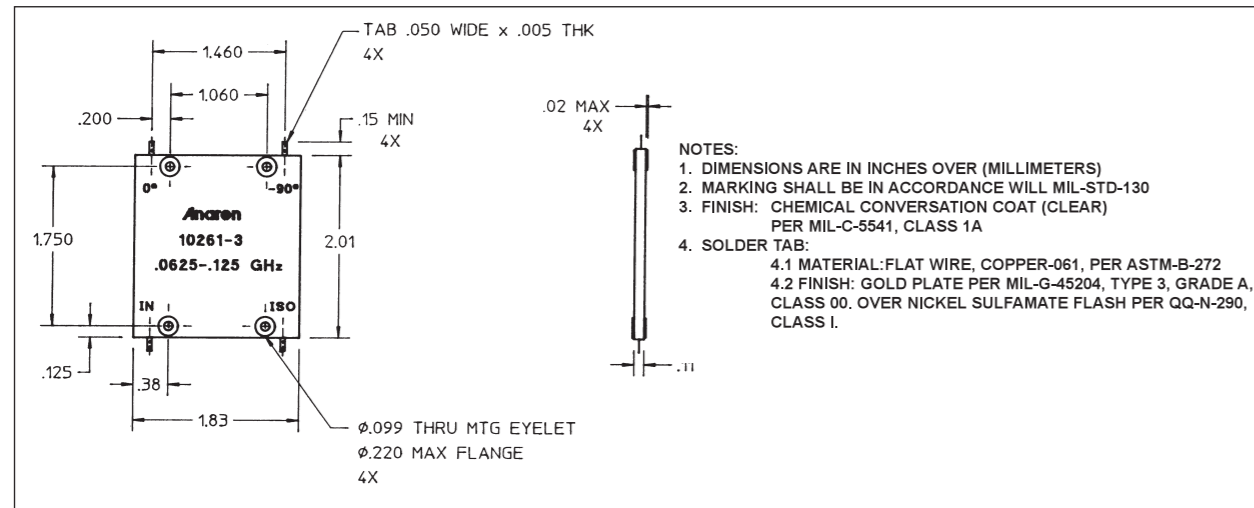
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 600 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
62.5 - 125	20/27	0.35	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	600	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers

3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

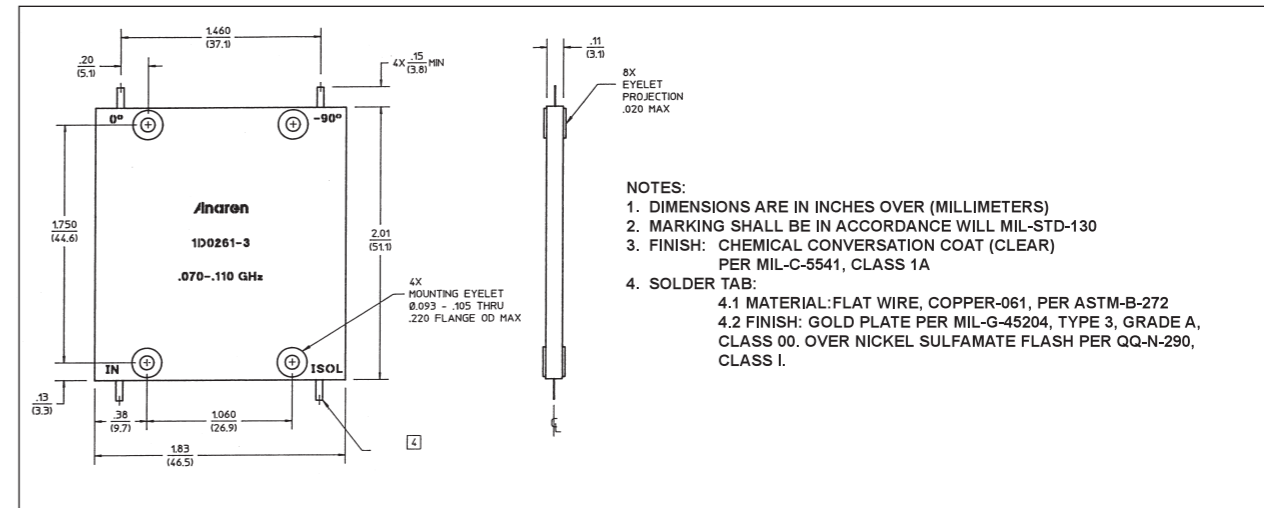
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 600 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
70 - 110	20/23	0.30	1.20/1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.30	±2.0	600	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers

3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

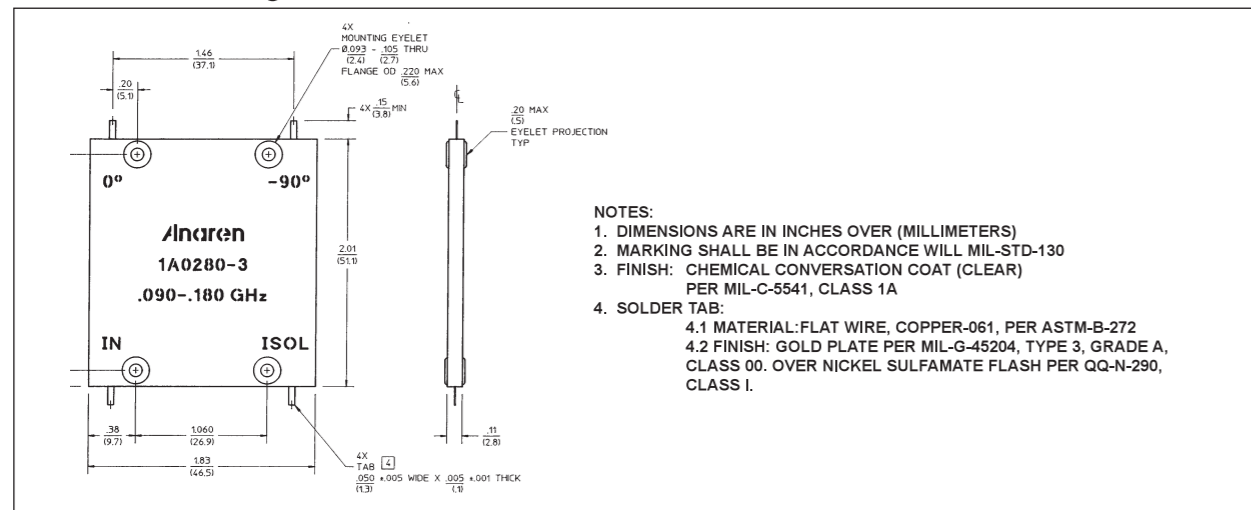
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 400 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
90 - 180	20/27	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	400	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers

3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

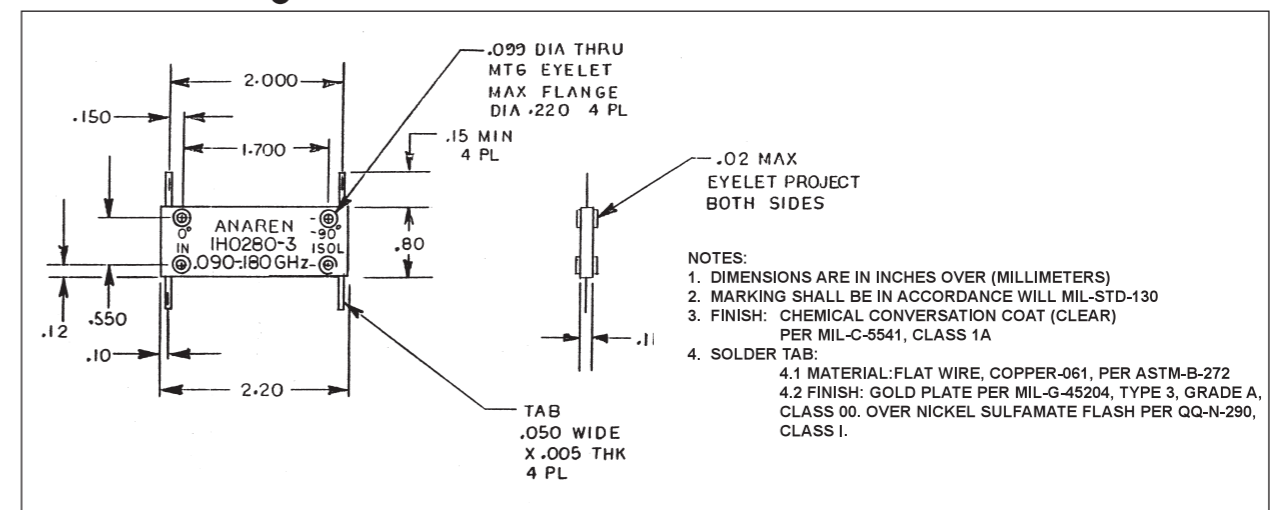
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 400 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
90 - 180	18/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	400	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

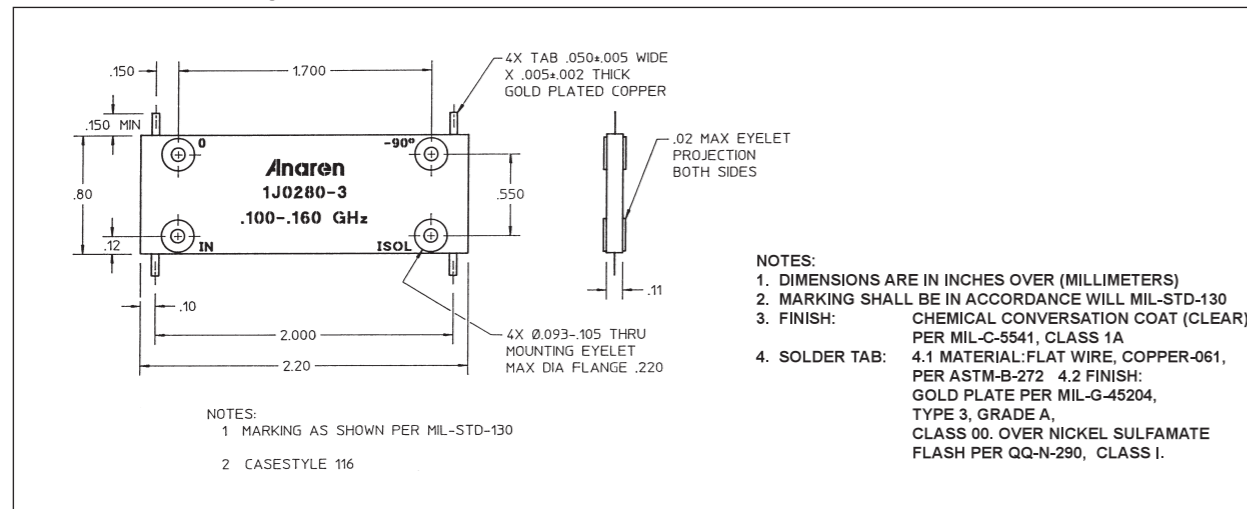
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 500 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
100 - 160	20/27	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.30	±2.0	500	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

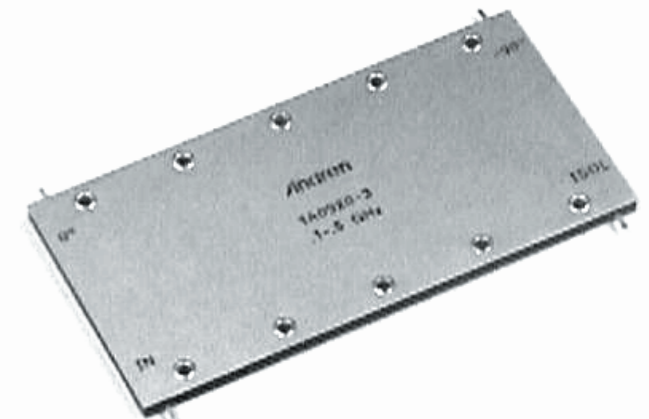
Outline Drawing



Hybrid Couplers
3 dB, 90°

Applications

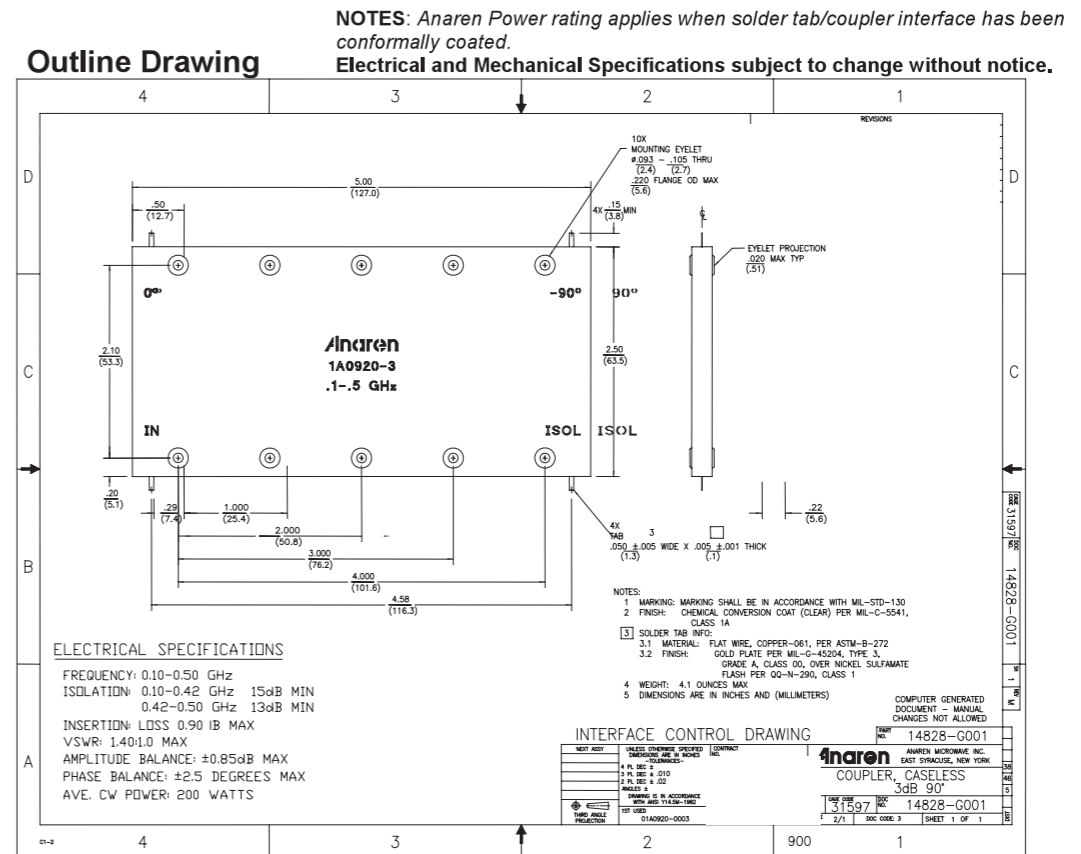
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

- 0.1 – 0.5 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements

Outline Drawing



Model RFP-4243



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

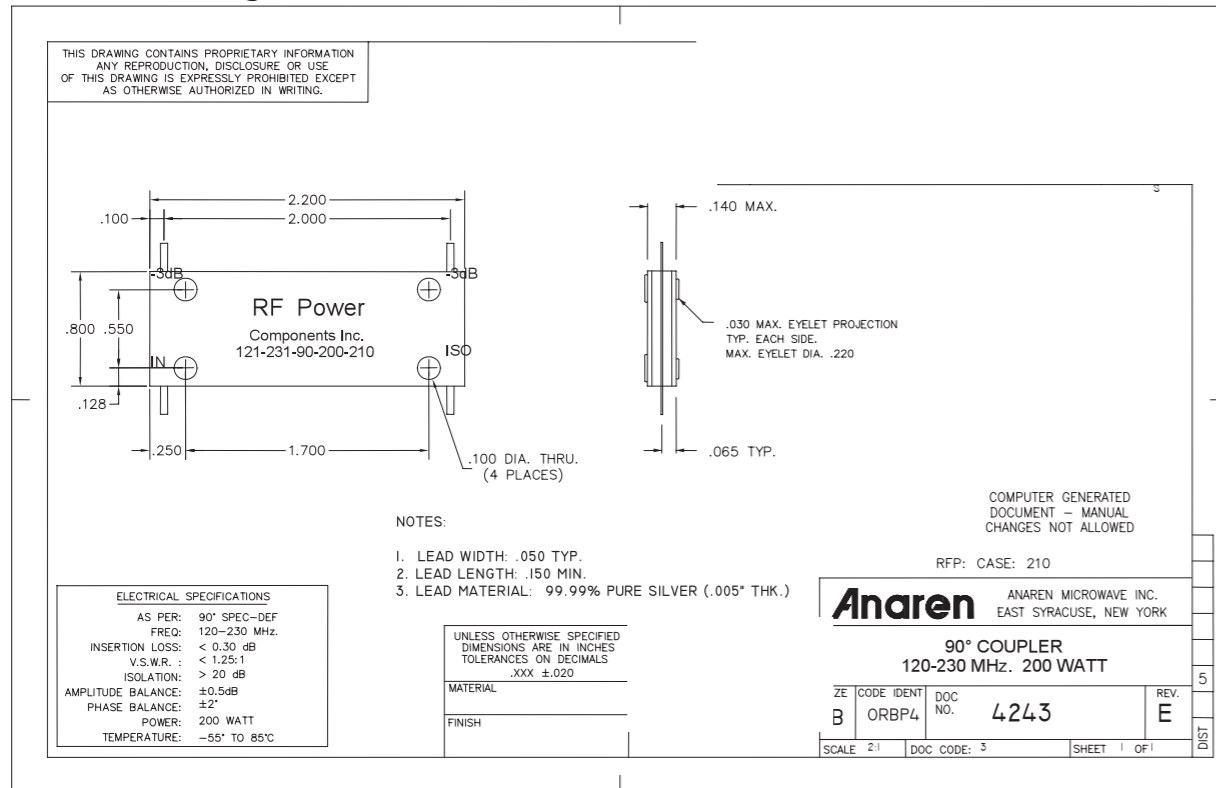
Features

- 0.12 – 0.23 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Asia: +86-512-62876400



Model 10262-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

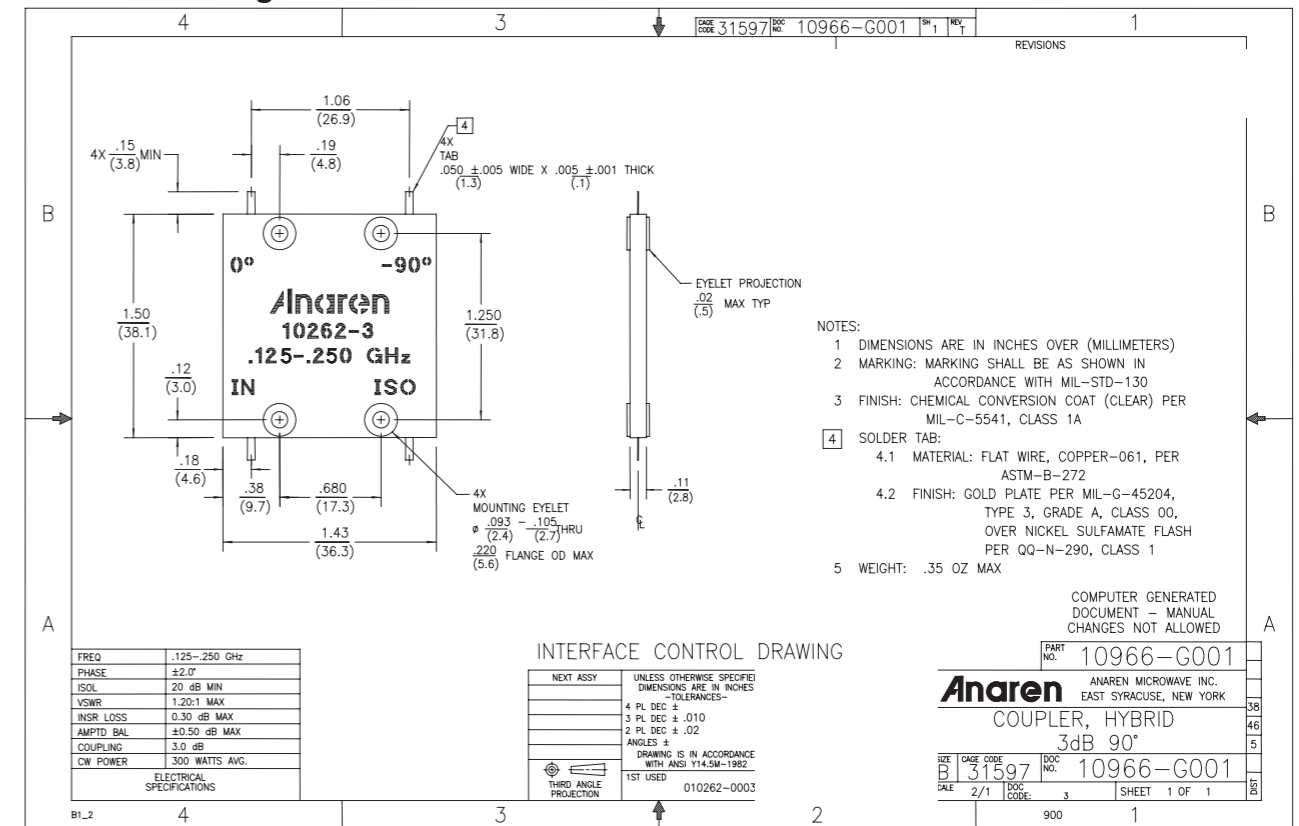
Features

- 0.125 – 0.25 GHz
- Welded Tab mount
- Reliable Performance
- Handles 300 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model RFP-4053



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.13 – 0.18 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements



Model 1H0262-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

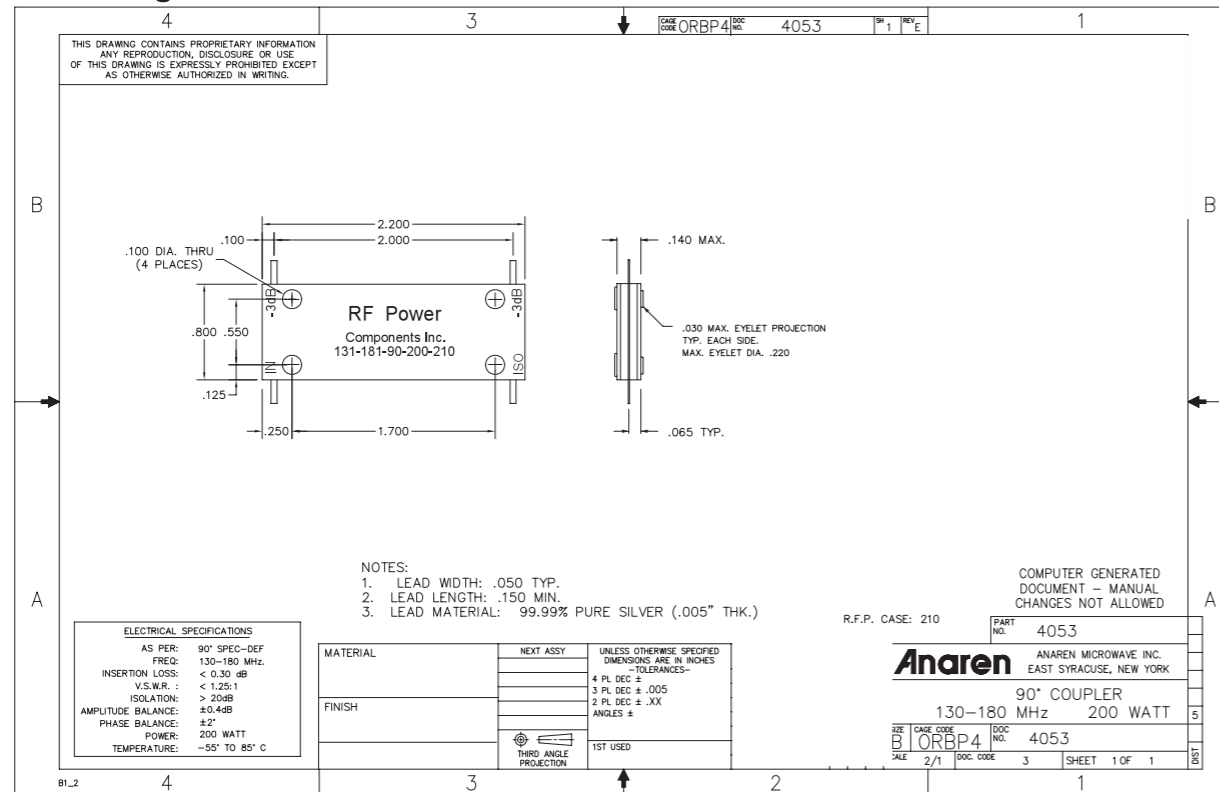
Features

- 0.16 – 0.23 GHz
- Welded Tab mount
- Reliable Performance
- Handles 400 Watts
- Meets MIL-E-5400 Class 3 Requirements



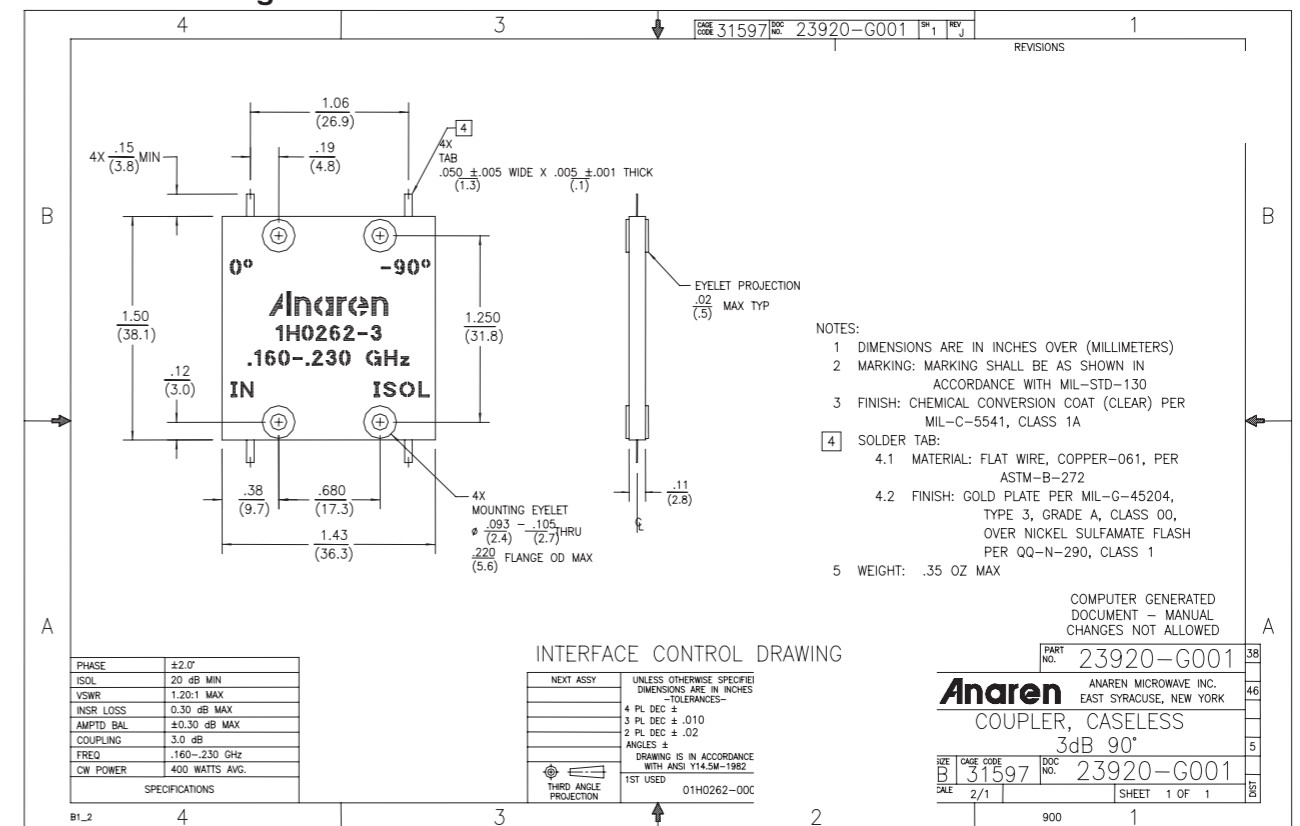
Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



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Hybrid Couplers
3 dB, 90°



Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

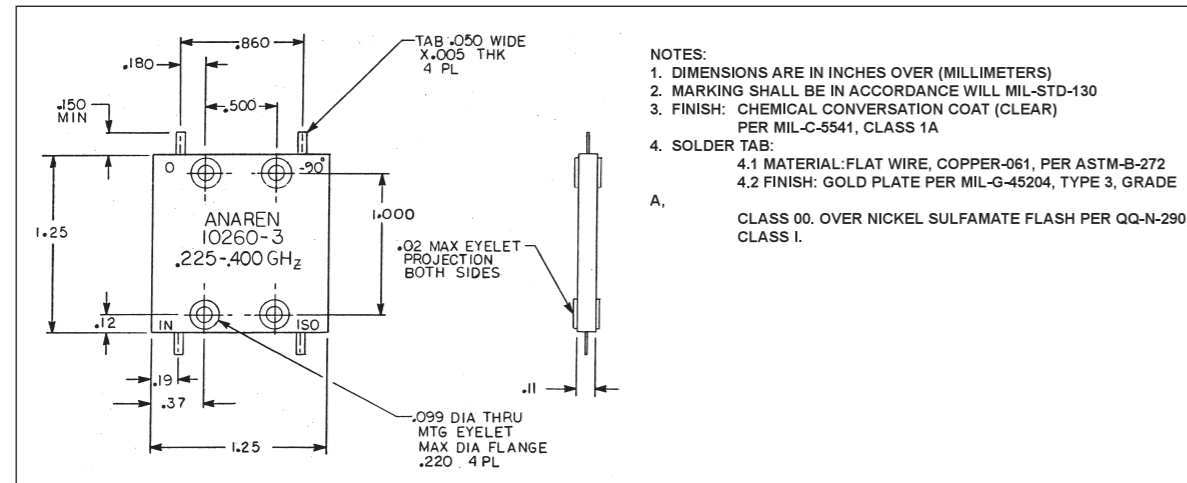
Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 250 Watts

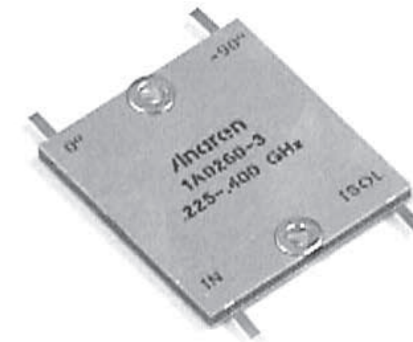
Electrical Specifications			
Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
225 - 400	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	250	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
3 dB, 90°



Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

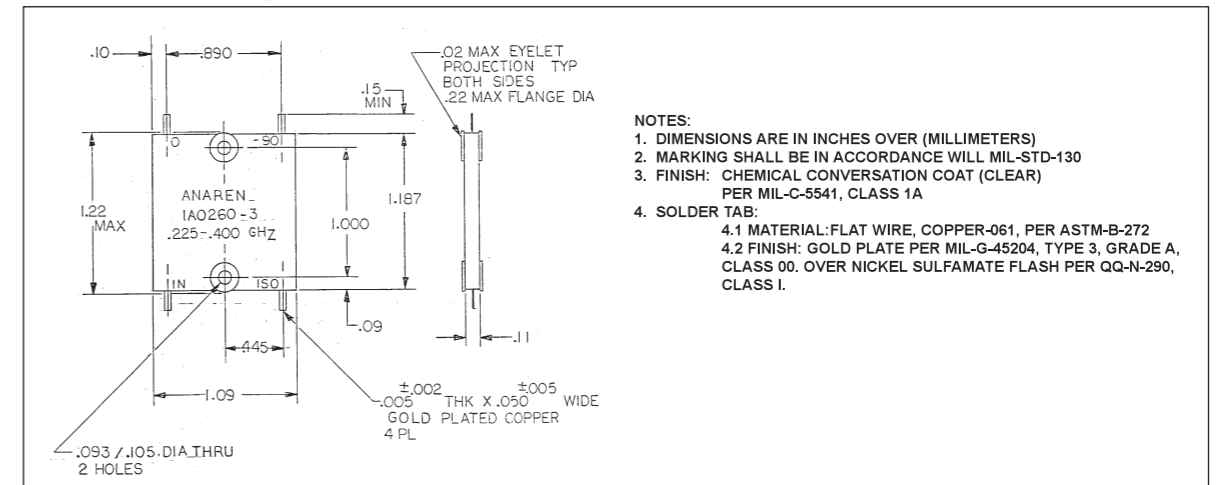
Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 250 Watts

Electrical Specifications			
Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
225 - 400	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	250	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



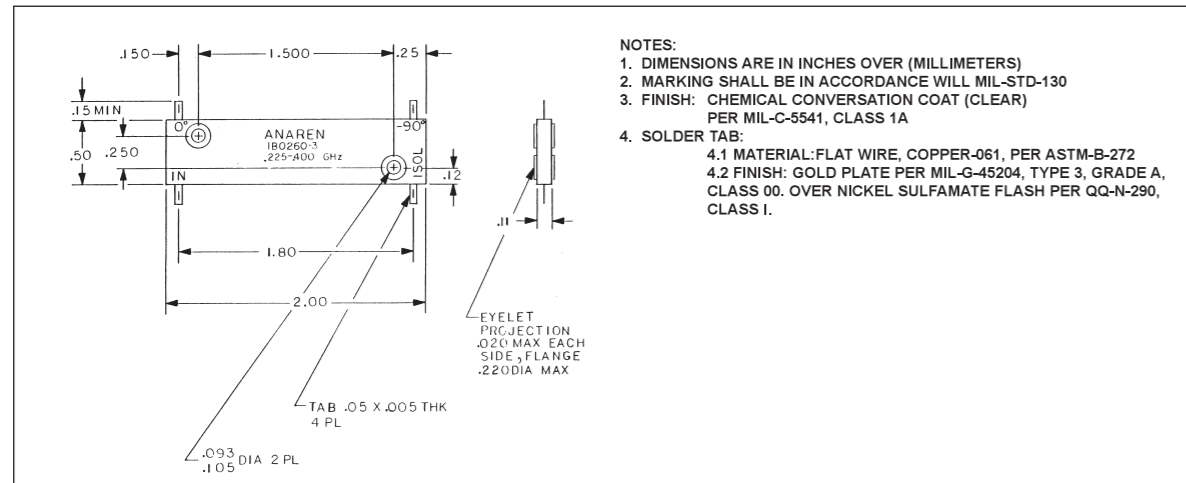
Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 250 Watts

Electrical Specifications			
Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
225 - 400	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	250	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Hybrid Couplers
3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



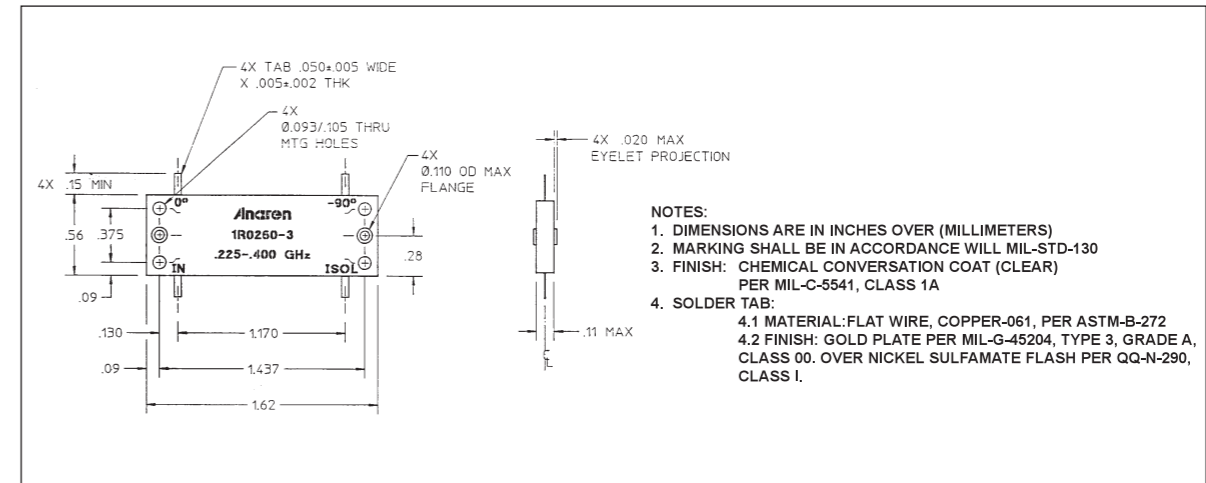
Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 250 Watts

Electrical Specifications			
Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
225 - 400	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	250	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Hybrid Couplers
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Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



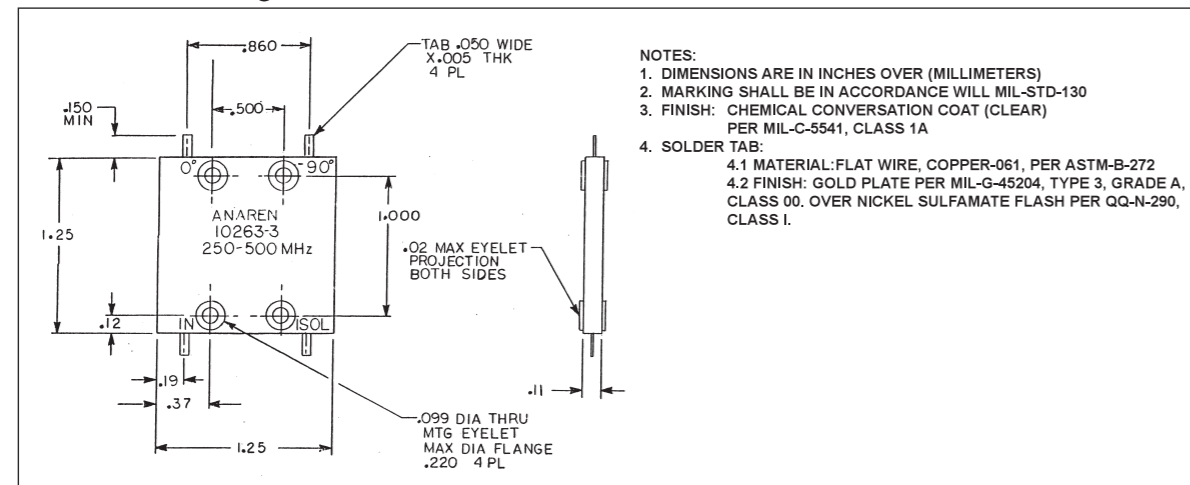
Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 200 Watts

Electrical Specifications			
Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
250 - 500	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	200	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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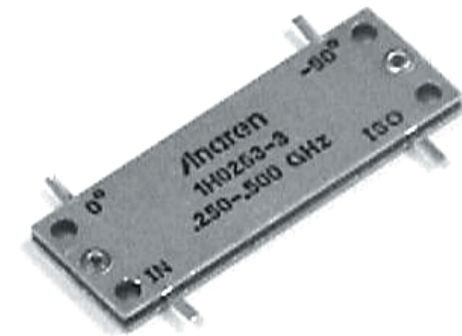
Hybrid Couplers
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Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

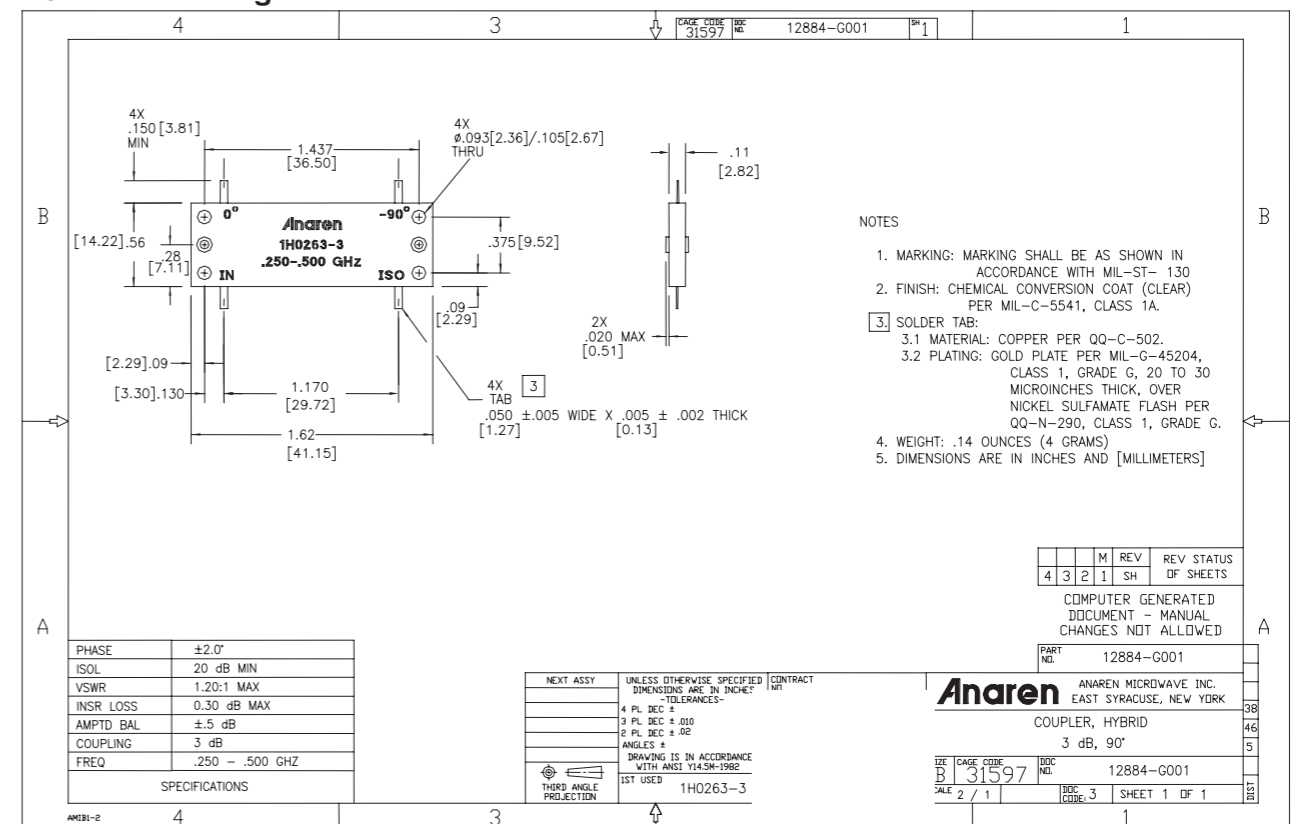
Features

- 0.25 – 0.5 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Applications

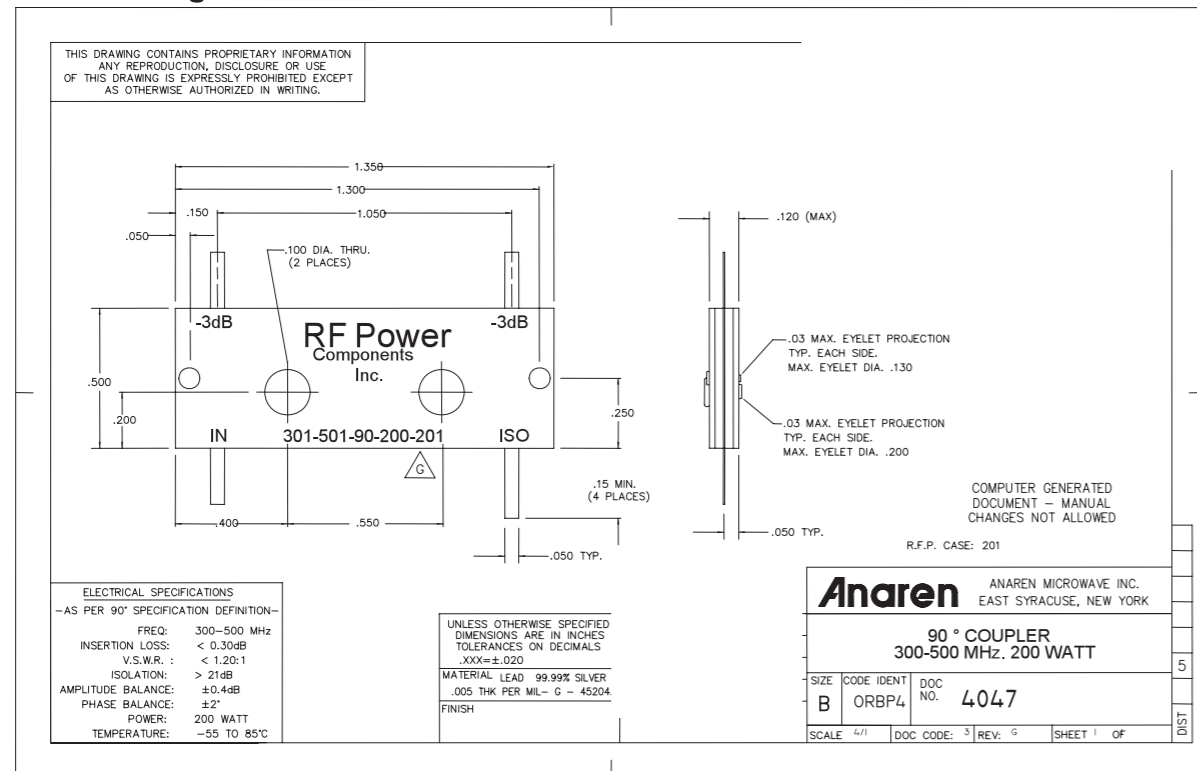
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.3 – 0.5 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
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Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

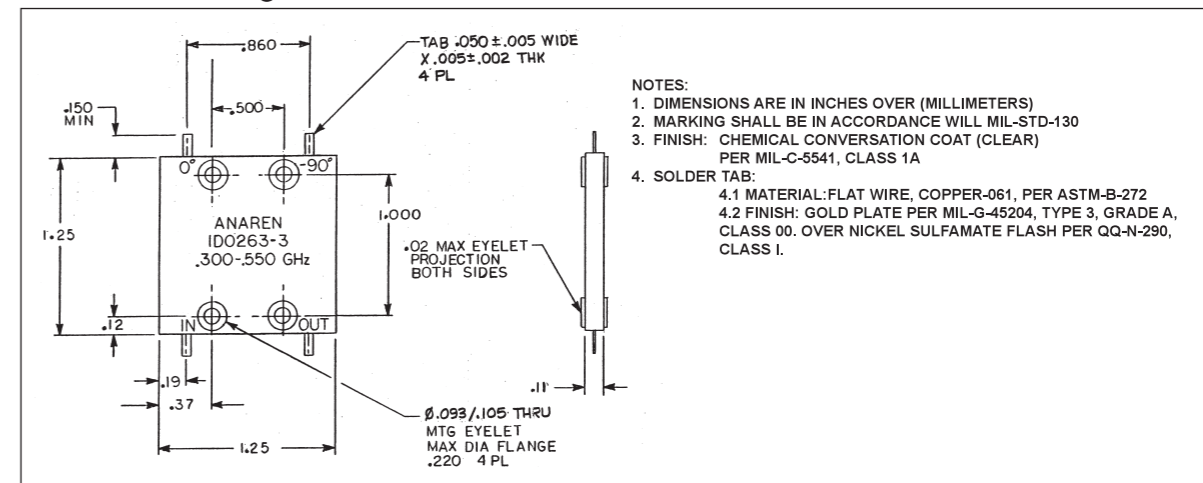
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 200 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
300 - 550	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	200	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
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Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

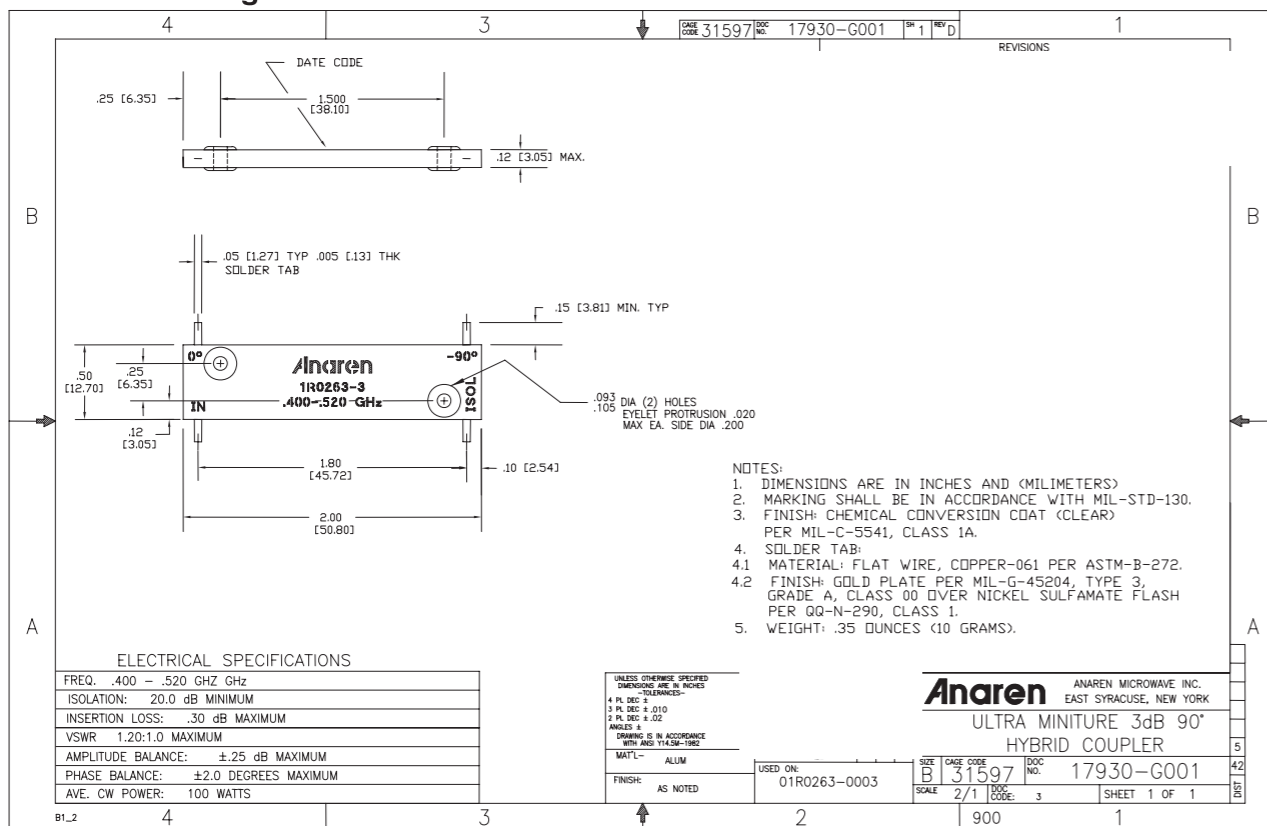
Features

- 0.4 – 0.52 GHz
- Welded Tab mount
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

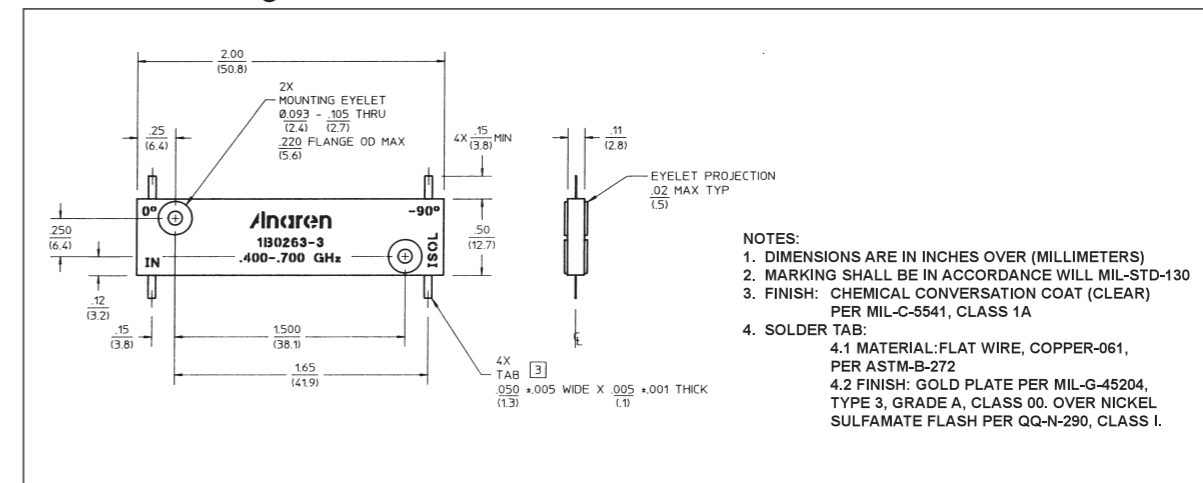
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 200 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
400 - 700	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±.50	±2.0	200	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
3 dB, 90°



Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

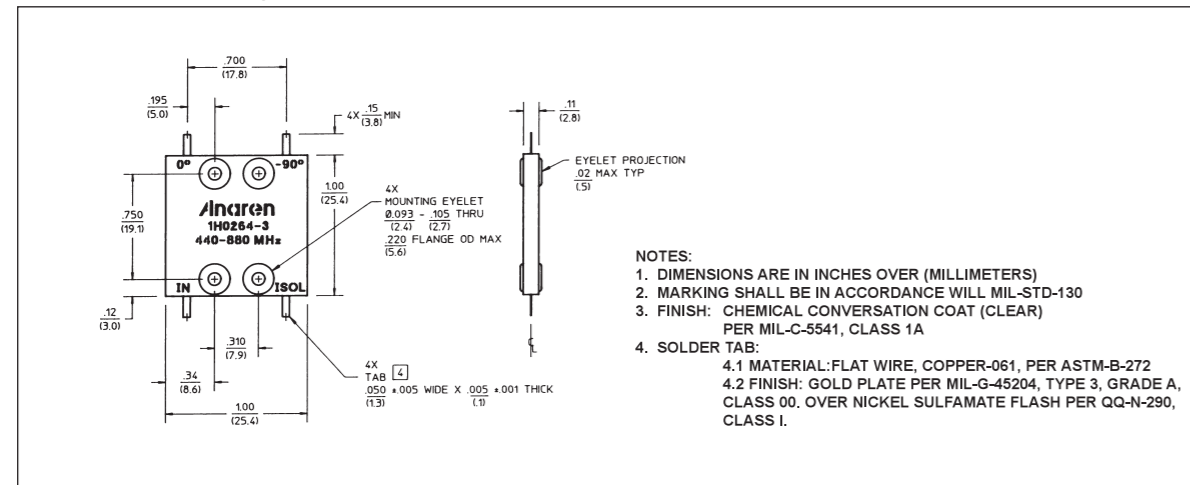
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 200 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
440 - 880	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	200	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms, Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

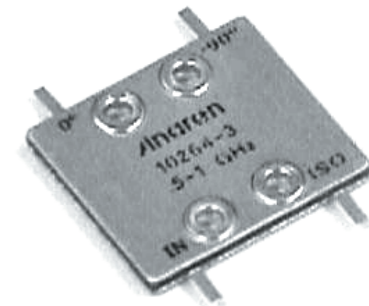
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Applications

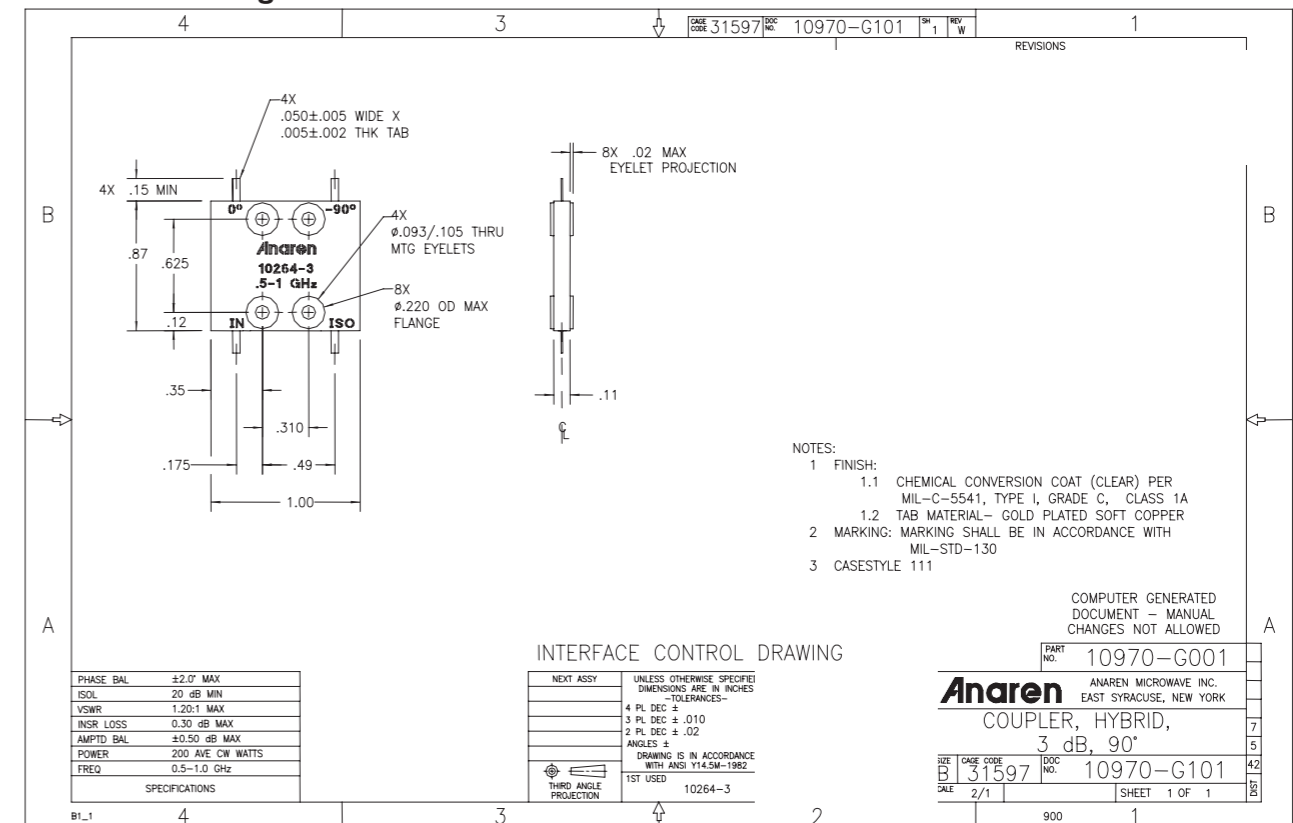
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.5 – 1.0 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

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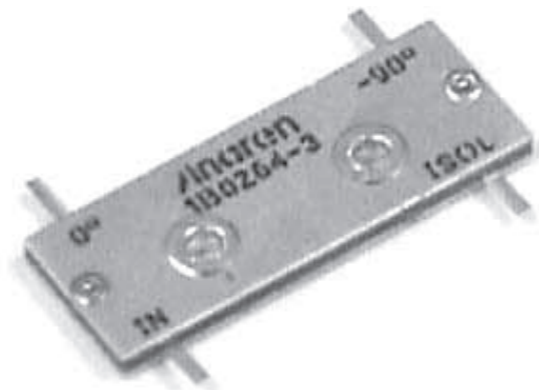
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Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

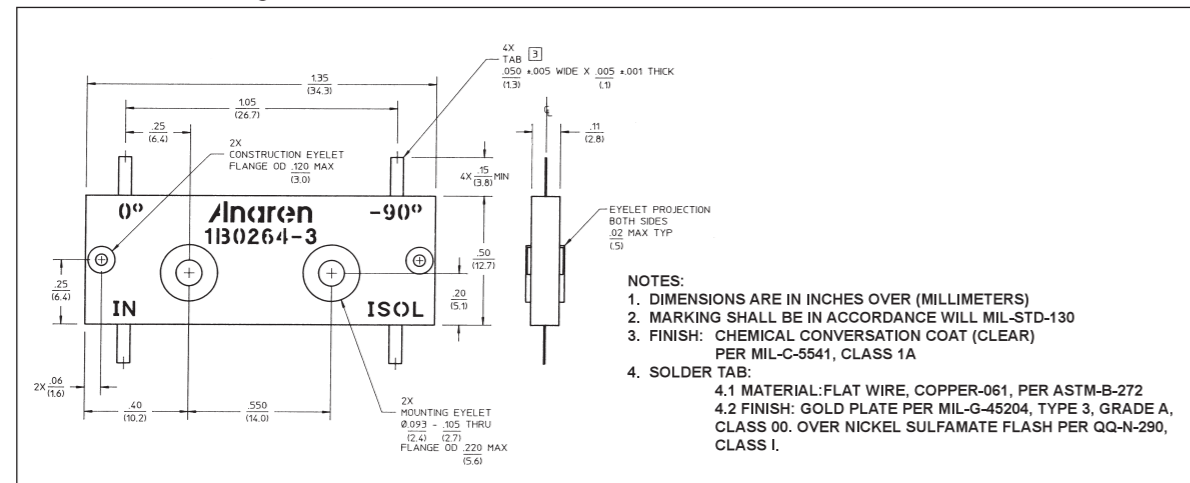
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 200 Watts

Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
0.5 - 1.0	20/25	0.30	1.20/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	200	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

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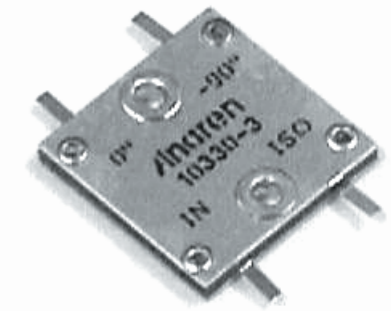
3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

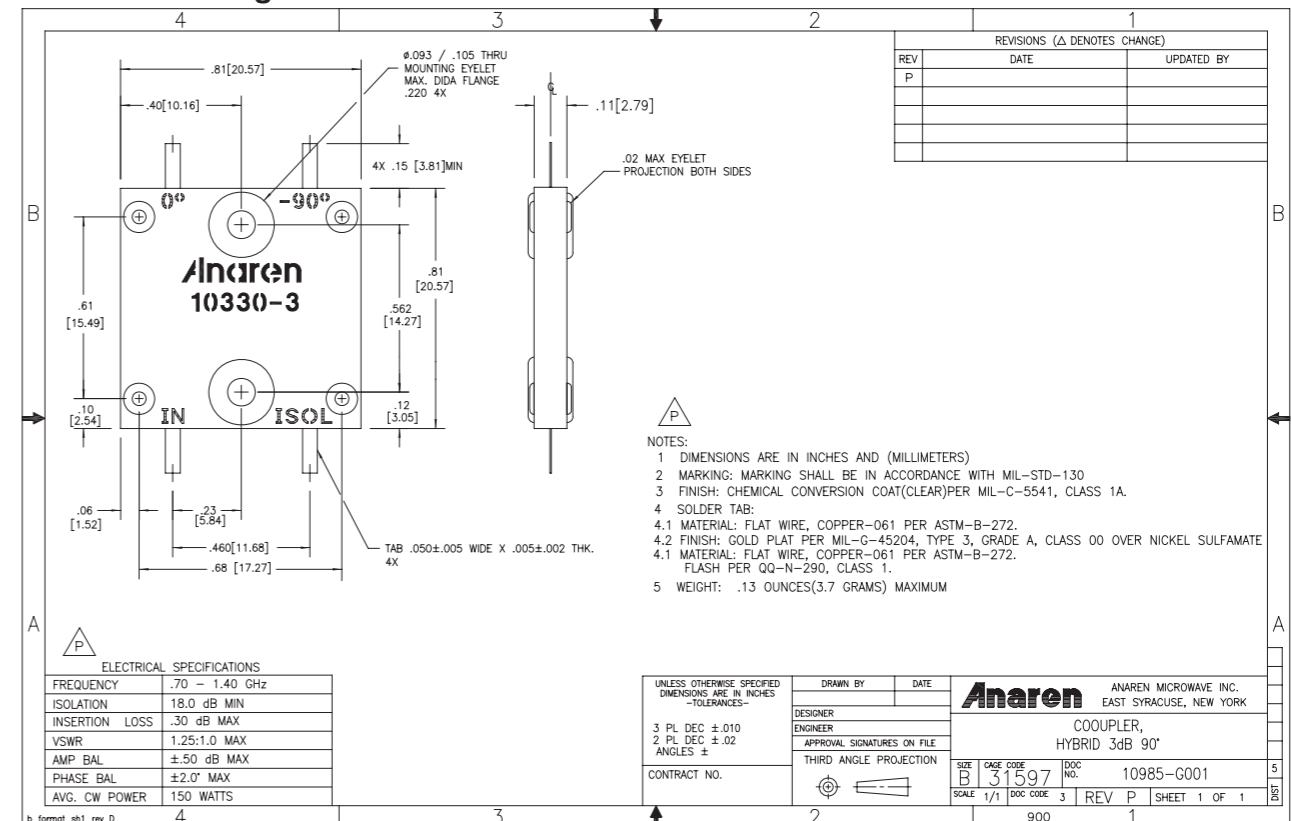
Features

- 0.7 – 1.4 GHz
- Welded Tab mount
- Reliable Performance
- Handles 150 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model RFP- 4015



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.8 – 1.0 GHz
- Welded Tab mount
- Reliable Performance
- Handles 200 Watts
- Meets MIL-E-5400 Class 3 Requirements



Model 1Y0265-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

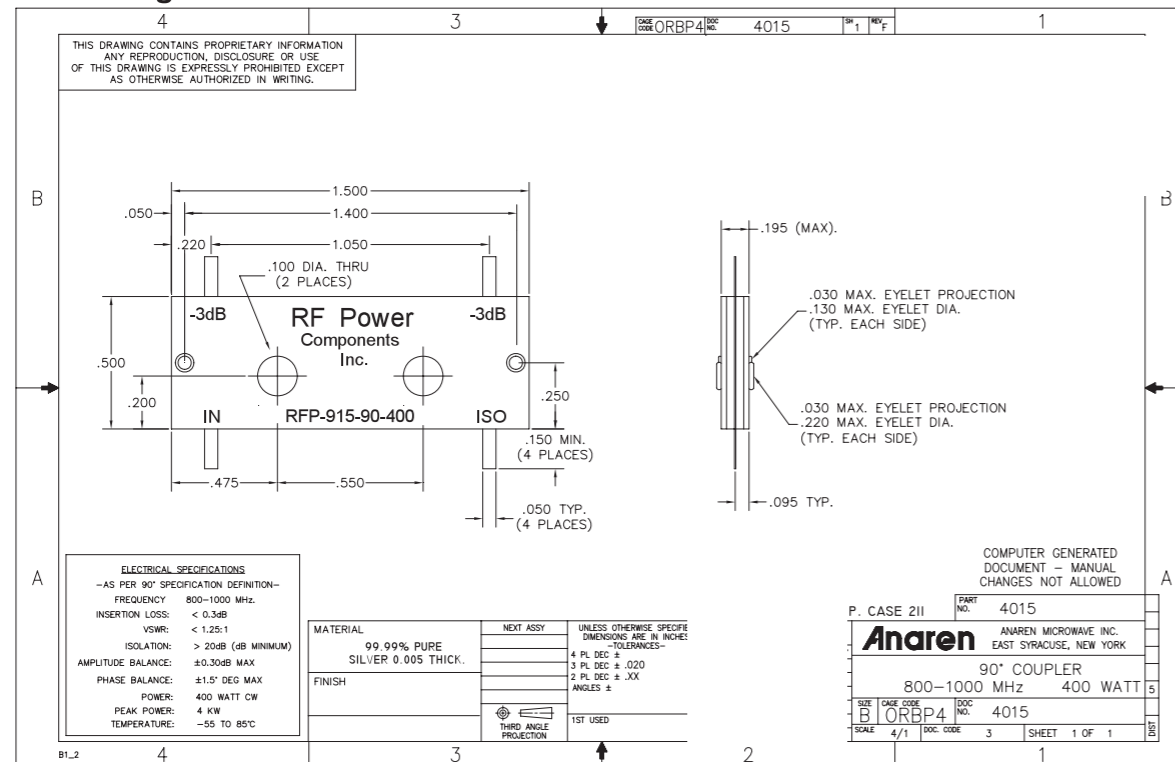
Features

- 0.8 – 2.1 GHz
- Welded Tab mount
- Reliable Performance
- Meets MIL-E-5400 Class 3 Requirements



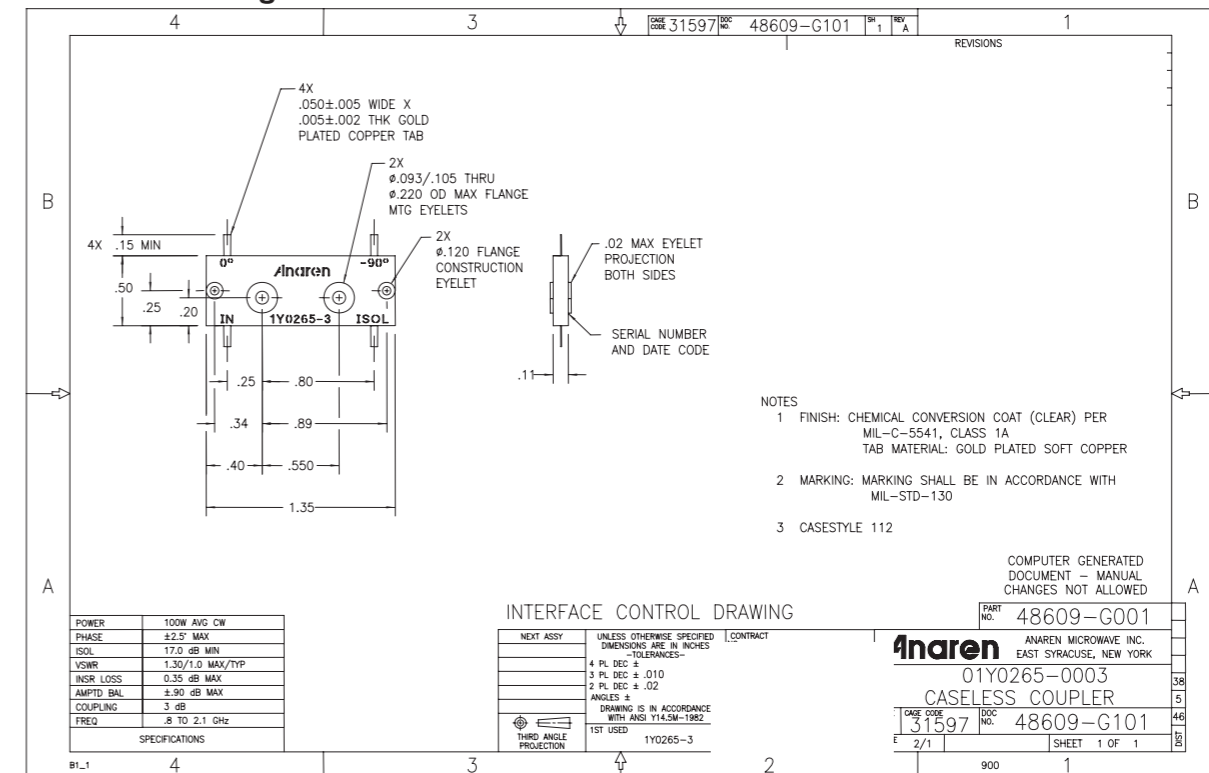
NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 1B0220-3



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 0.8 – 2.5 GHz
- Welded Tab mount
- Reliable Performance
- Handles 55 Watts
- Meets MIL-E-5400 Class 3 Requirements



Model 1A0220-3

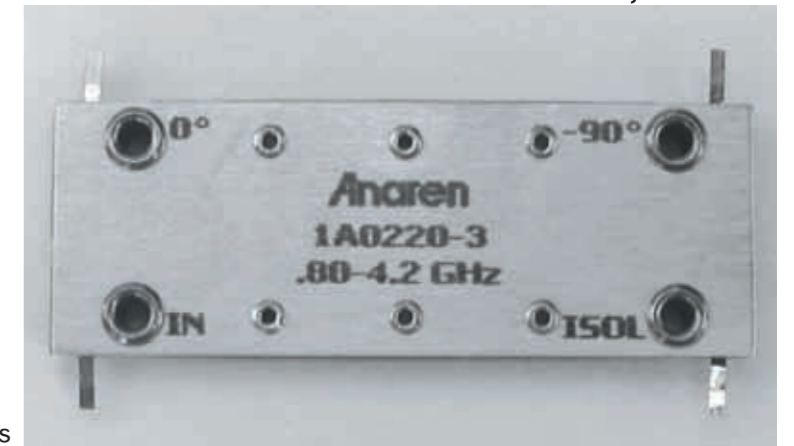
Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

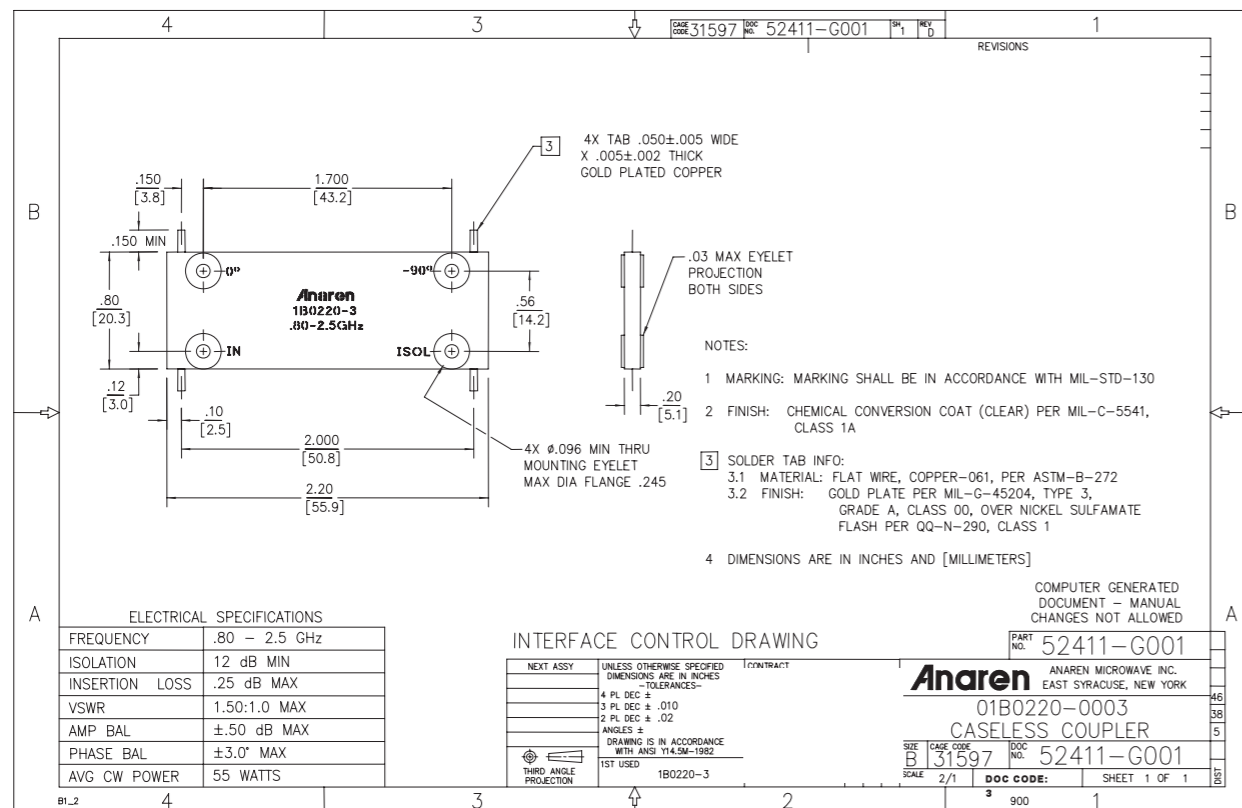
Features

- 0.8 – 4.2 GHz
- Welded Tab mount
- Reliable Performance
- Handles 55 Watts
- Meets MIL-E-5400 Class 3 Requirements



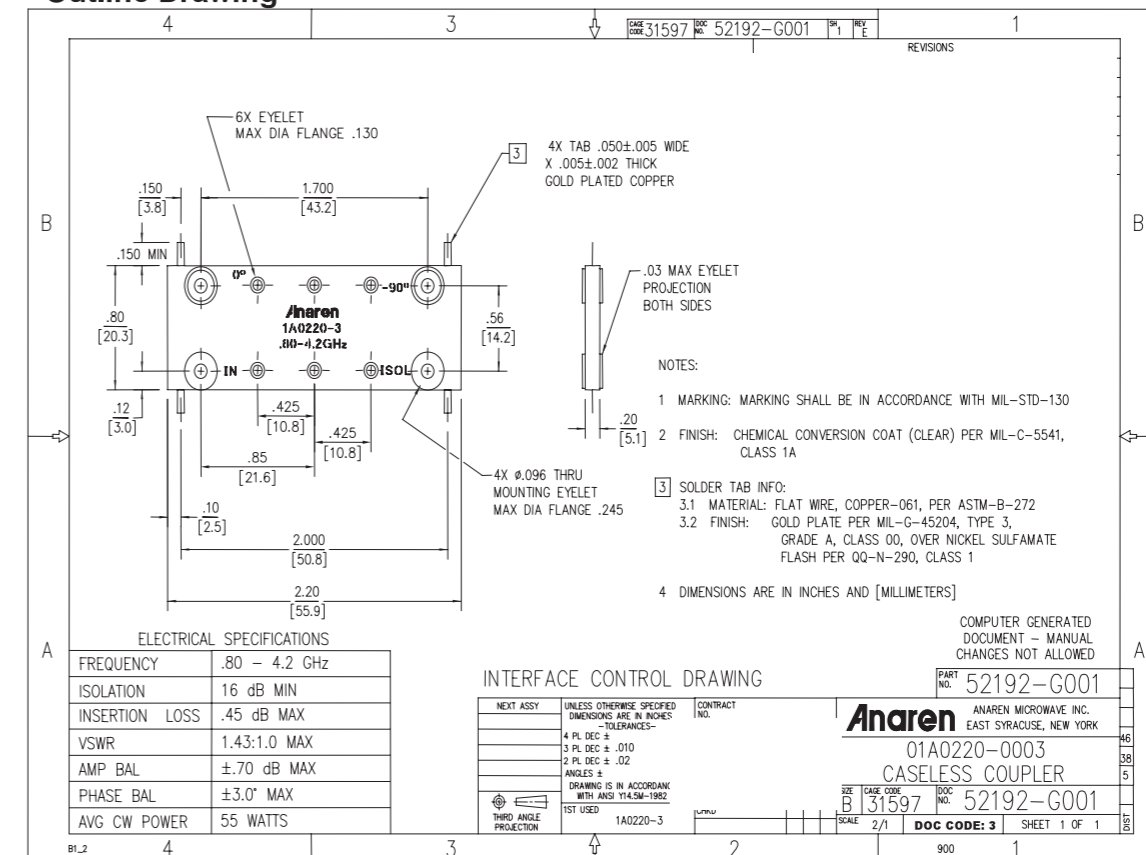
Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



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Hybrid Couplers

3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

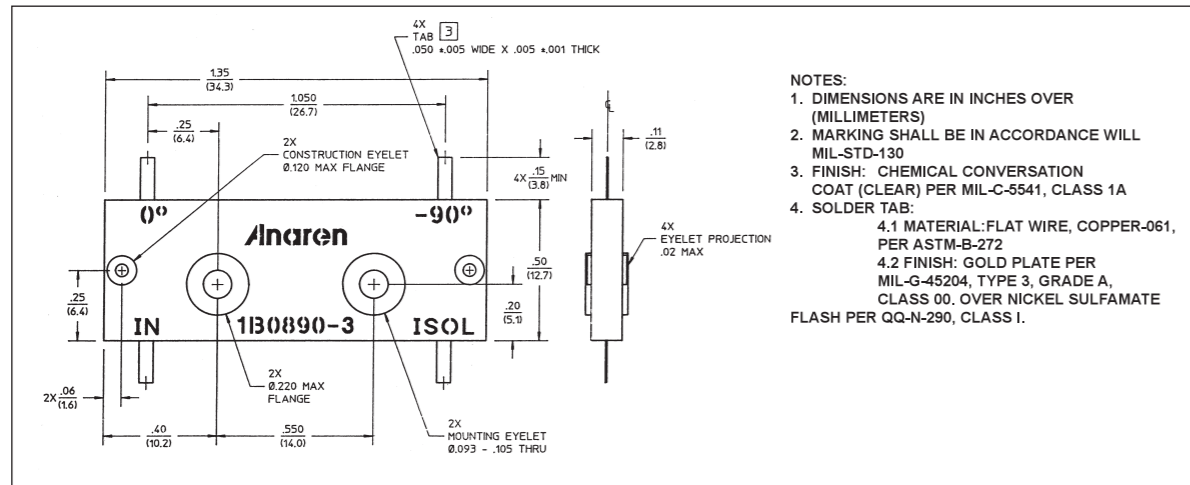
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 150 Watts

Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
0.85 - 1.45	20/22	0.30	1.25/1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	150	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms, Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Hybrid Couplers

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Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

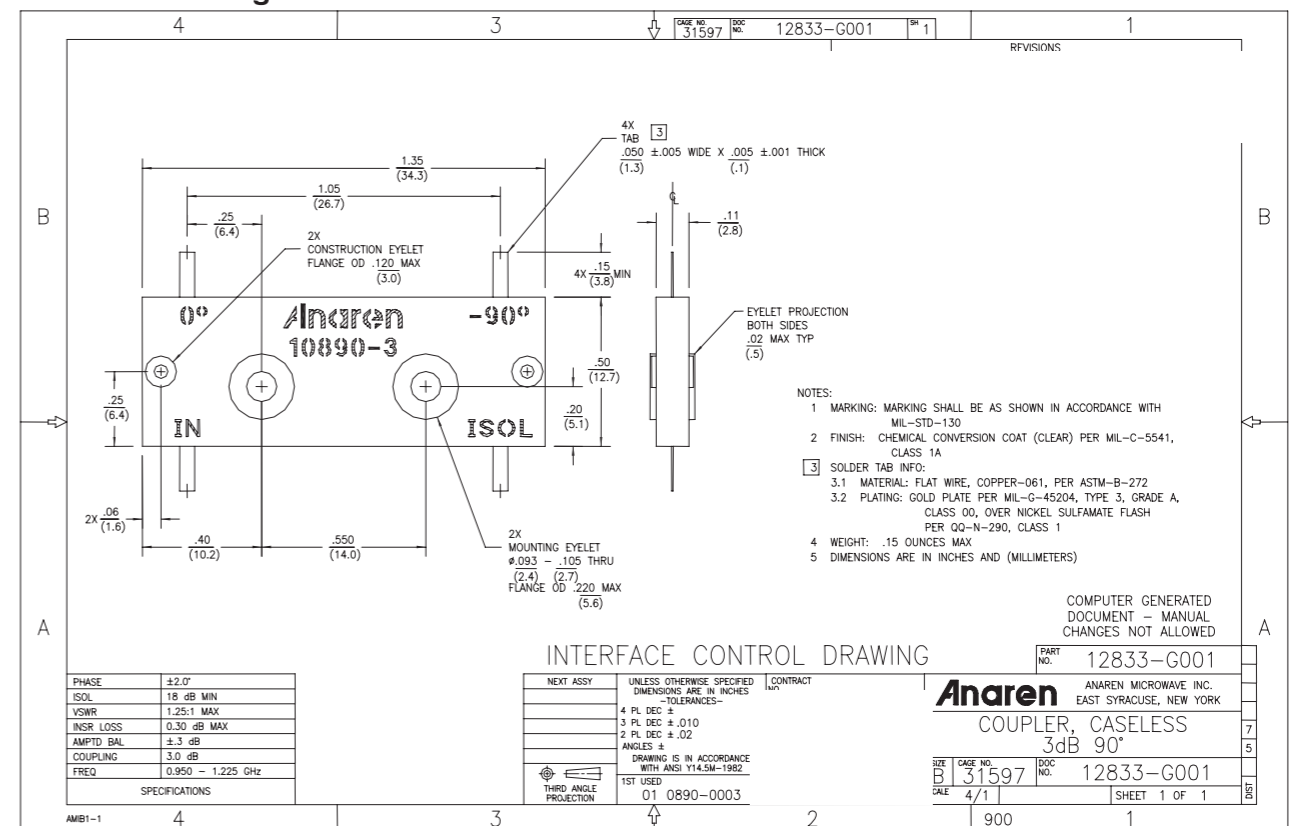
Features

- 0.95 – 1.225 GHz
- Welded Tab mount
- Reliable Performance
- Handles 150 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
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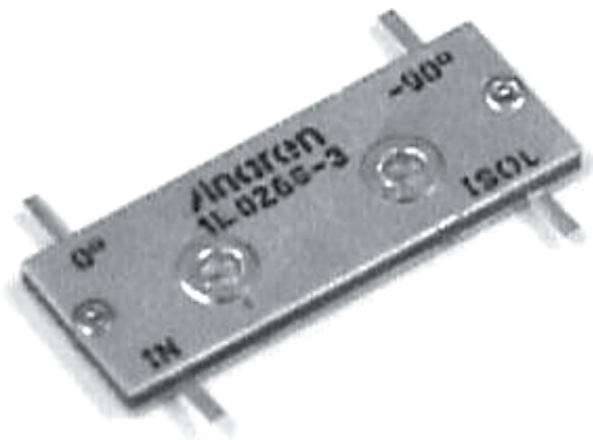
Hybrid Couplers
3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

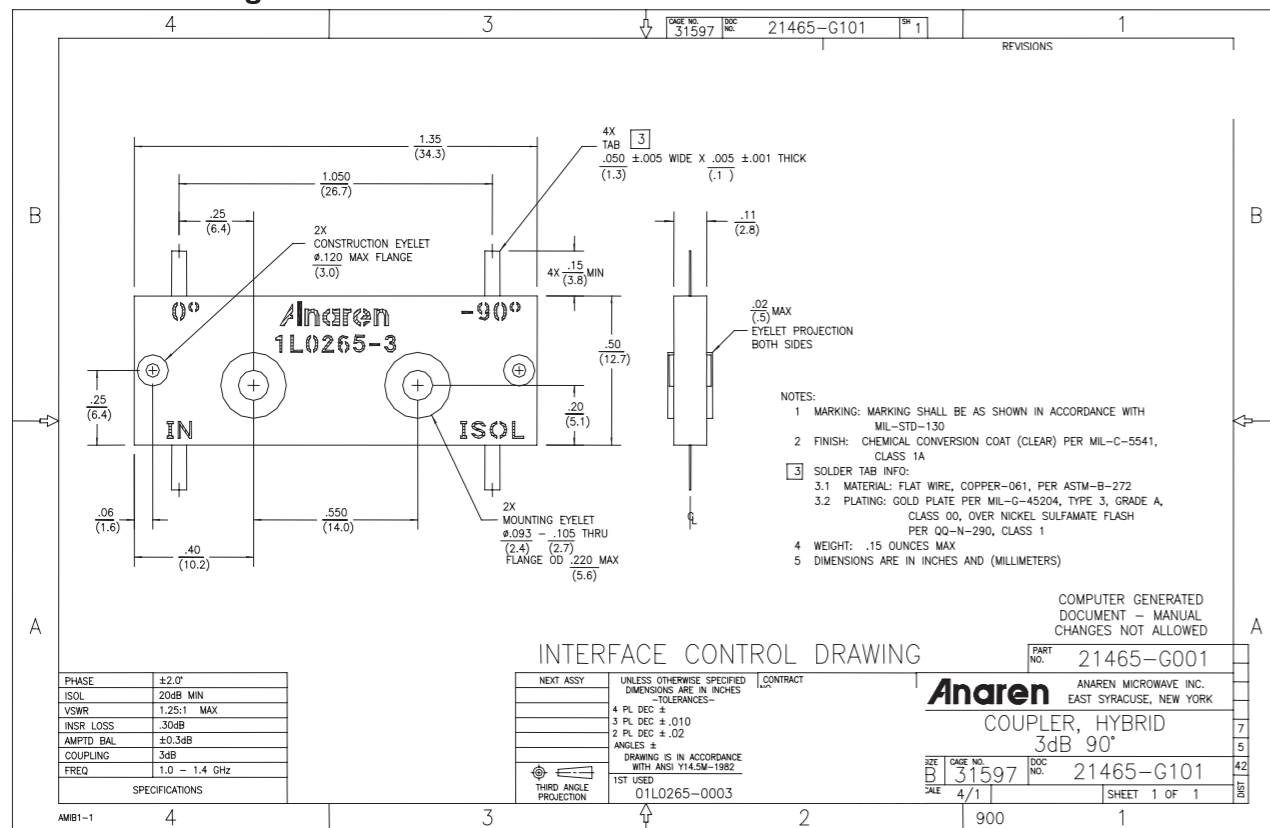
Features

- 1.0 – 1.4 GHz
- Welded Tab mount
- Reliable Performance
- Handles 150 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Hybrid Couplers
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Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

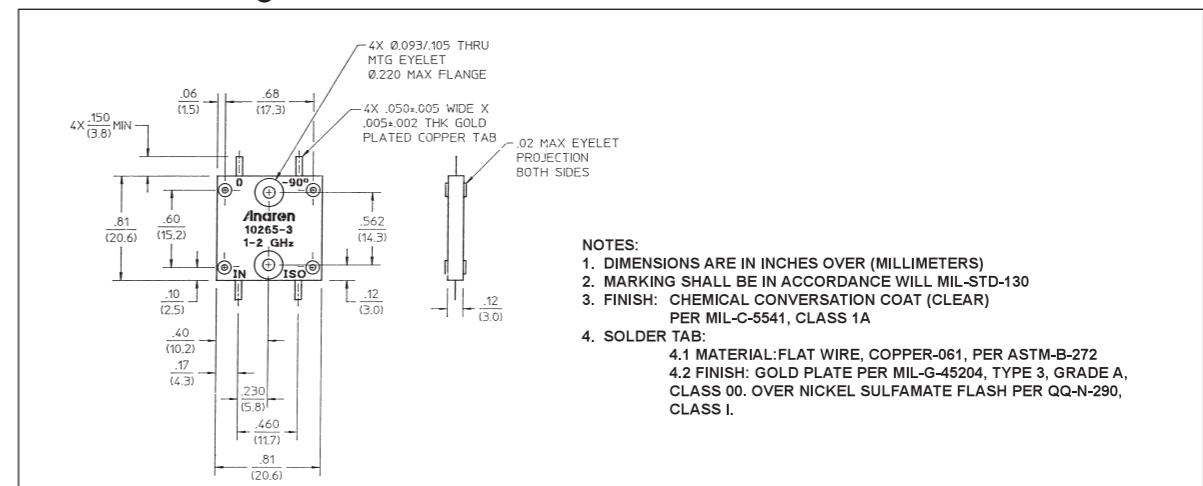
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 100 Watts

Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
1.0 - 2.0	18/24	0.30	1.25/1.10
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	100	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



- NOTES:
1. DIMENSIONS ARE IN INCHES OVER (MILLIMETERS)
 2. MARKING SHALL BE IN ACCORDANCE WILL MIL-STD-130
 3. FINISH: CHEMICAL CONVERSION COAT (CLEAR) PER MIL-C-5541, CLASS 1A
 4. SOLDER TAB:
 - 4.1 MATERIAL: FLAT WIRE, COPPER-061, PER ASTM-B-272
 - 4.2 FINISH: GOLD PLATE PER MIL-G-45204, TYPE 3, GRADE A, CLASS 00. OVER NICKEL SULFAMATE FLASH PER QQ-N-290, CLASS I.

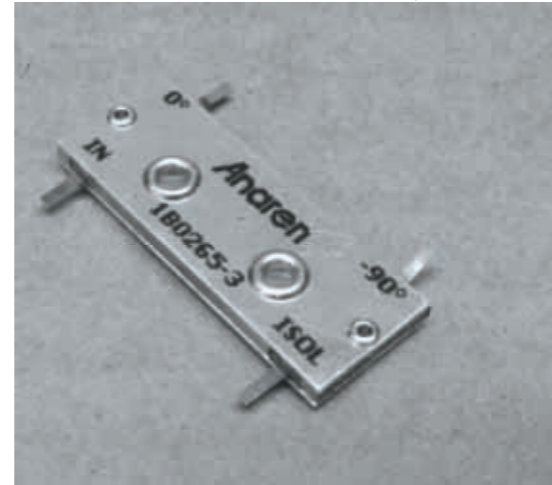
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Model 1B0265-3



Hybrid Couplers 3 dB, 90°



Applications

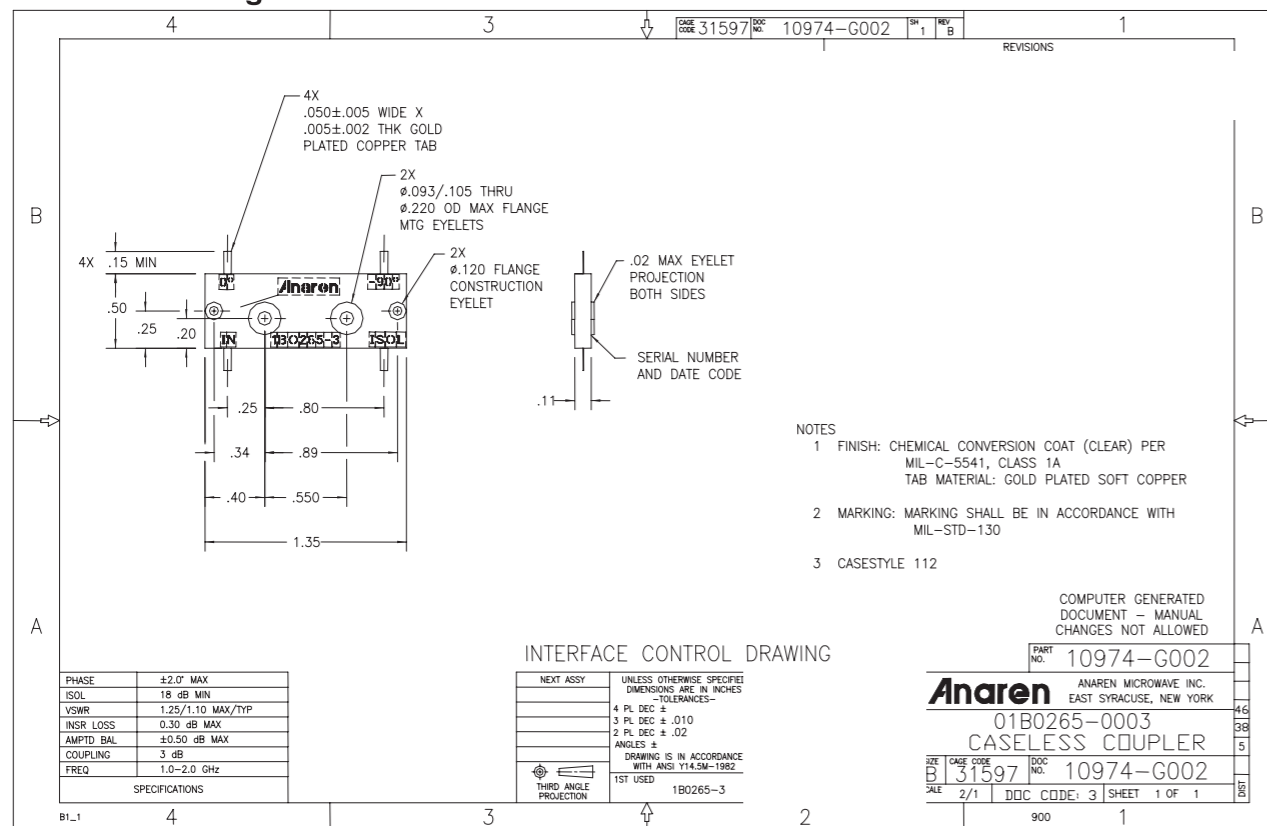
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 1.0 – 2.0 GHz
- Welded Tab mount
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 1C0220-3

Hybrid Couplers 3 dB, 90°



Applications

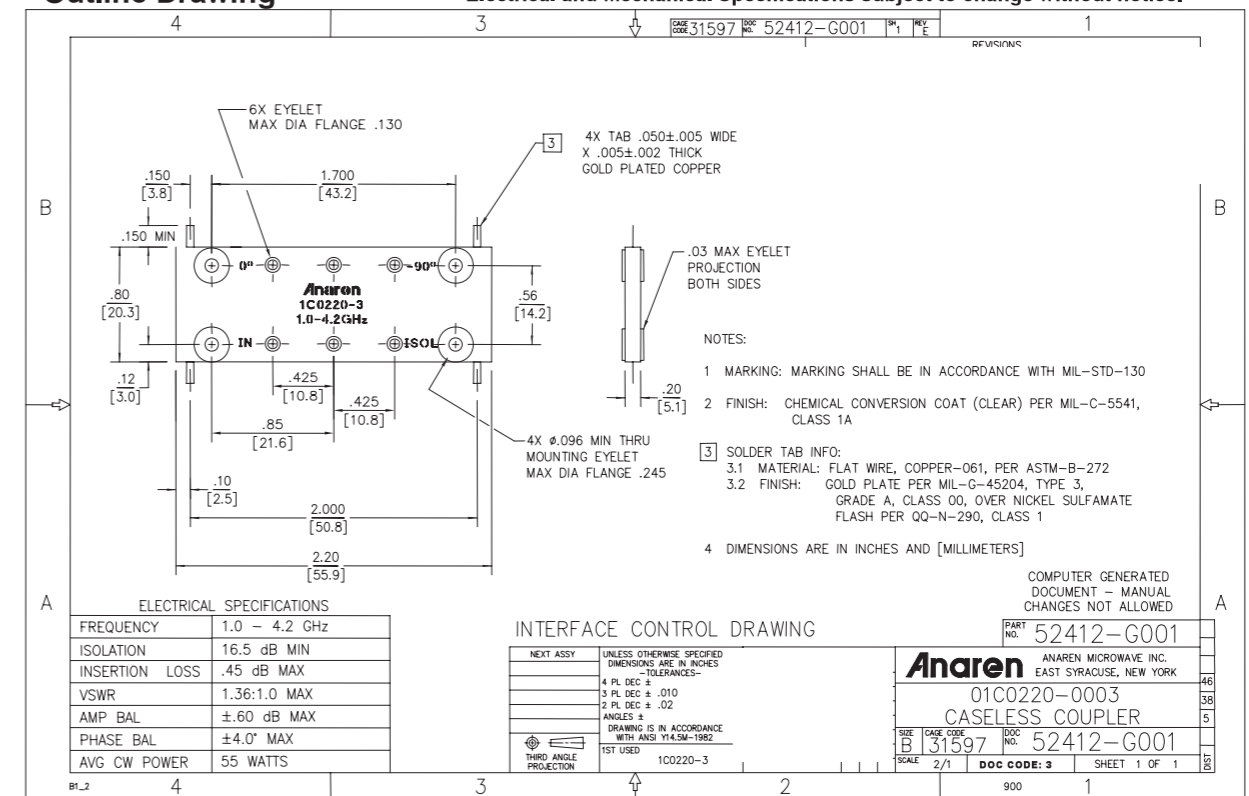
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 1.0 – 4.2 GHz
- Welded Tab mount
- Reliable Performance
- Handles 55 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 1K0265-3



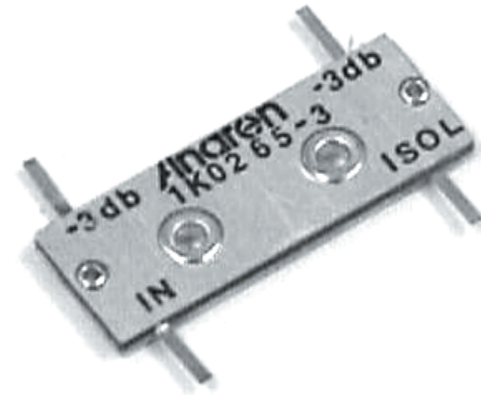
Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

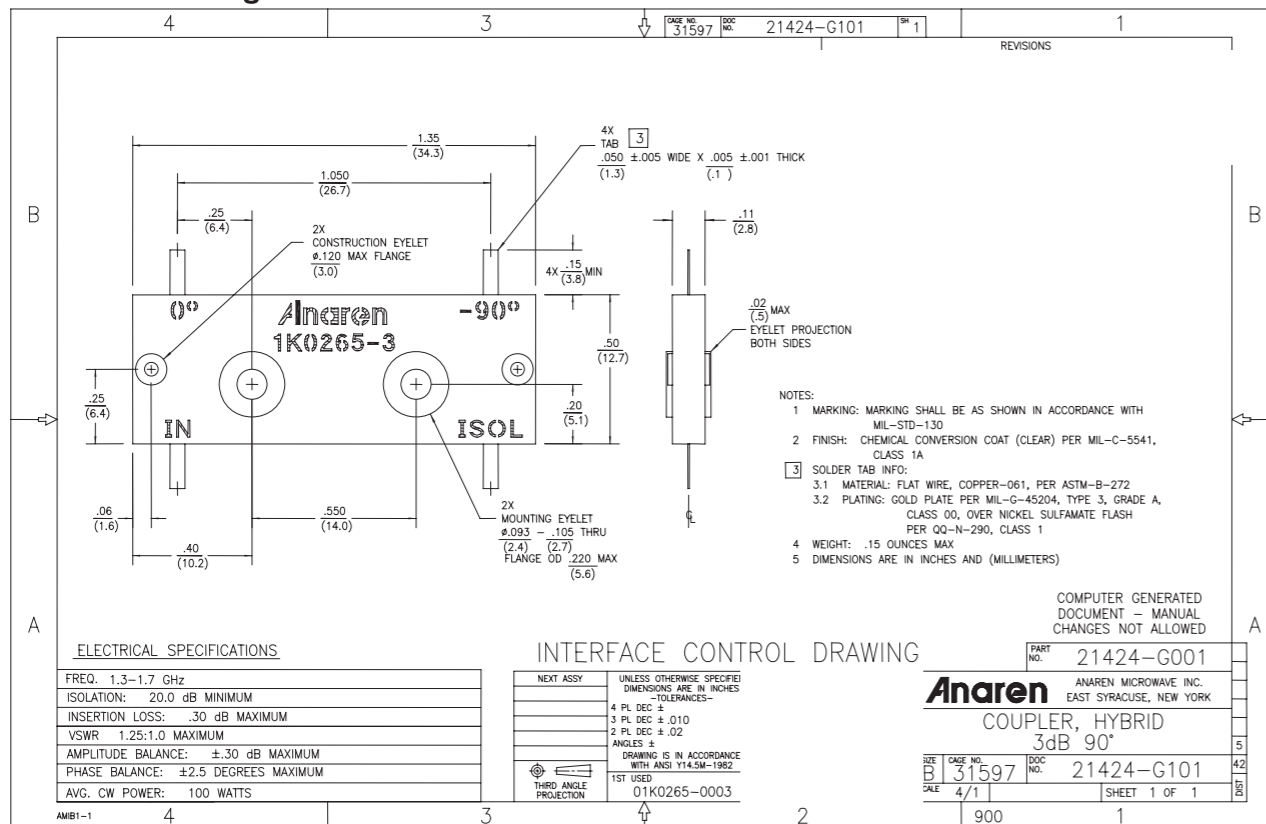
Features

- 1.3 – 1.7 GHz
- Welded Tab mount
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



USA/Canada: (315) 432-8909
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Model 1E0320-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 100 Watts

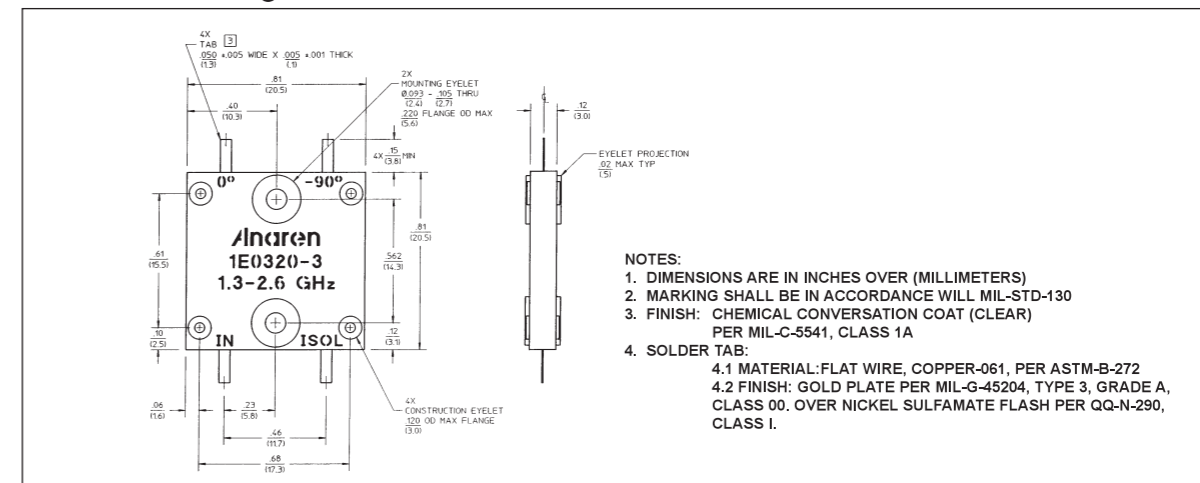
Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
1.3 - 2.6	18/25	0.35	1.30/1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.5	100	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.

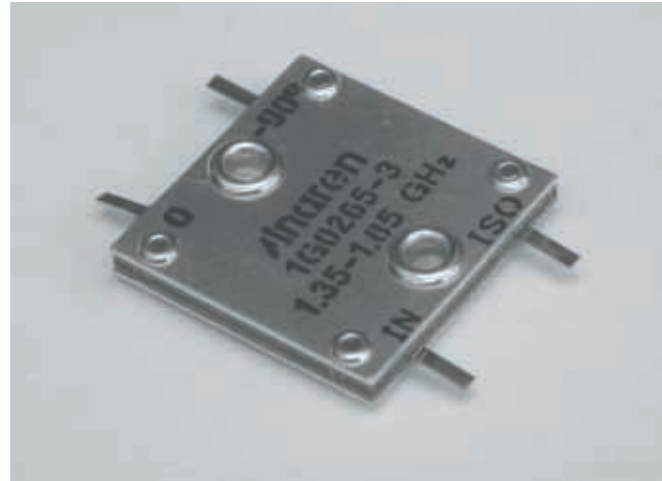
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Hybrid Couplers
3 dB, 90°



Applications

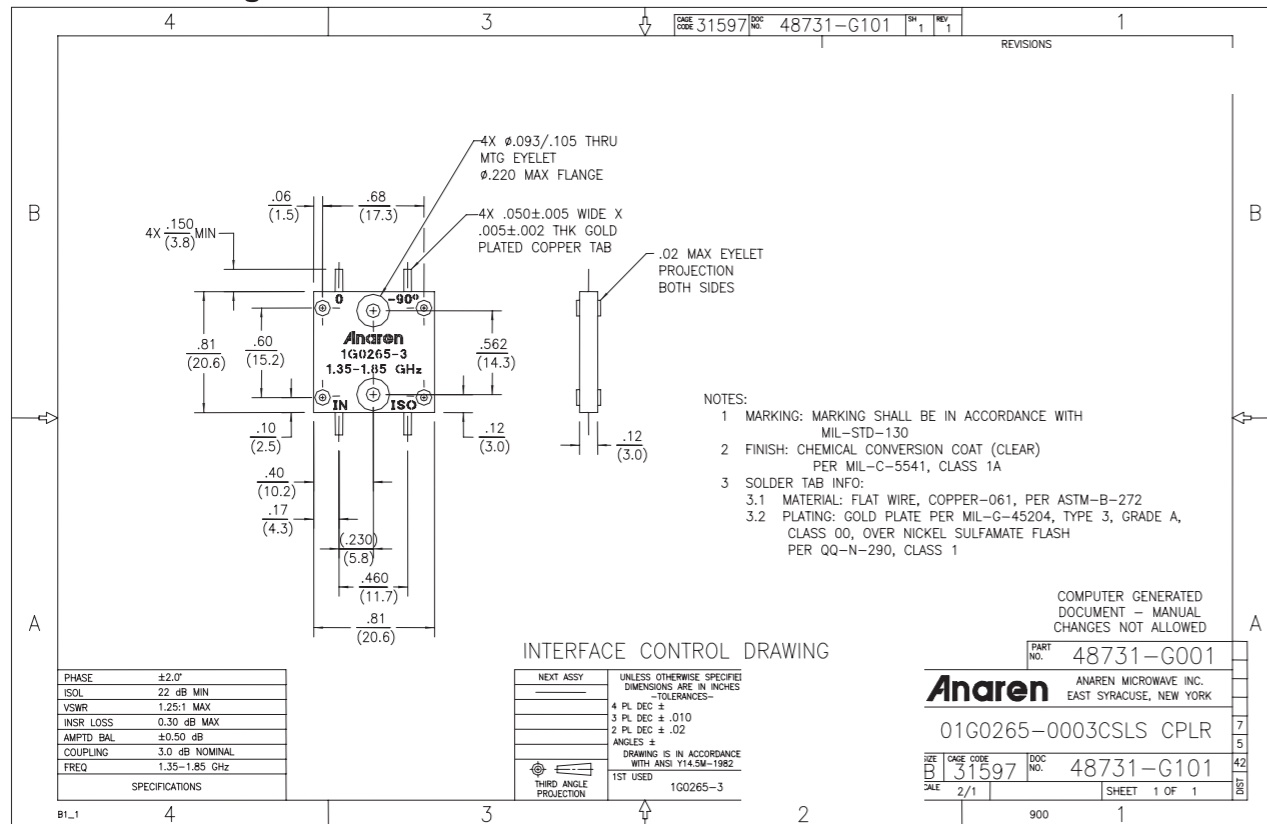
- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 1.35 – 1.85 GHz
- Welded Tab mount
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

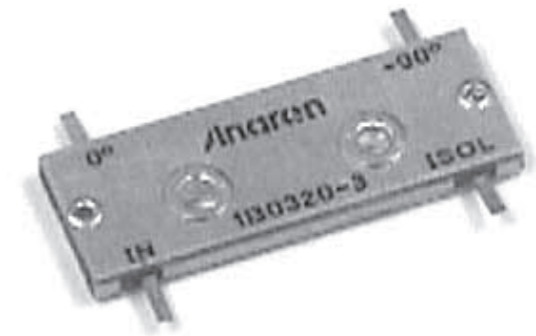
Outline Drawing



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Hybrid Couplers
3 dB, 90°



Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

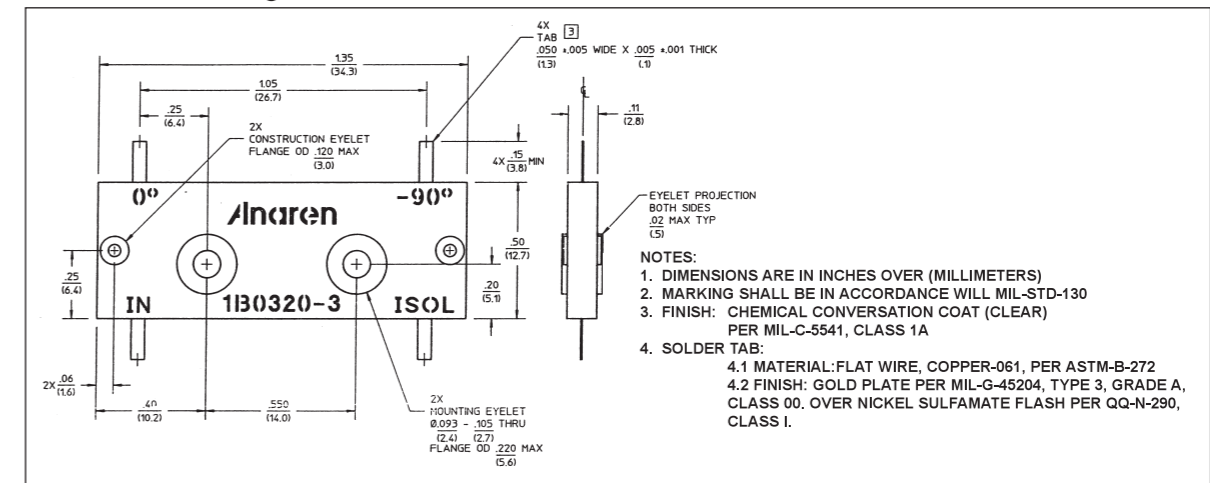
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 100 Watts

Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
1.7 - 2.5	18/25	0.35	1.30/1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	100	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Impedance: 50 ohms. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

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Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

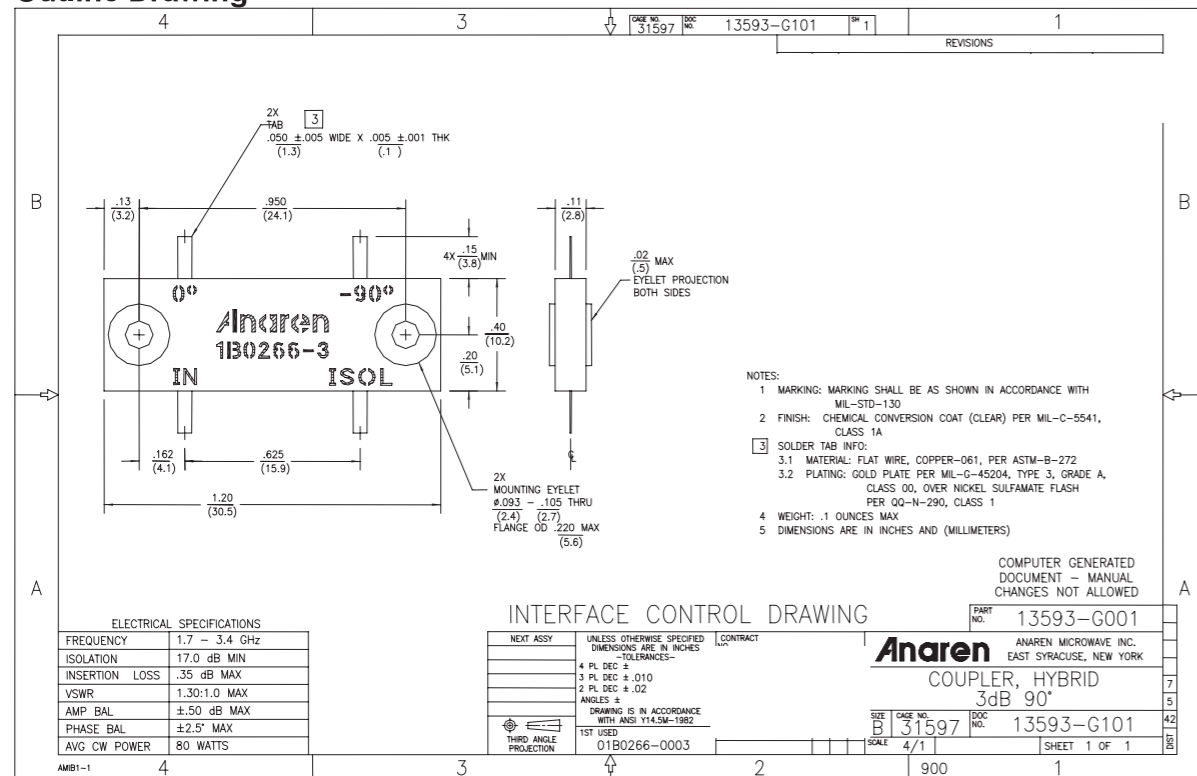
Features

- 1.7-3.4 GHz
- 2-Way Power Split
- Welded Tab mount
- Reliable Performance
- Handles 80 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

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Applications

- Microstrip Circuits
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

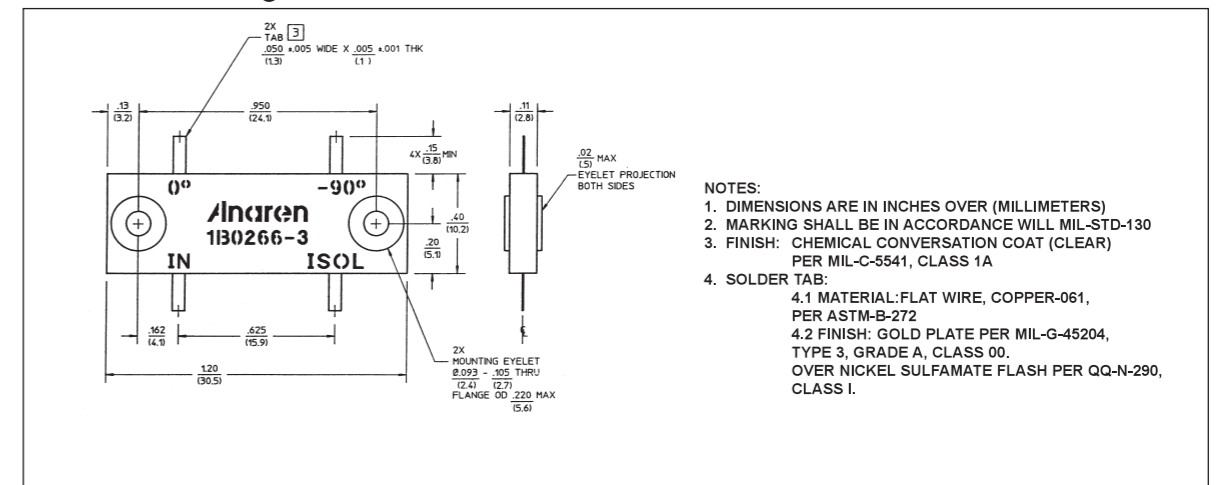
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 60 Watts

Electrical Specifications

Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
2.0 - 4.0	17/21	0.35	1.30/1.20
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.5	60	

Notes: Electrical specifications apply only with properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-STD-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated, Impedance: 50 ohms, Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 1C0266-3



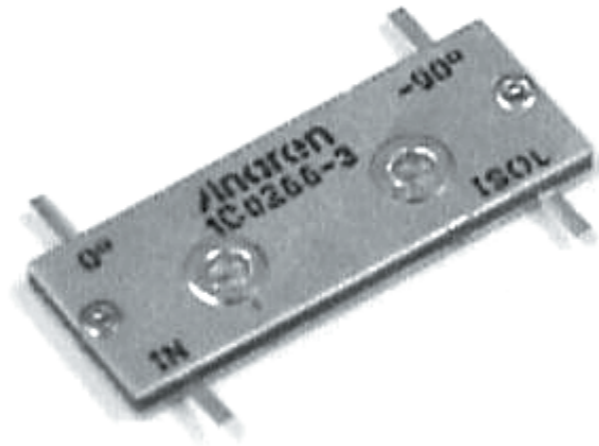
Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

- 2.0 – 4.0 GHz
- Welded Tab mount
- Reliable Performance
- Handles 60 Watts
- Meets MIL-E-5400 Class 3 Requirements



Model 1D0266-3

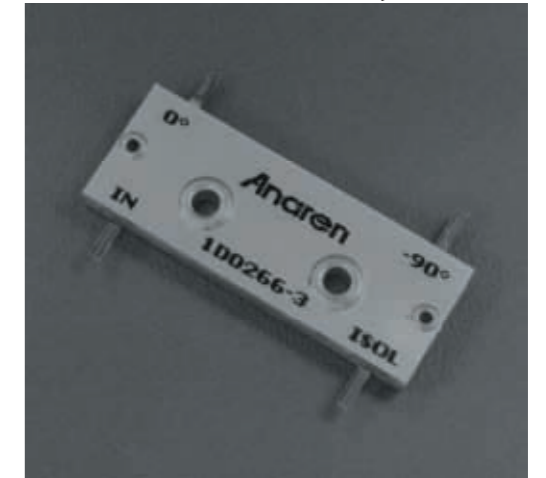
Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

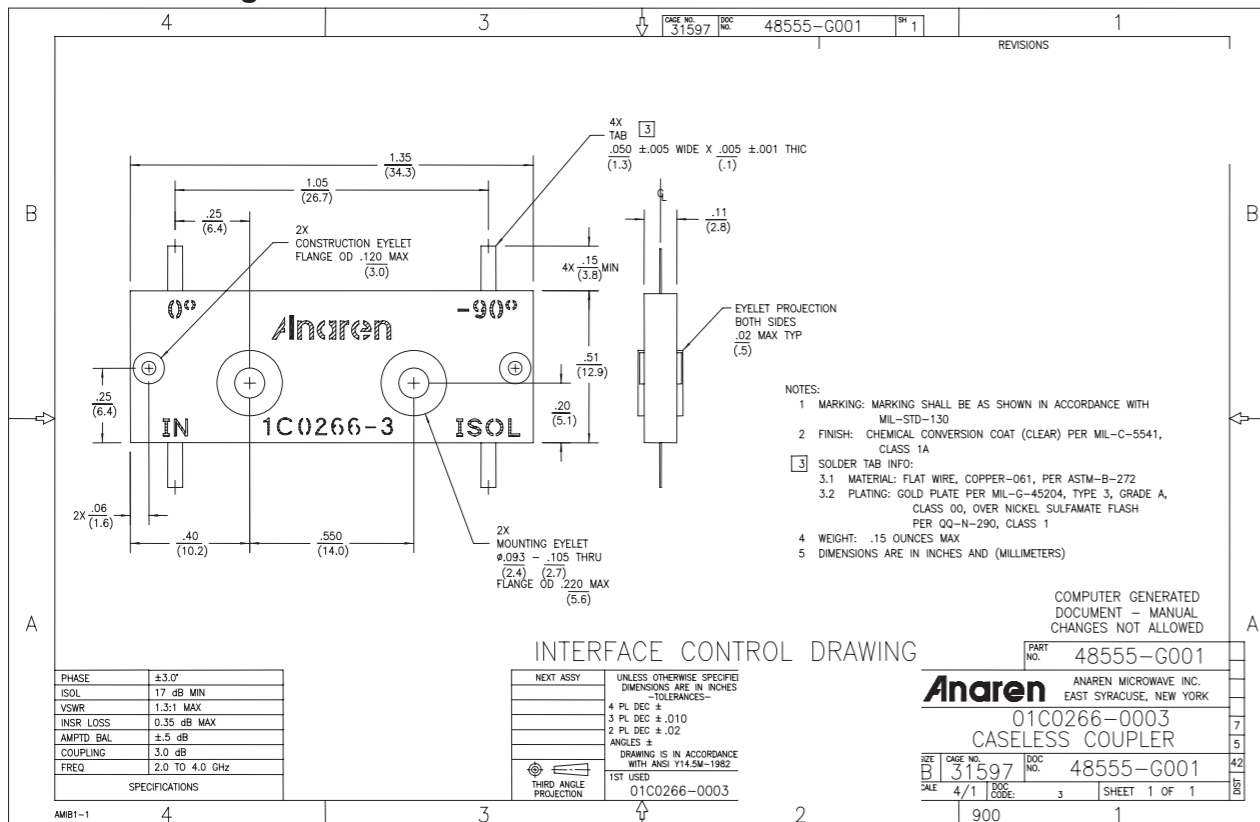
Features

- 2.0 – 4.2 GHz
- Welded Tab mount
- Reliable Performance
- Handles 60 Watts
- Meets MIL-E-5400 Class 3 Requirements



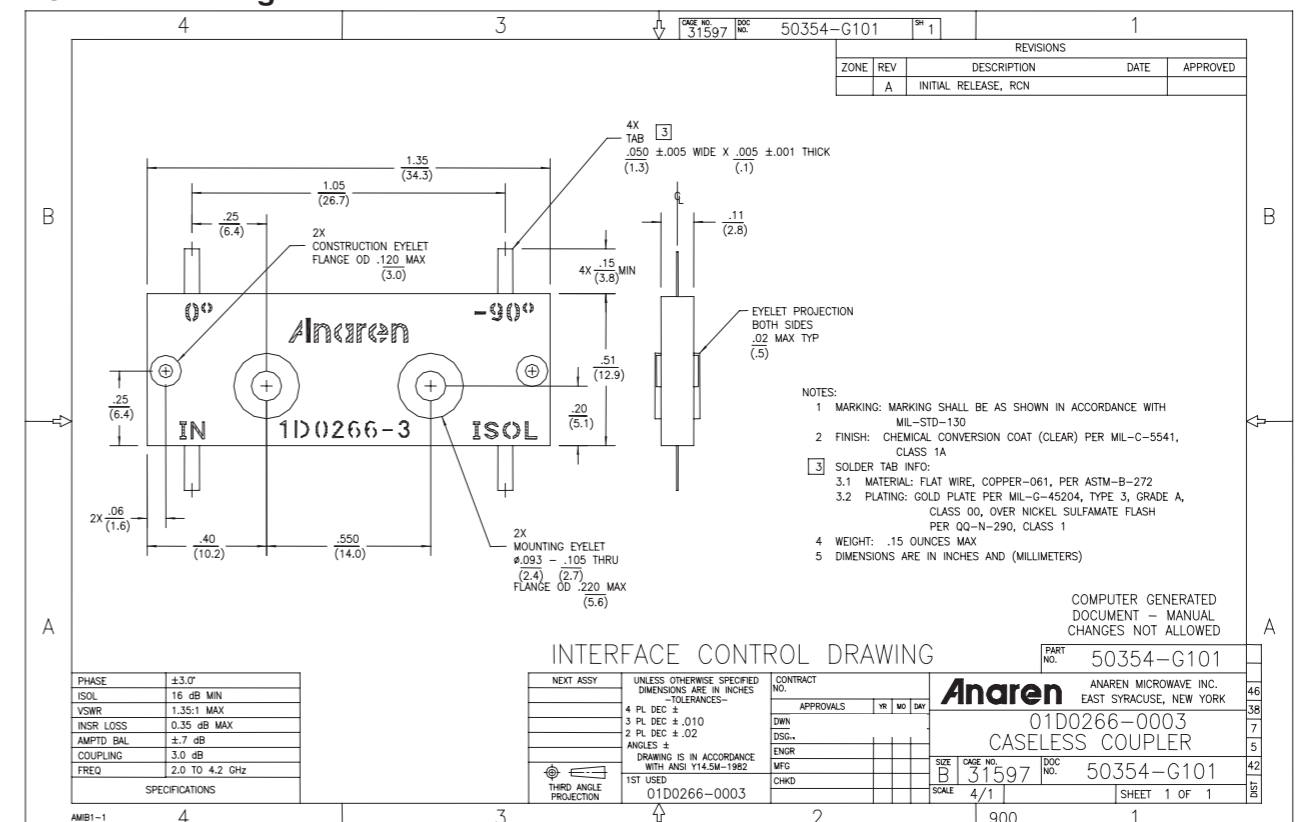
Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.



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Model 11270-3



Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

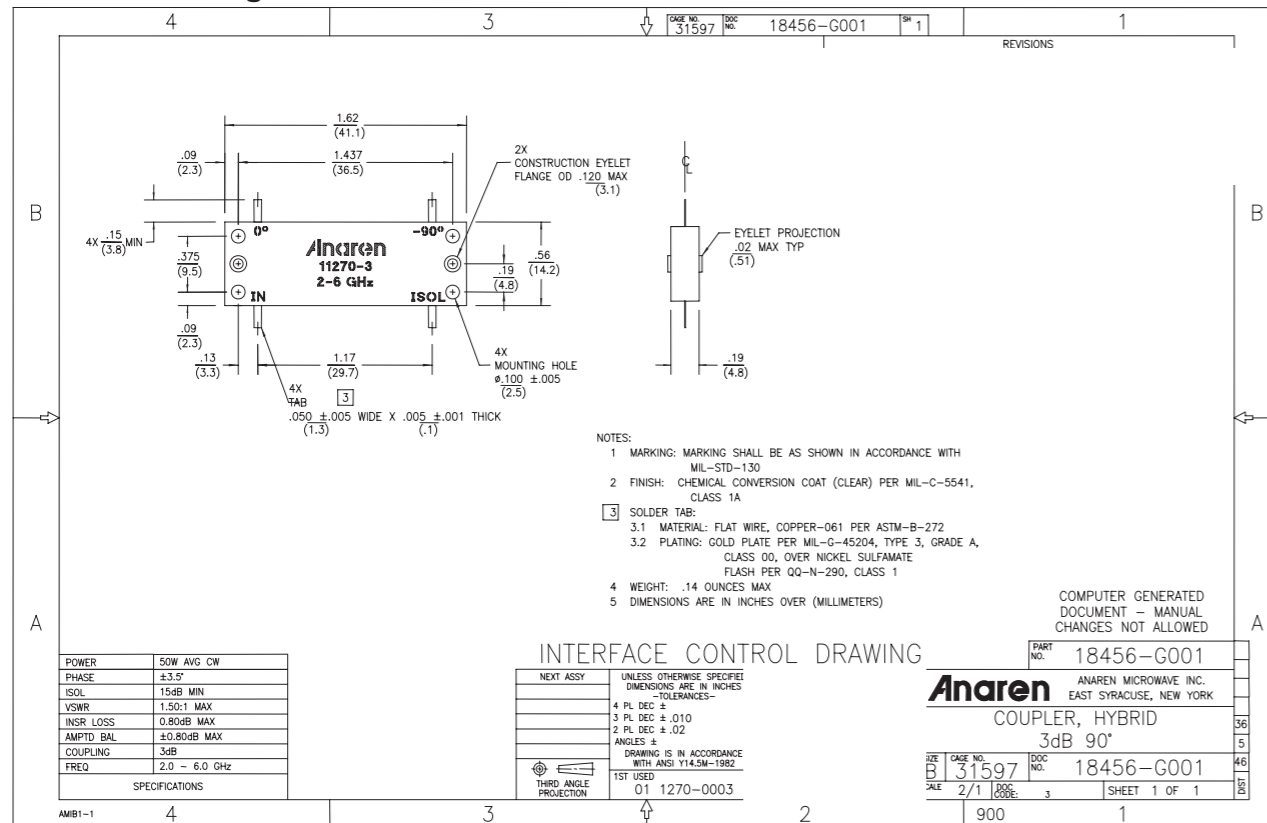
Features

- 2.0 – 6.0 GHz
- Welded Tab mount
- Reliable Performance
- Handles 50 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Model 1A0266-3

Hybrid Couplers 3 dB, 90°

Applications

- Microstrip Circuits
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

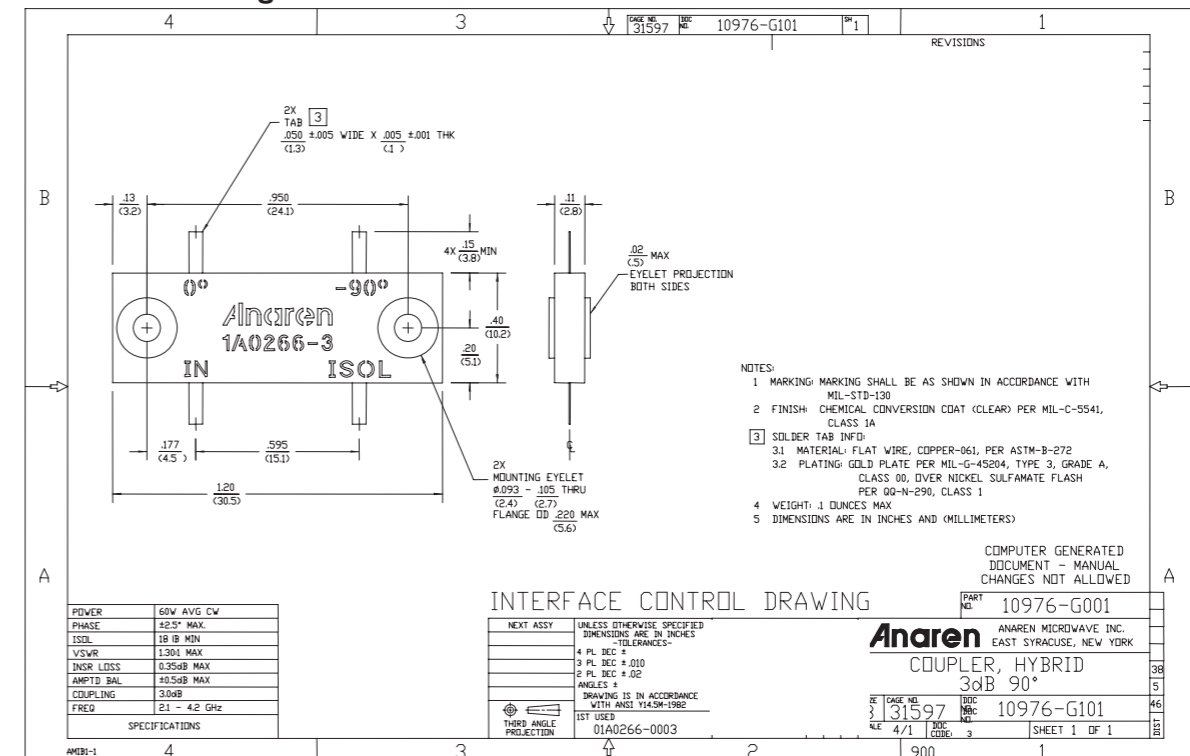
Features

- 2.1 – 4.2 GHz
- Welded Tab mount
- Reliable Performance
- Handles 60 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



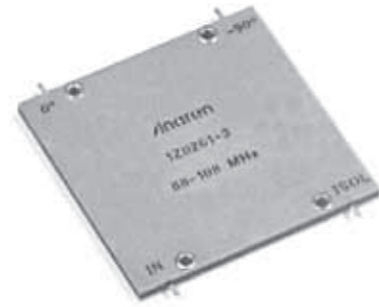
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Hybrid Couplers
High Power 3 dB, 90°



Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

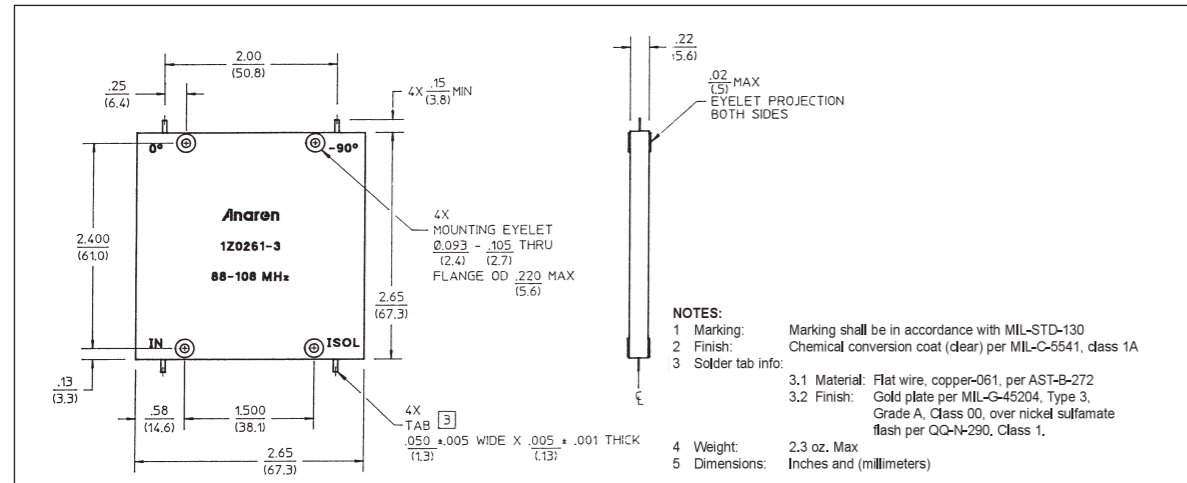
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 980 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
88 - 108	23	0.25	1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.30	±2.0	980	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Electrical specifications apply only properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-Std-105, Level ii, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
High Power 3 dB, 90°



Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

Features

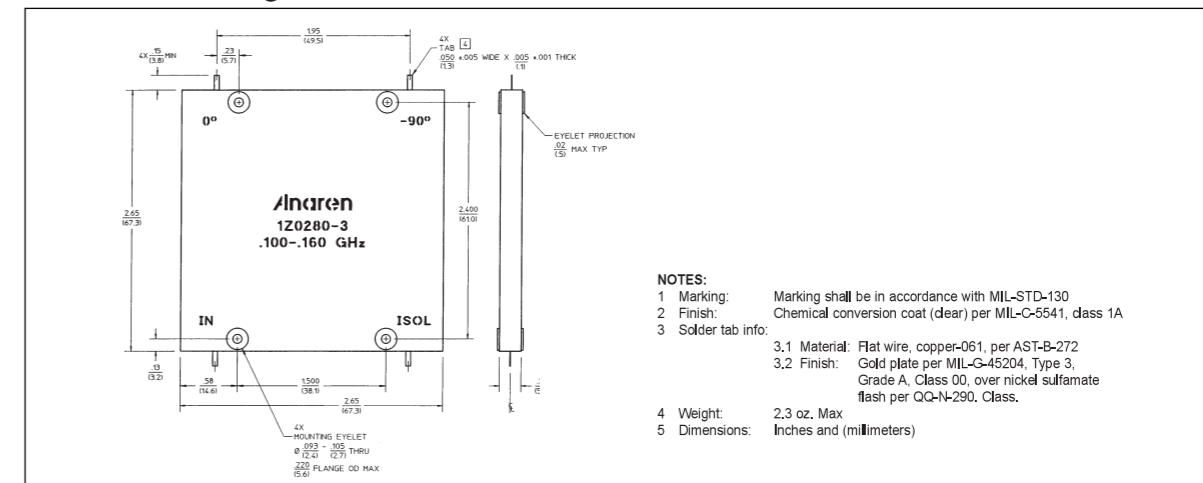
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 700 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
100 - 160	23	0.25	1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.40	±2.0	700	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Electrical specifications apply only properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-Std-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
High Power 3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

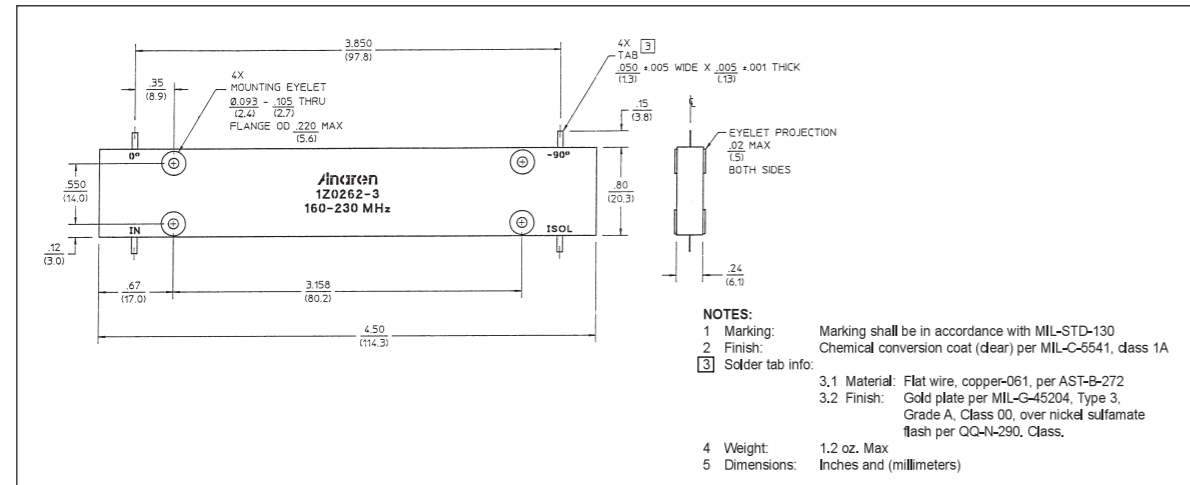
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 560 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
160 - 230	23	0.25	1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.30	±2.0	560	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Electrical specifications apply only properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-Std-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren. Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers
High Power 3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

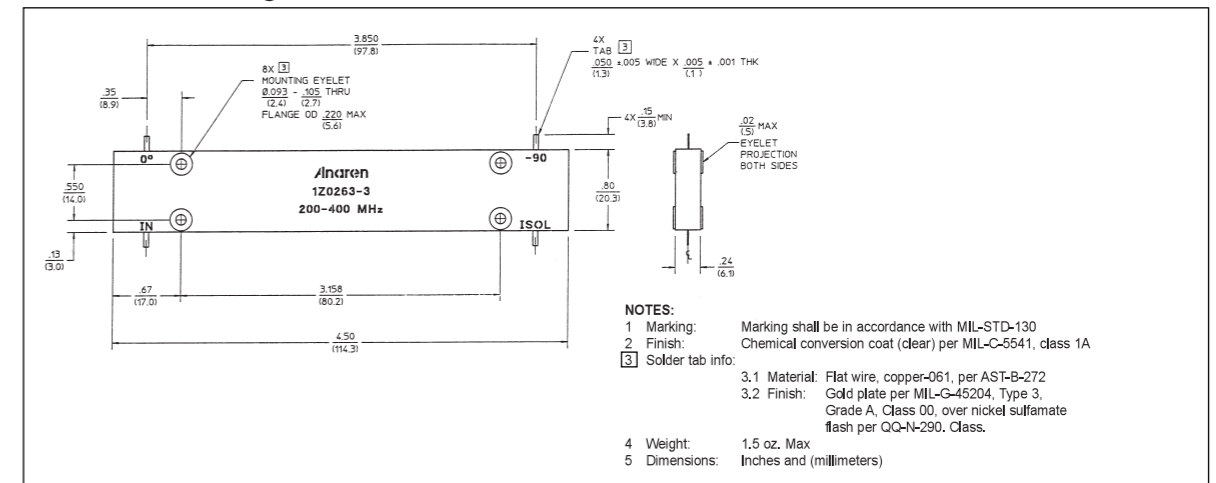
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 420 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
200 - 400	20	0.25	1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±2.0	420	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Electrical specifications apply only properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-Std-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren. Power rating applies when solder tab/coupler interface has been conformally coated.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrid Couplers

High Power 3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Divider/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds



Features

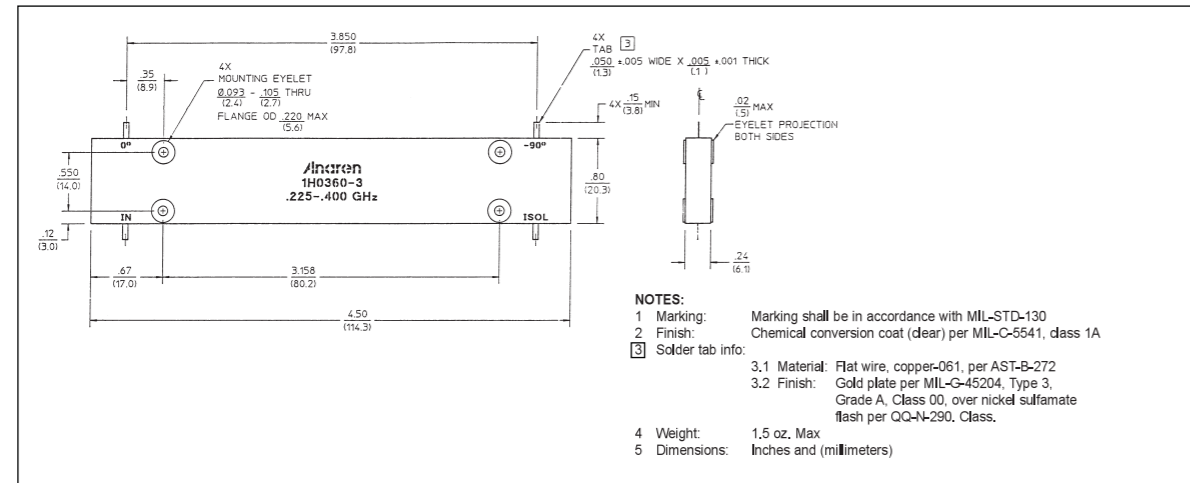
- Welded Tab Mount
- 2-Way Power Split
- Reliable Performance
- Handles 420 Watts

Electrical Specifications

Frequency MHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
225 - 400	23	0.25	1.15
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.40	±2.0	420	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Electrical specifications apply only properly designed test fixtures. Testing is done at ambient temperature only. Sample testing is performed to MIL-Std-105, Level 2, AQL 1.0. Test includes coupling, amplitude balance, insertion loss and isolation. If your application requires additional testing, consult Anaren. Power rating applies when solder tab/coupler interface has been conformally coated. Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing

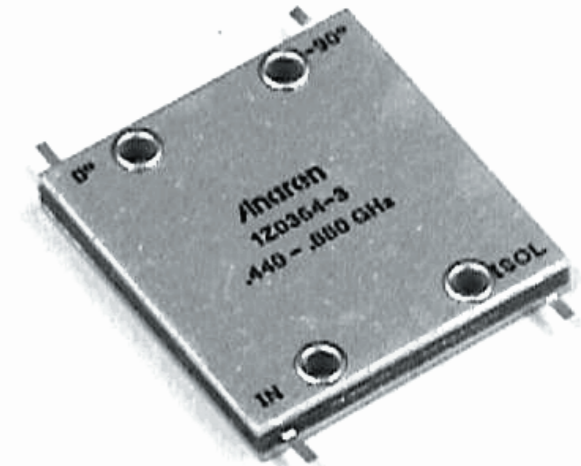


Hybrid Couplers

High Power 3 dB, 90°

Applications

- Microstrip Circuits
- Power Amps
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

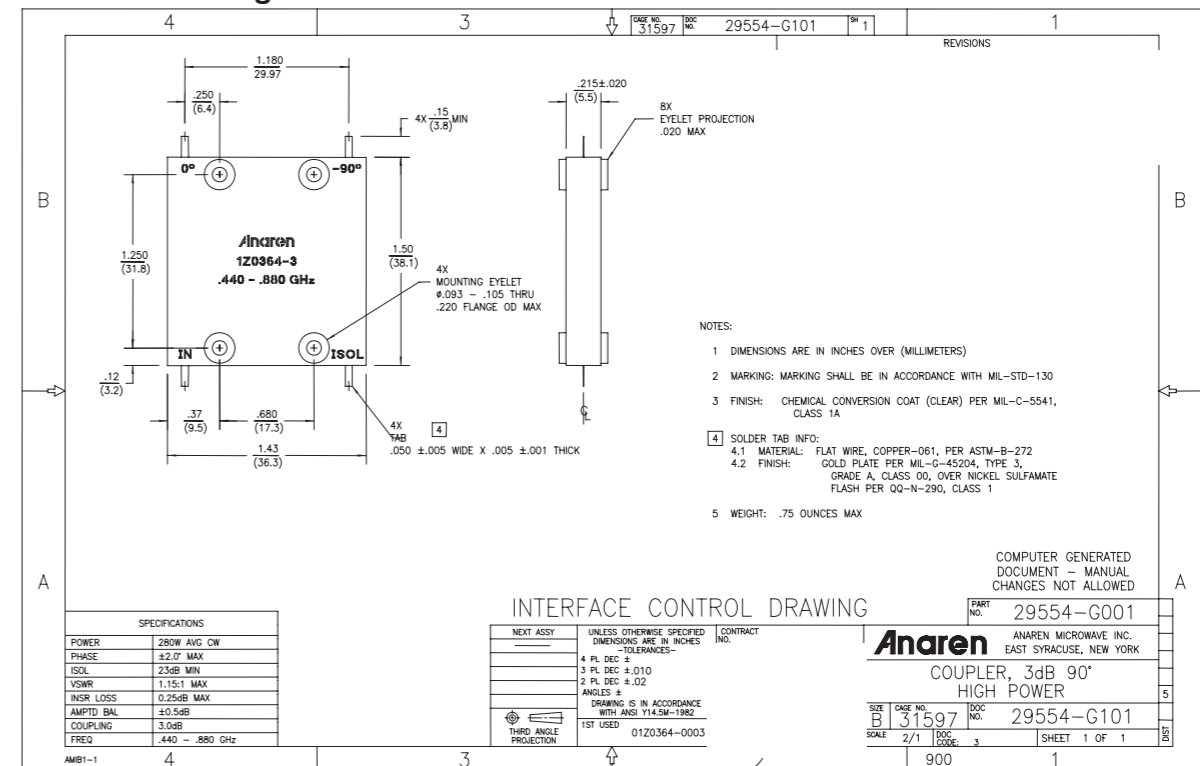


Features

- 0.44 – 0.88 GHz
- 2 – Way power Split
- Welded Tab mount
- Reliable Performance
- Handles 280 Watts
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Hybrids Coupler, cased Selection Matrix

90° Hybrids, cased									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Port Impedance (Ω)	Return Loss (VSWR:1)	Insertion Loss (dB)	Amplitude Balance (+/- dB)	Phase Balance (+/- °)	Isolation (dB)
10540-3	0.03 - 0.076	800	2.2 x 3.75	50	.2	0.5	0.75	5	20
10011-3	0.062 - 0.125	100	3 x 1.75	50	1.25	0.35	0.5	2.5	21
10012-3	0.125 - 0.25	100	3 x 2.25	50	1.25	0.3	0.5	3	21
10010-3	0.225 - 0.4	250	1.65 x 1.62	50	1.2	0.3	0.5	2	23
10013-3	0.25 - 0.5	200	1.65 x 1.62	50	1.2	0.3	0.5	2	23
10023-3	0.25 - 1.0	200	4 x 2.25	50	1.3	0.5	0.75	3	20
10014-3	0.5 - 1.0	200	1.65 x 1.62	50	1.22	0.3	0.5	2	22
10574-3	0.5 - 1.0	200	1.9 x 1.37	50	1.29	0.3	0.5	2	22
1A0024-3	0.5 - 2.0	100	4 x 2.25	50	1.45	0.6	0.8	5	15
1B0024-3	0.5 - 3.0	100	6 x 1.35	50	1.65	1.2	0.8	5	16
1C0680-3	0.7 - 1.4	150	1.25 x 1.25	50	1.25	0.3	0.5	2	18
1A0004-3	0.8 - 1.0	200	1.72 x 1.315	50	1.2	0.3	0.35	3	21
1B0680-3	0.95 - 1.225	200	1.25 x 1.25	50	1.25	0.3	0.3	2	20
10015-3	1.0 - 2.0	150	1.65 x 1.62	50	1.27	0.3	0.5	2	22
1H0565-3	1.0 - 2.0	150	2.49 x 0.58	50	1.2	0.3	0.5	2	25
10025-3	1.0 - 4.0	100	3 x 2.25	50	1.5	0.5	0.75	5	15
1J0560-3	1.3 - 2.6	100	1.61 x 0.58	50	1.25	0.3	0.5	2	23
10040-3	1.4 - 2.8	100	1.25 x 1.25	50	1.25	0.3	0.5	2	20
10016-3	2.0 - 4.0	100	1.25 x 1.25	50	1.3	0.3	0.5	2	20
1H0566-3	2.0 - 4.0	100	1.61 x 0.58	50	1.25	0.3	0.5	2	23
10017-3	4.0 - 8.0	80	1.25 x 1.25	50	1.35	0.6	0.5	4	18
1H0567-3	4.0 - 8.0	80	1.08 x 0.58	50	1.3	0.35	0.5	3	18
10029-3	4.5 - 18.0	60	1.4 x 0.75	50	1.58	1.3	0.6	7	16
1E0018-3	7.0 - 11.0	70	1.25 x 1.25	50	1.45	0.5	0.5	6	17
1J0770-3	7.5 - 18.0	60	1.08 x 0.58	50	1.5	0.8	0.65	7	14
10018-3	8.0 - 12.4	70	1.25 x 1.25	50	1.5	0.6	0.5	6	16
1H0568-3	8.0 - 12.4	70	1.08 x 0.58	50	1.35	0.5	0.4	3	18
1H0569-3	12.4 - 18.0	60	1.08 x 0.58	50	1.5	0.8	0.4	5	14

180° Hybrids, cased									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Port Impedance (Ω)	Return Loss (VSWR) Max:1	Insertion Loss (dB)	Amplitude Balance (+/- dB)	Phase Balance (+/- °)	Isolation (dB)
30054	0.5 - 1.0	200	3 x 2.25	50	1.25	0.6	0.5	8	20
30110	0.6 - 1.2	200	3.4 x 2.45	50	1.27	0.6	0.5	8	18
30055	1.0 - 2.0	150	3 x 2.25	50	1.35	0.6	0.5	6	18
3A0055	1.0 - 2.0	150	3.4 x 2.1	50	1.35	0.6	0.2	8	20
3A0200	1.3 - 2.6	100	3.4 x 2.1	50	1.4	0.6	0.4	8	20
30056	2.0 - 4.0	100	1.65 x 1.62	50	1.6	0.65	0.5	10	15
3A0056	2.0 - 4.0	100	3 x 2.25	50	1.55	0.65	0.4	8	19
30057	4.0 - 8.0	80	1.25 x 1.25	50	1.9	0.8	0.5	10	15
30070	6.0 - 18.0	60	2.2 x 1.925	50	1.9	2.2	0.5	10	15
30160	7.0 - 11.0	70	1.25 x 1.25	50	1.8	1.2	0.5	10	15

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Model 10540-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

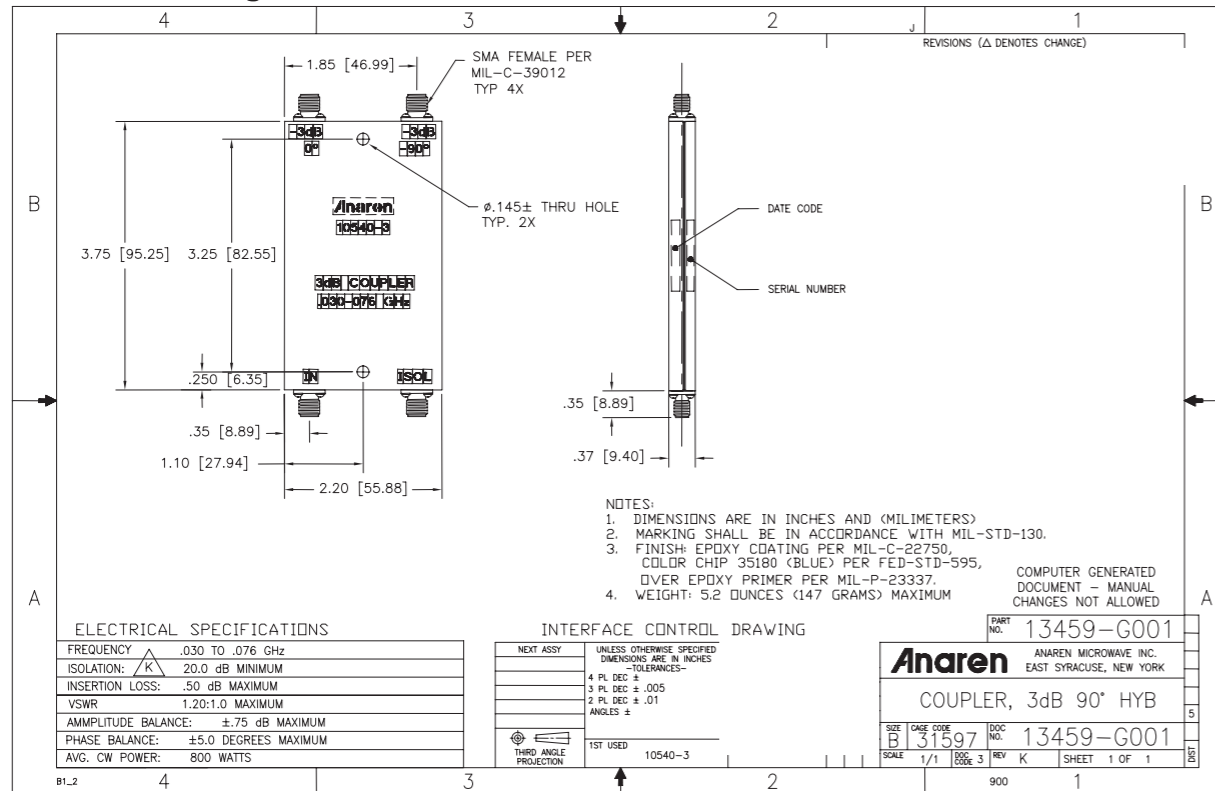
Features

- Military Grade
- 0.03 – 0.076 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Asia: +86-512-62876400



Model 10011-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

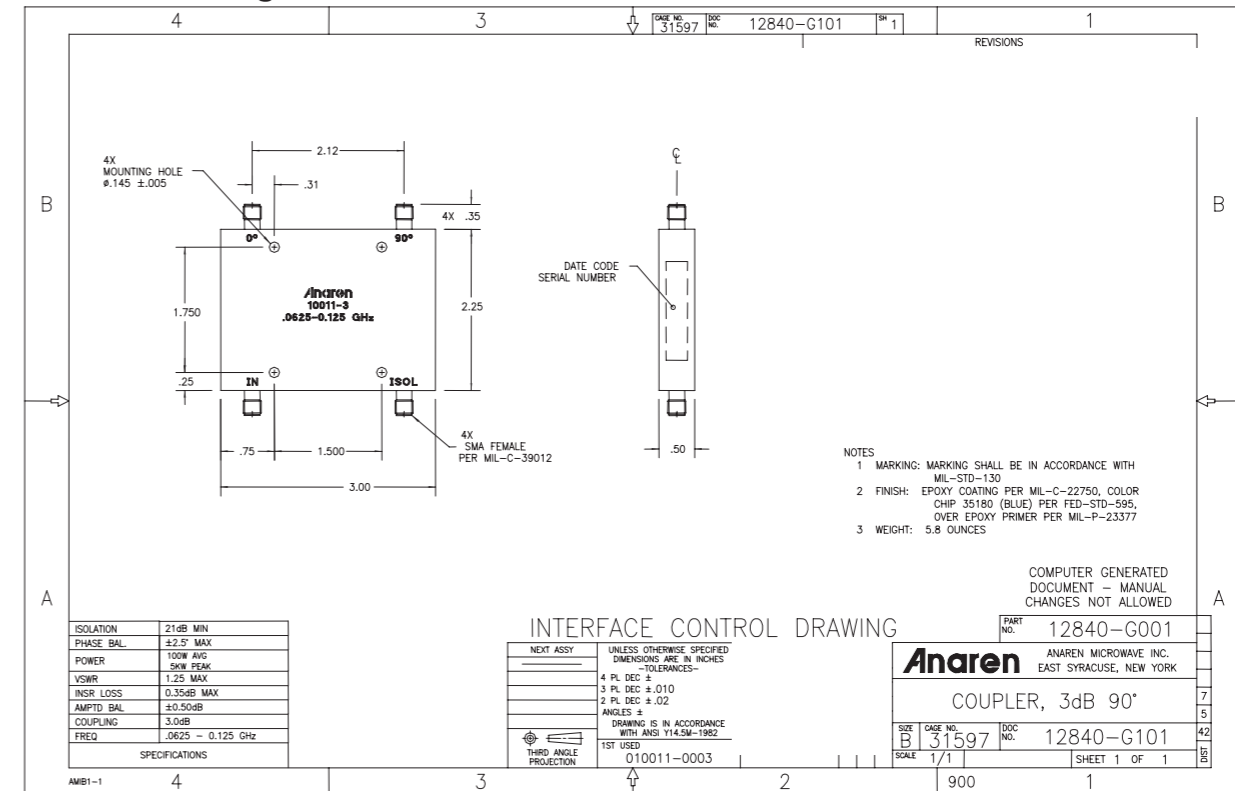
Features

- Military Grade
- 0.0625 – 0.125 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 10012-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

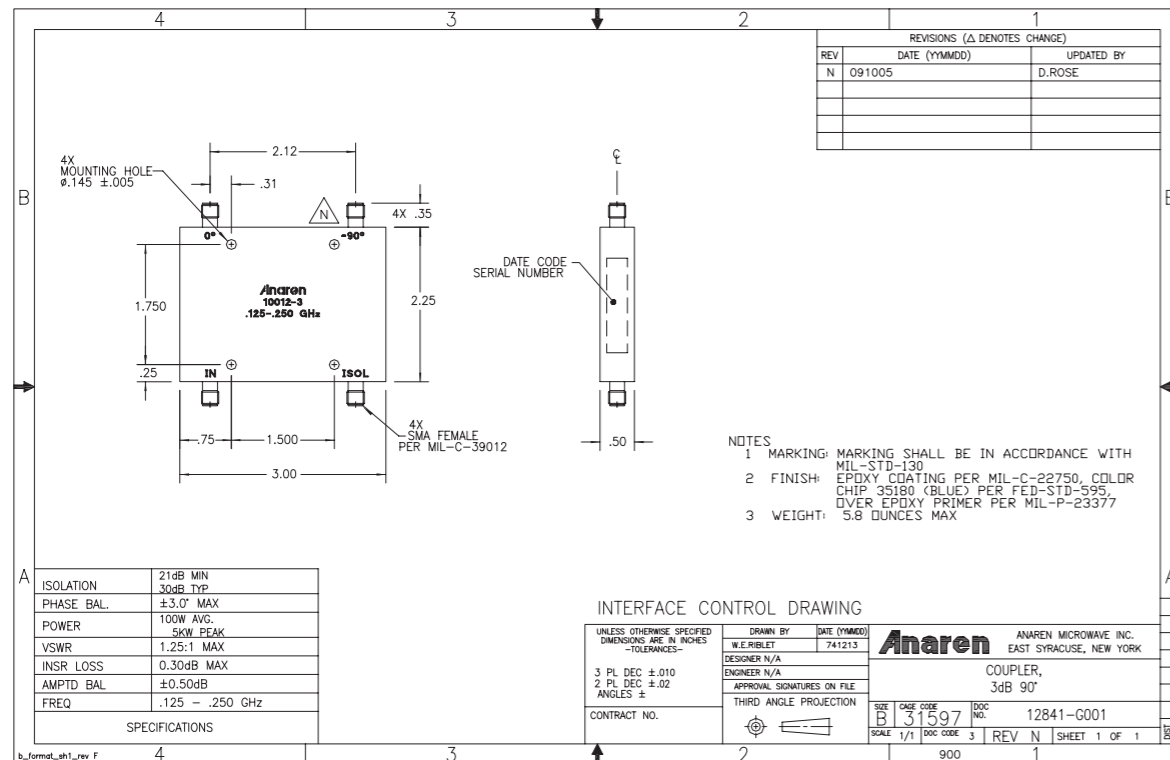
Features

- Military Grade
- 0.125 – 0.250 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 10010-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

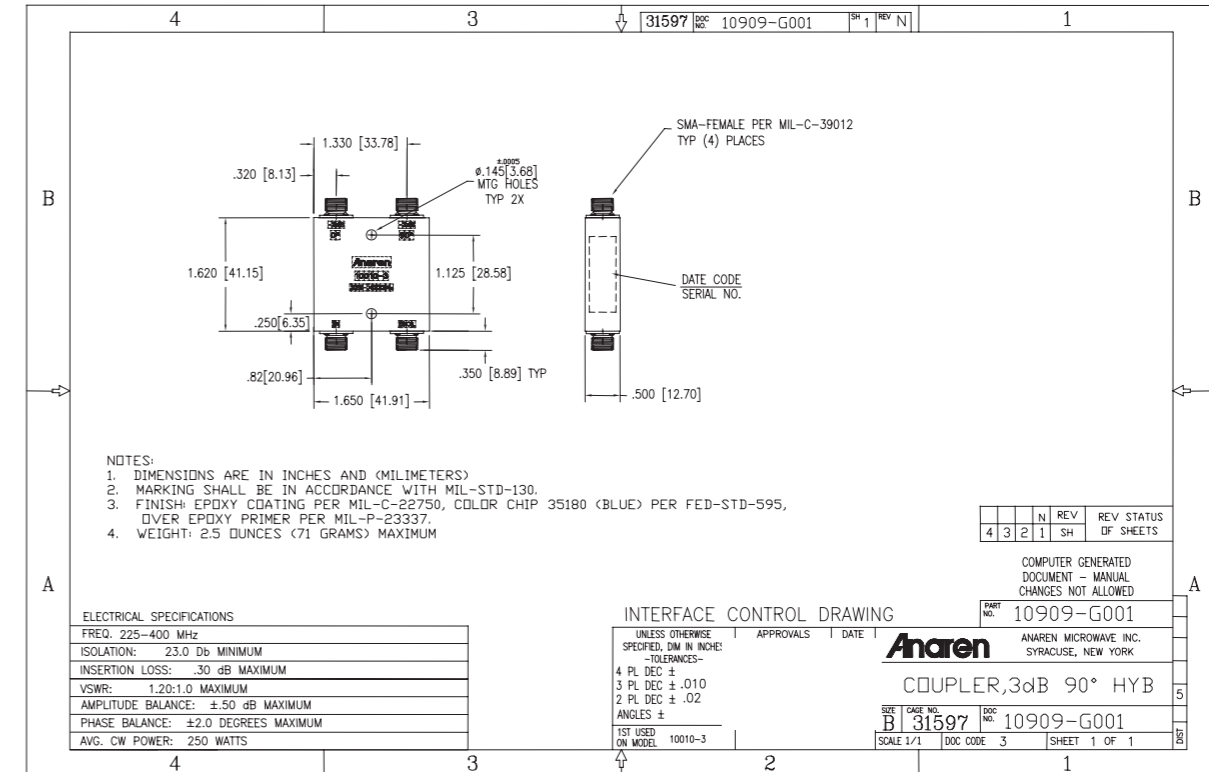
Features

- Military Grade
- 0.225 – 0.4 GHz
- 2 – Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



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Model 10013-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

- Military Grade
- 0.25 – 0.5 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 10023-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

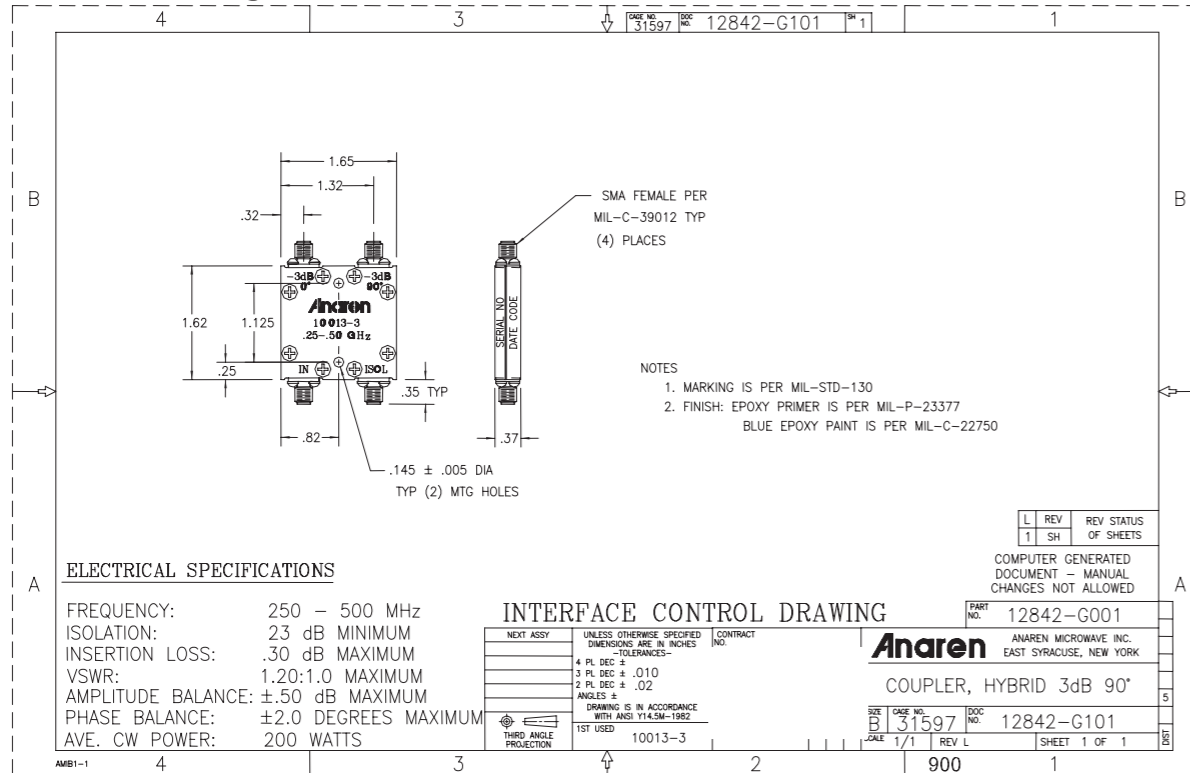
Features

- Military Grade
- 0.25 – 1.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



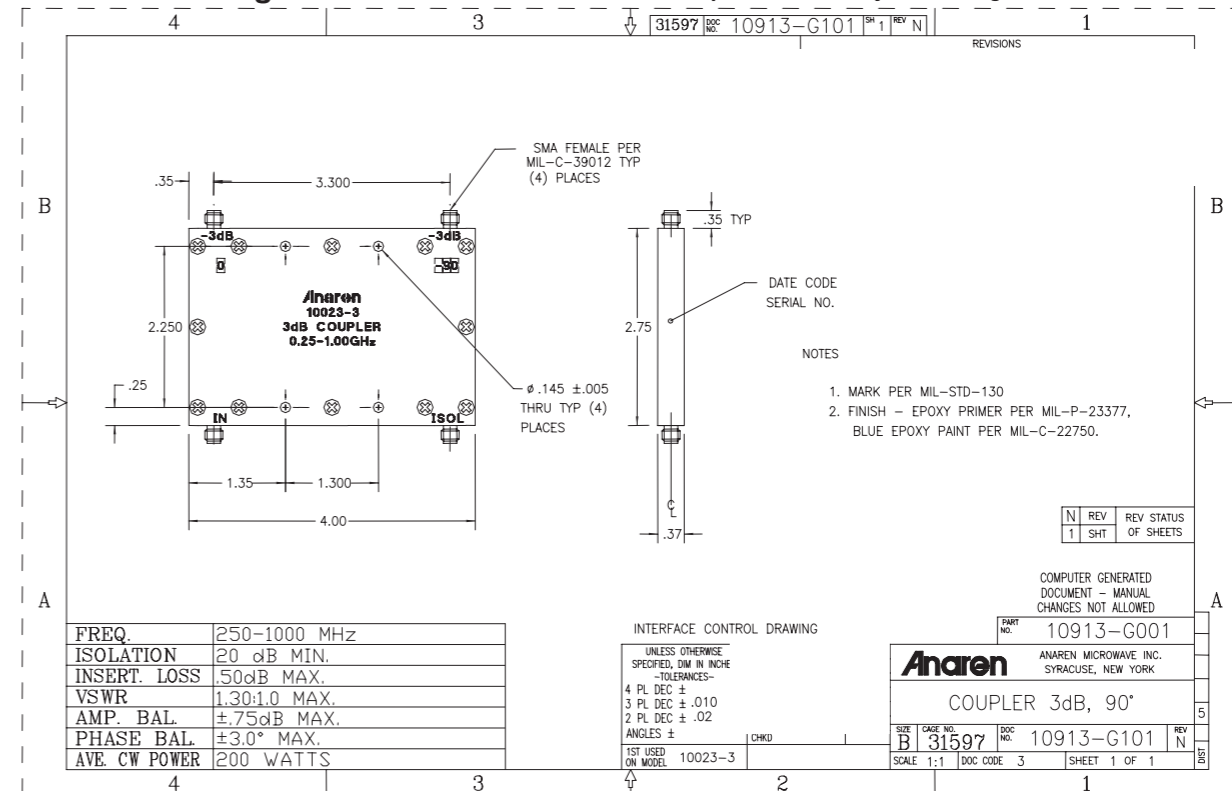
Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

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Model 10014-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

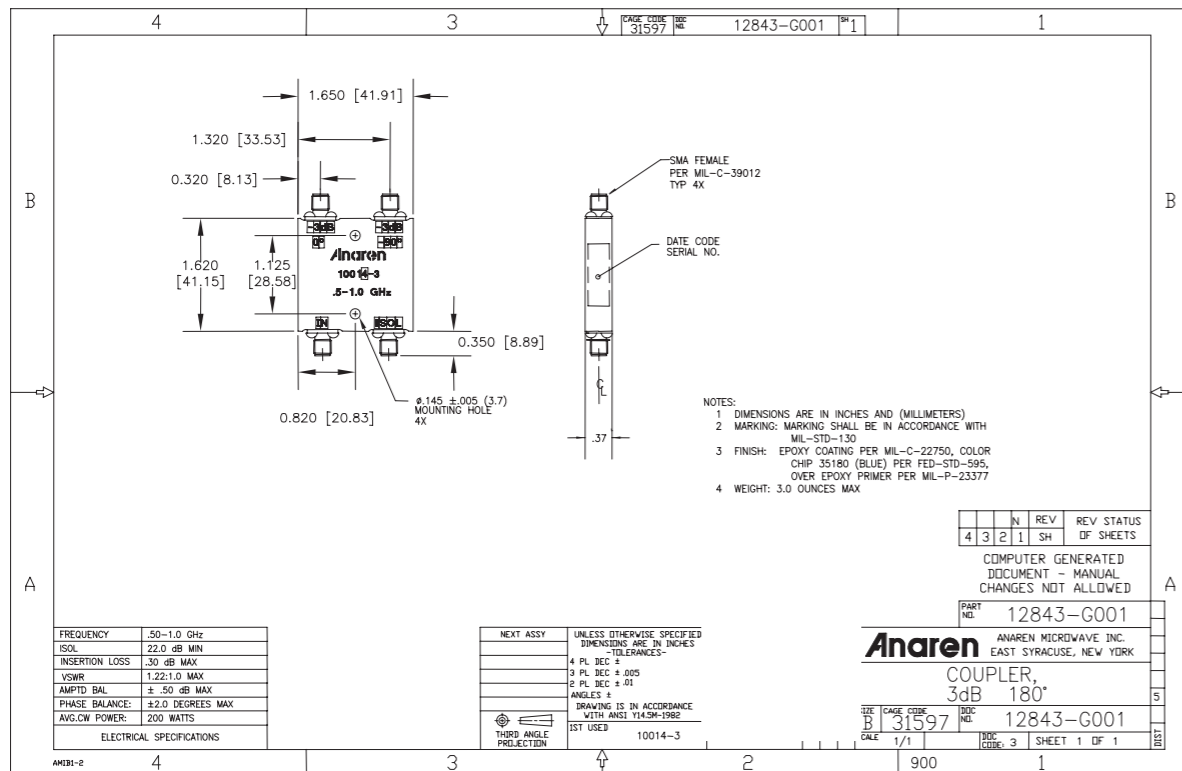
Features

- Military Grade
- 0.5 – 1.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 10574-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

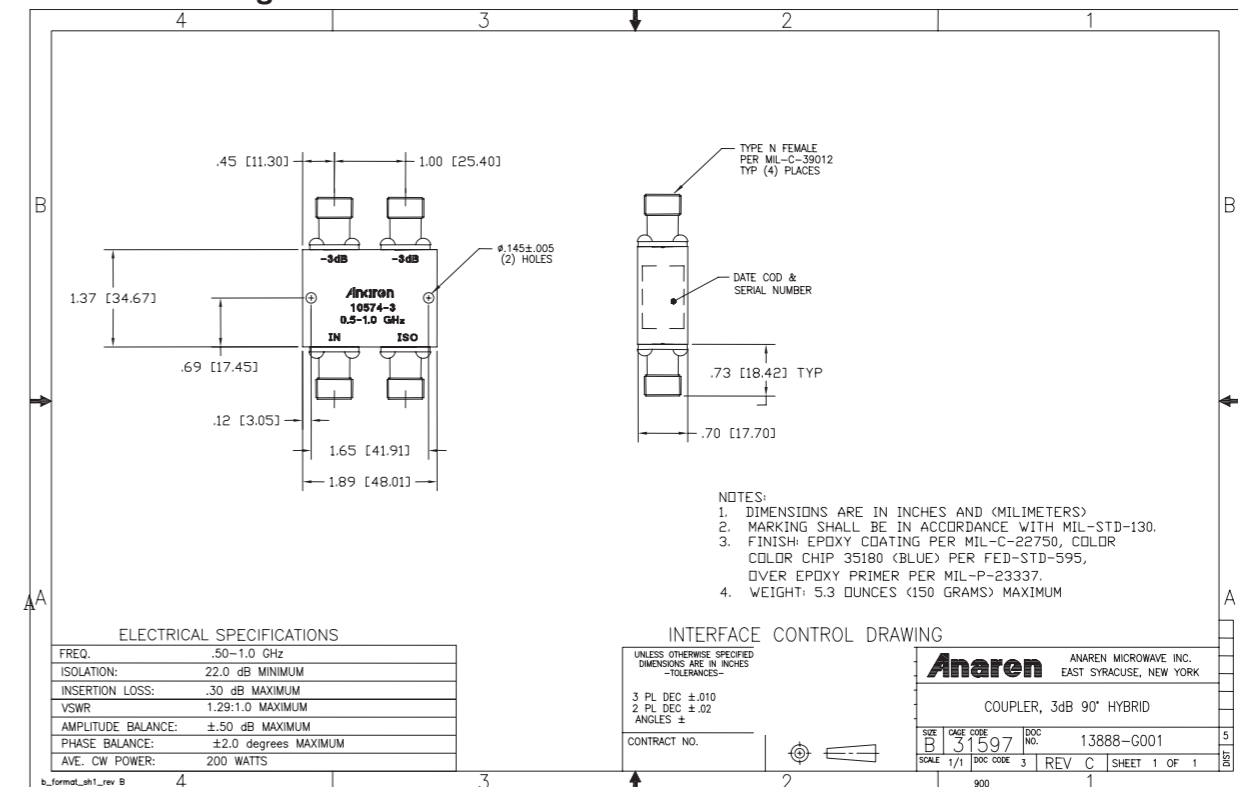
Features

- Military Grade
- 0.5 – 1.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 1A0024-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

- Military Grade
- 0.5 – 2.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 1B0024-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

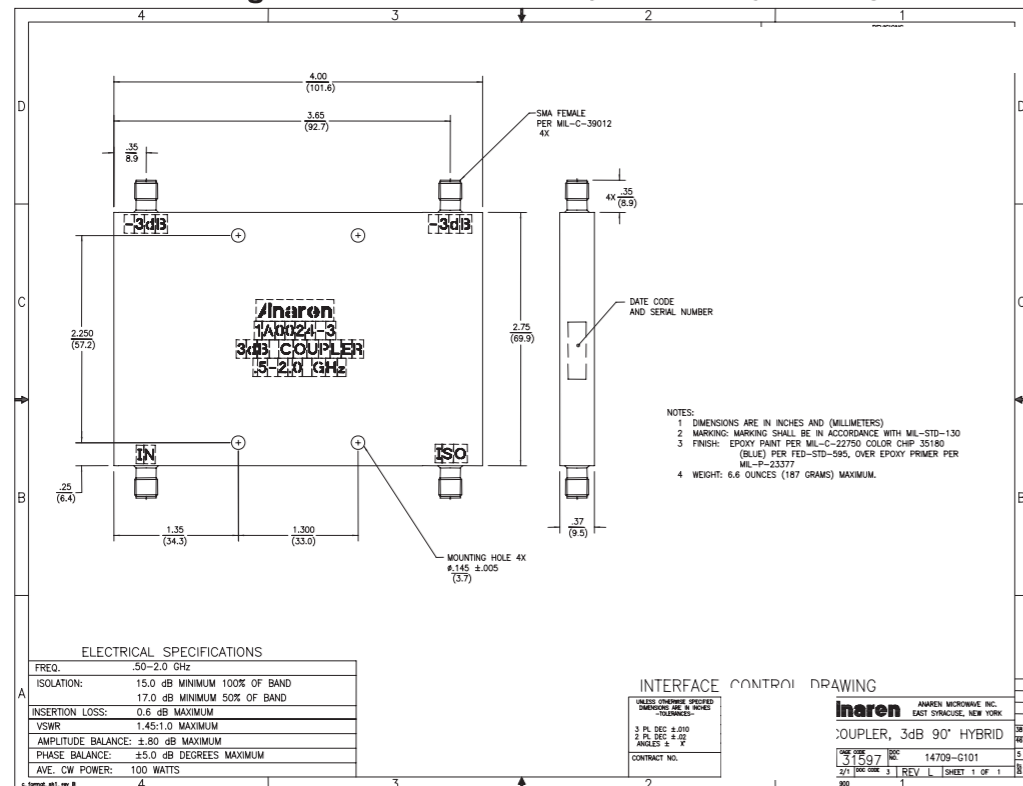
Features

- Military Grade
- 0.5 – 3.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



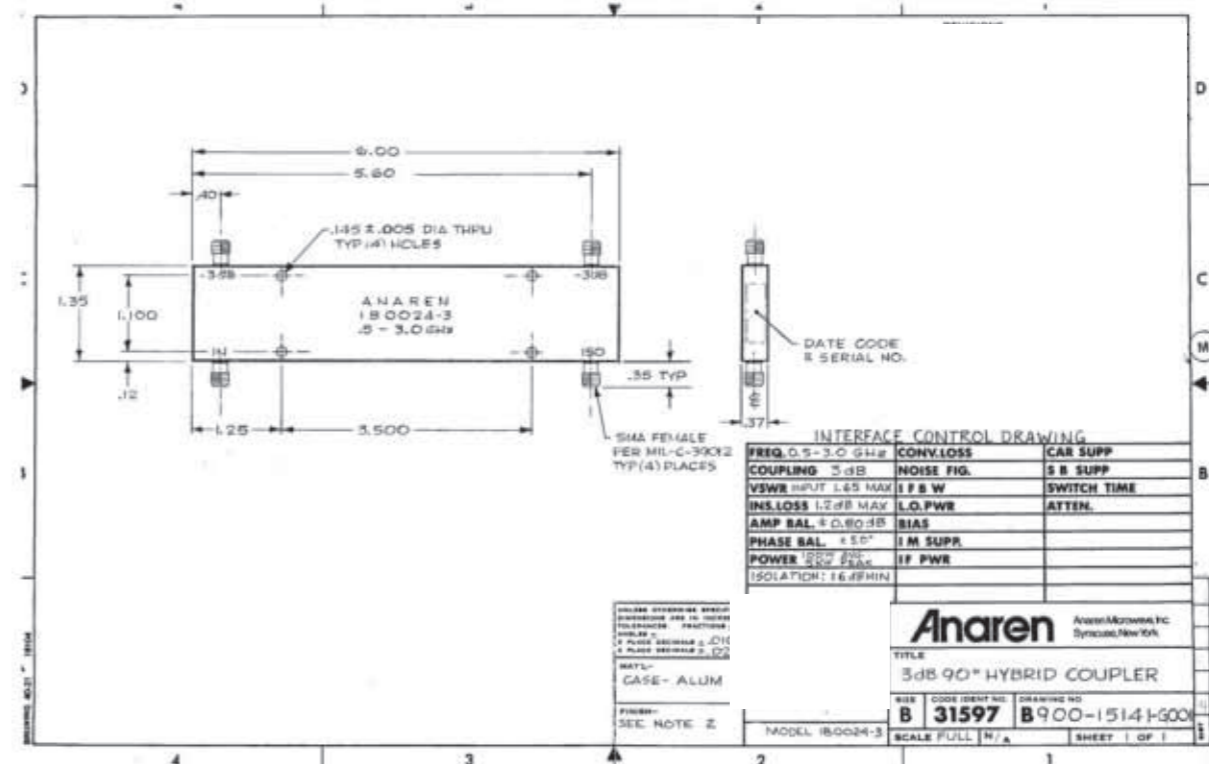
Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 1C0680-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

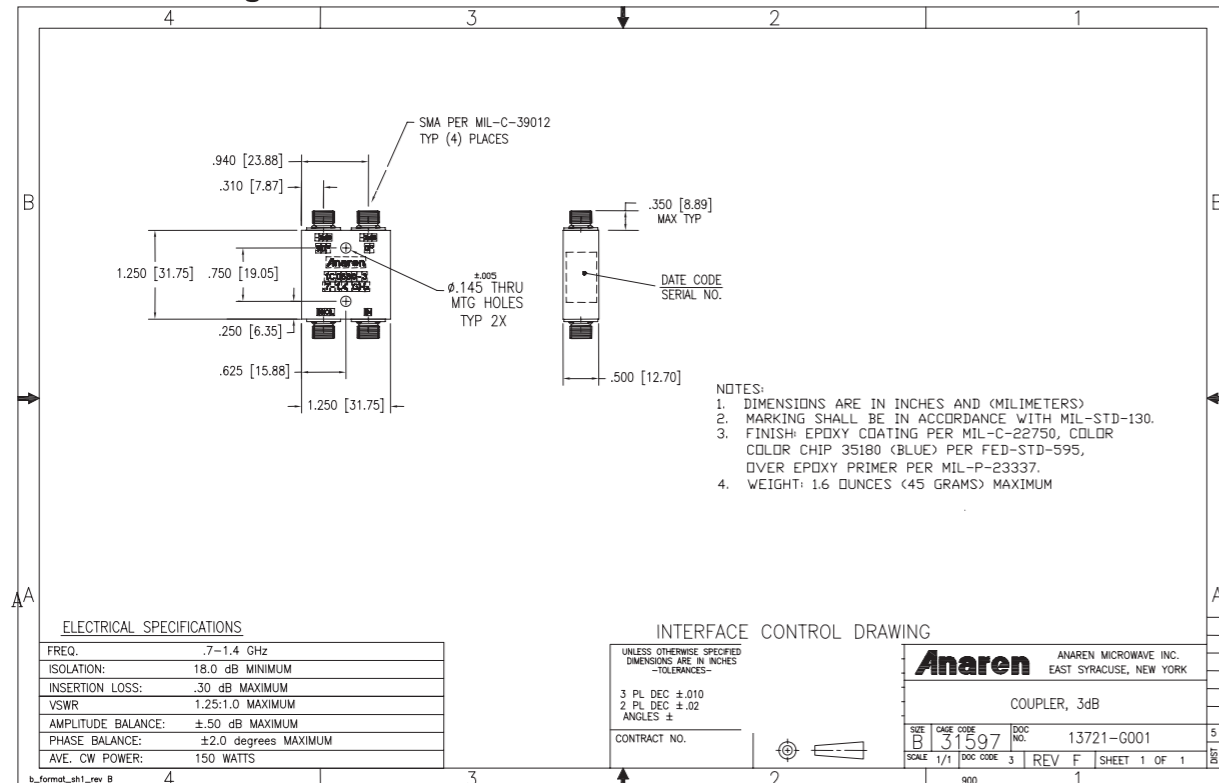
Features

- Military Grade
- 0.7 – 1.4 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Asia: +86-512-62876400



Model 1A0004-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

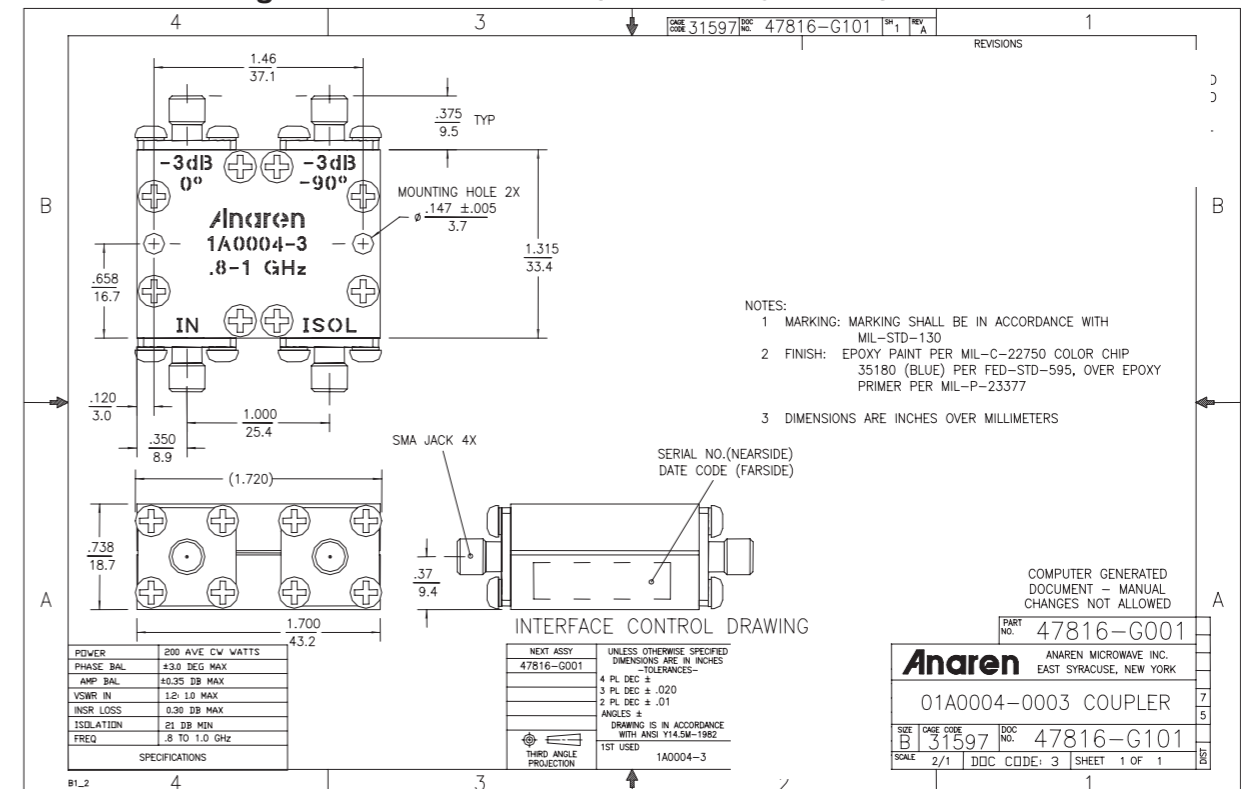
Features

- Military Grade
- 0.8 – 1.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 1B0680-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

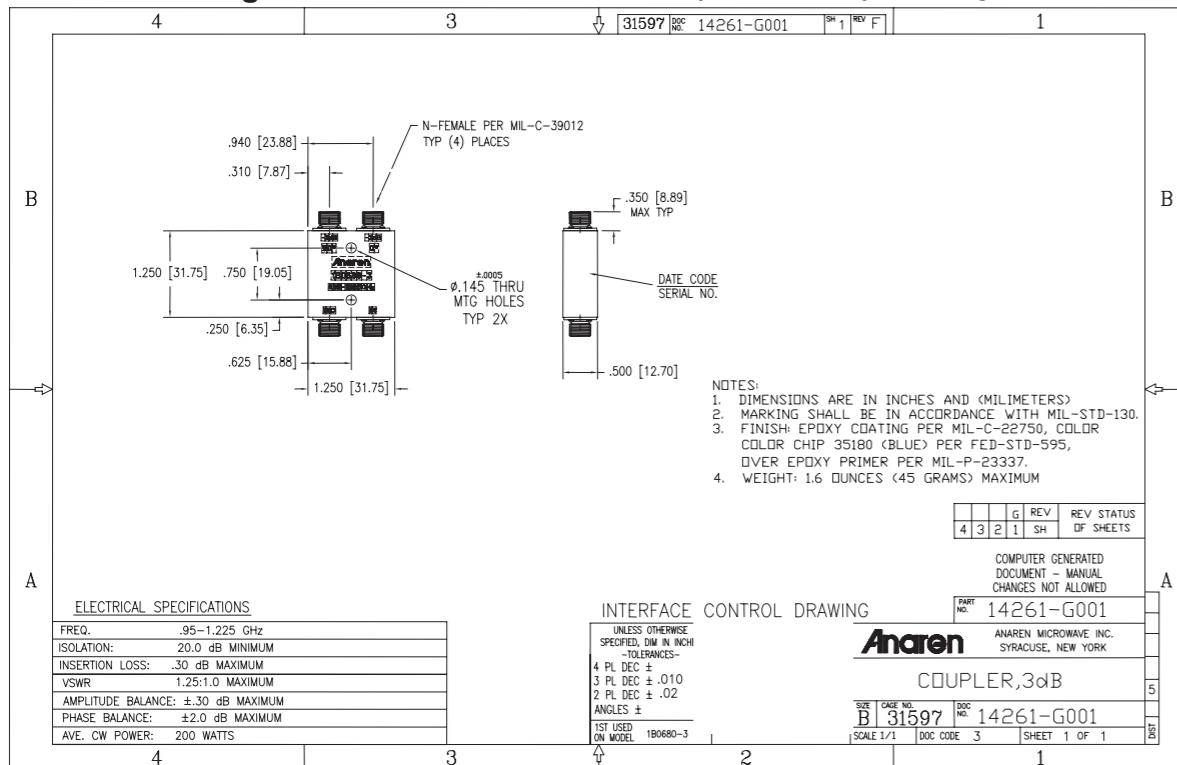
Features

- Military Grade
- 0.95 – 1.225 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 10015-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

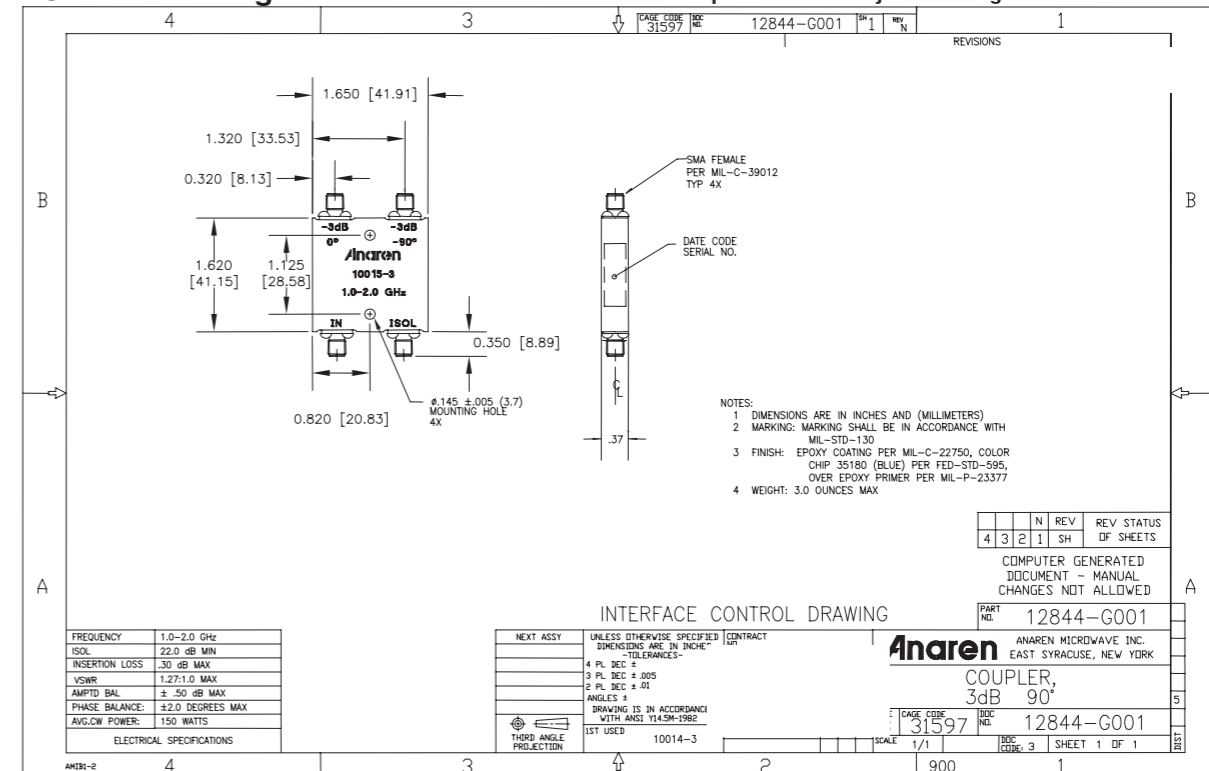
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 1H0565-3



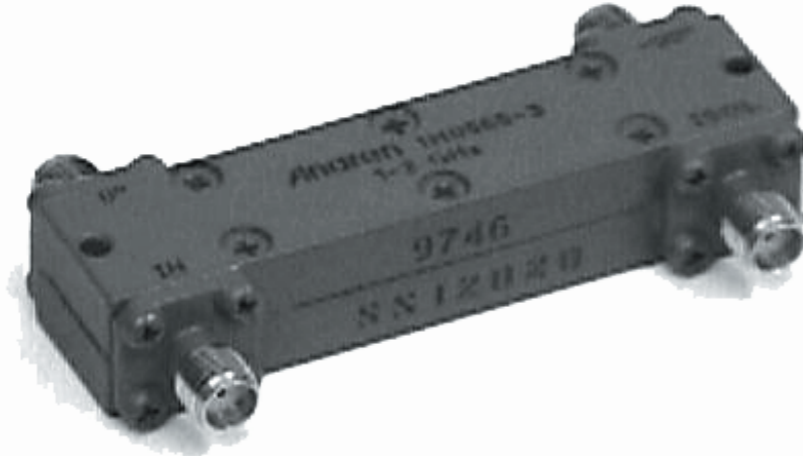
Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

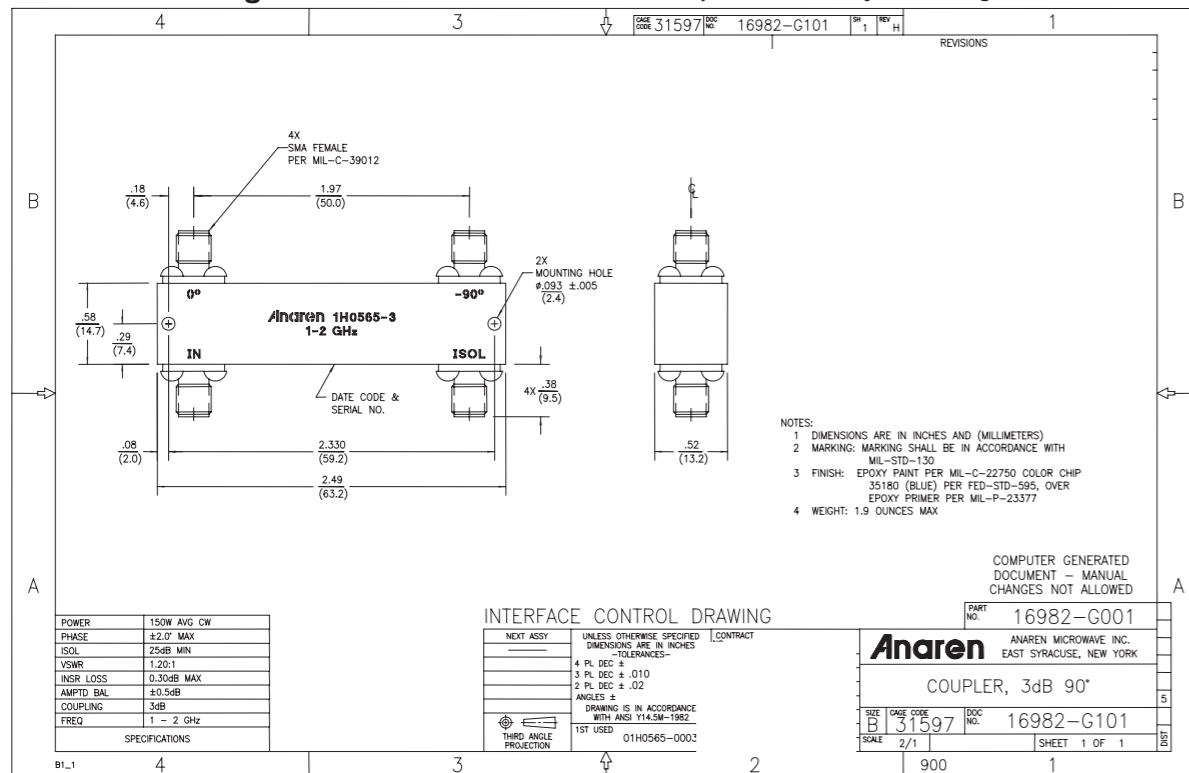
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 10025-3

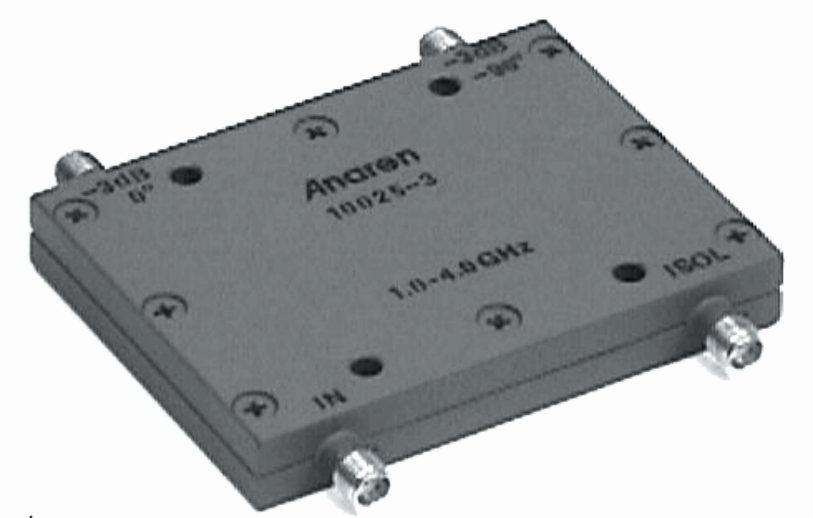
Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

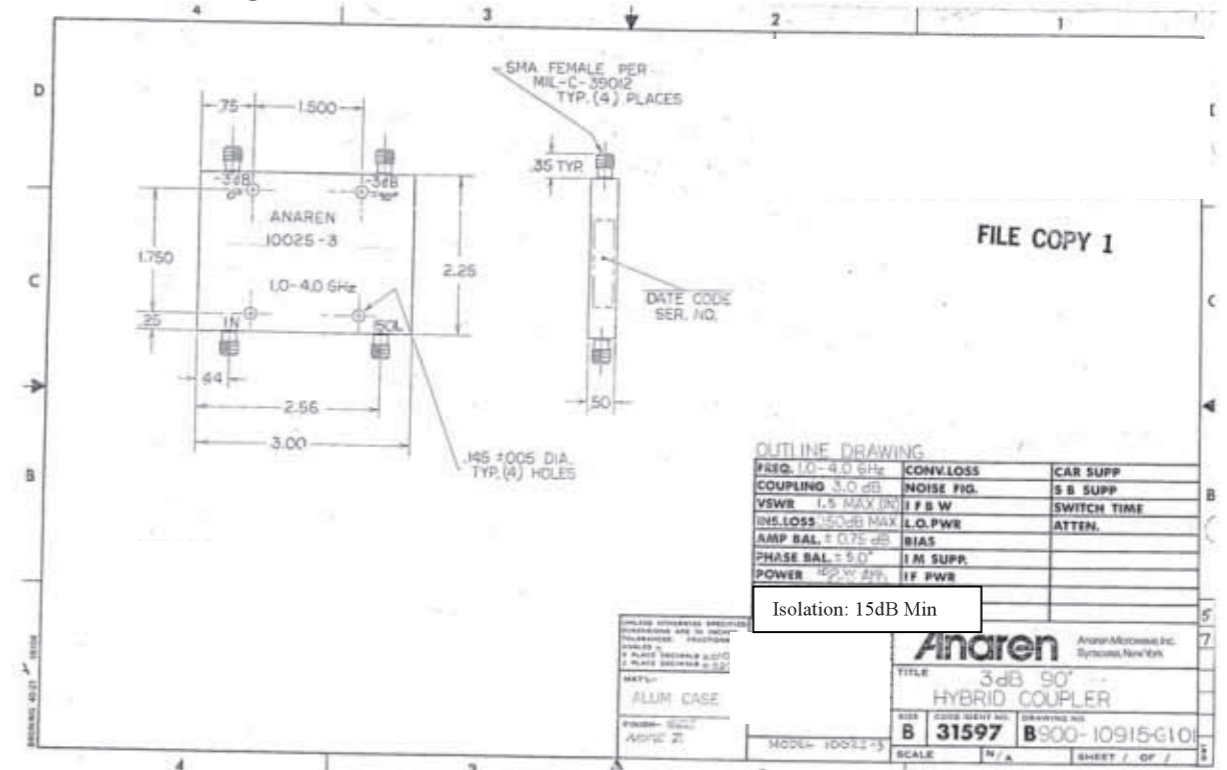
Features

- Military Grade
- 1.0 – 4.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 1J0560-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

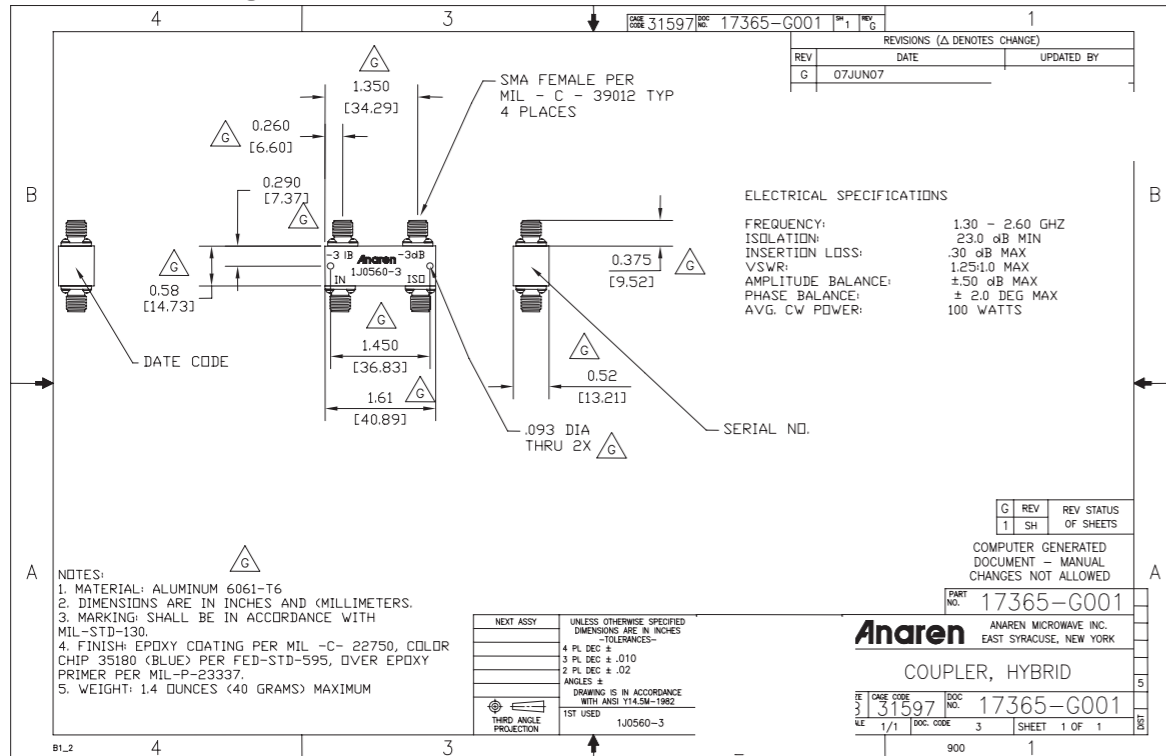
Features

- Military Grade
- 1.3 – 2.6 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 10040-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

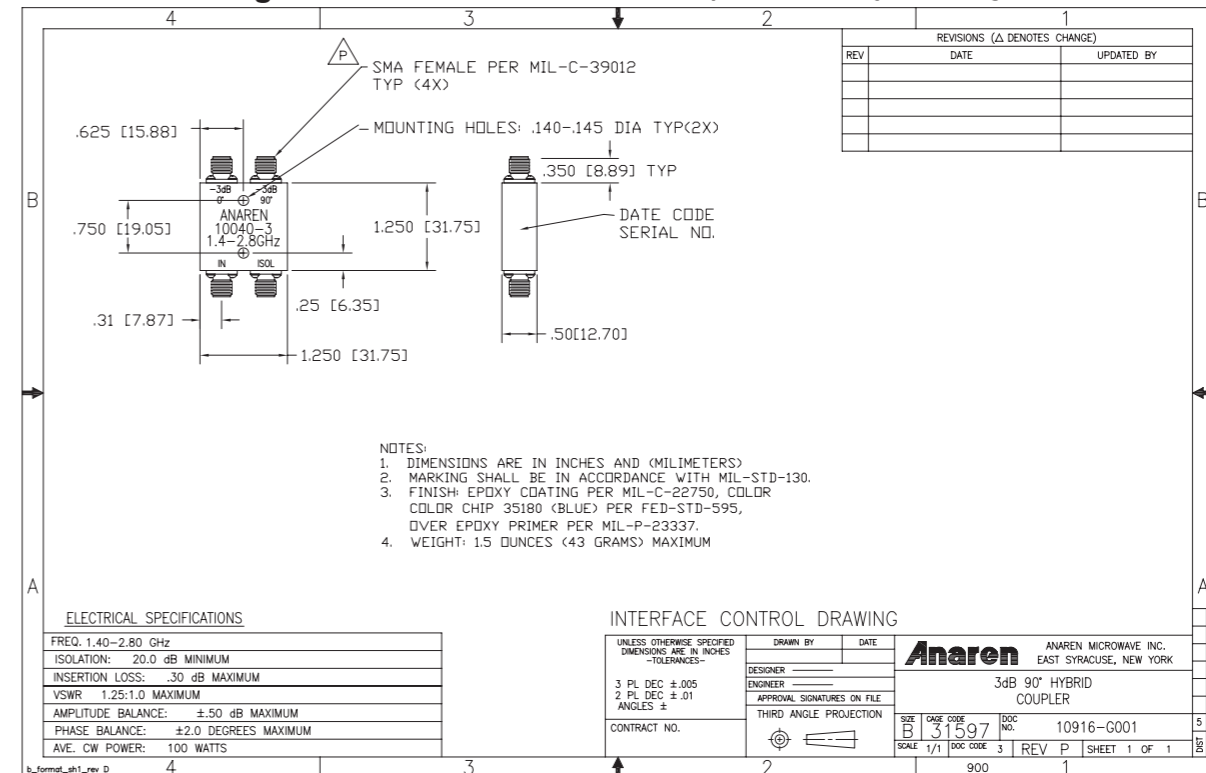
- Military Grade
- 1.4 – 2.8 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Photo shows protective connector caps

Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 10016-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 1H0566-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

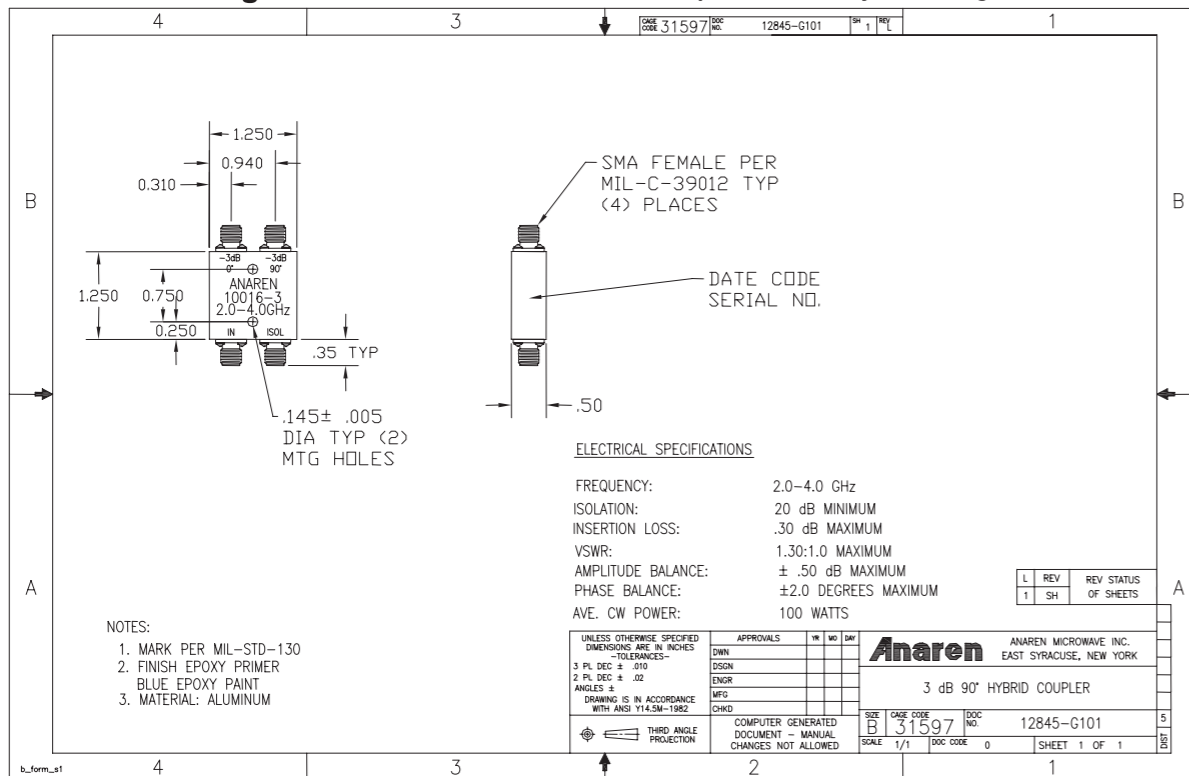
Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



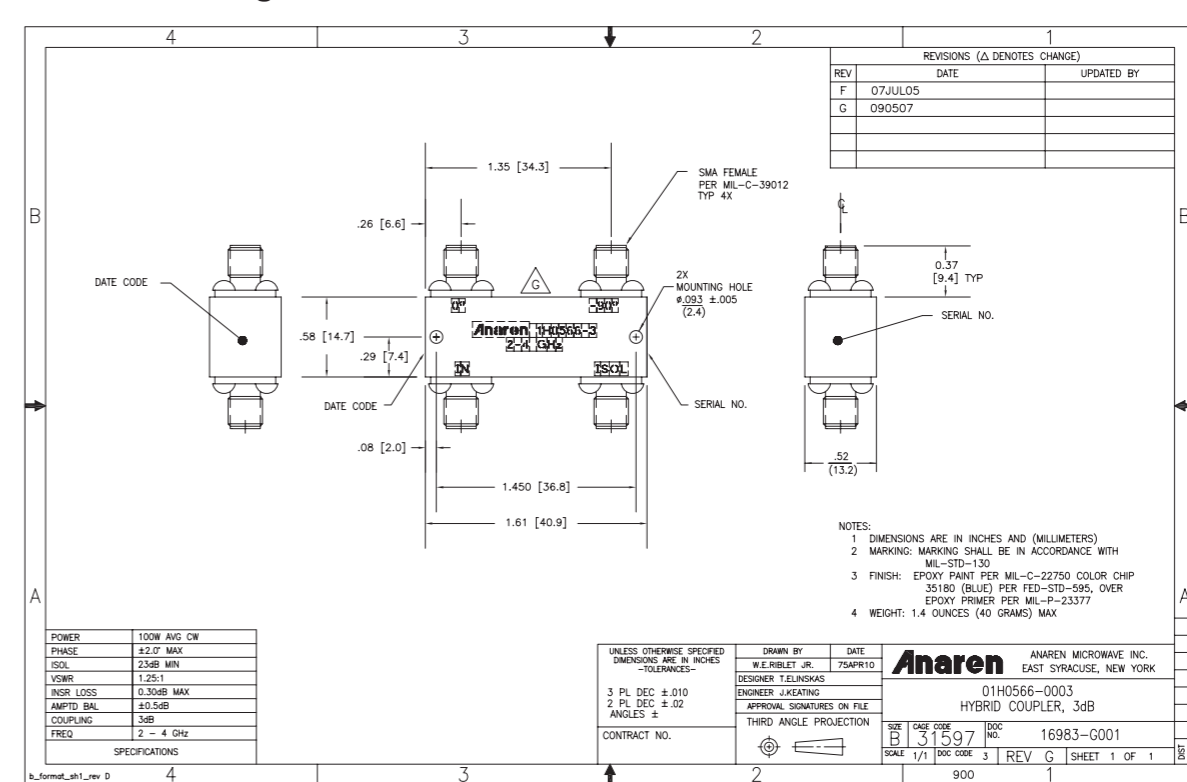
Outline Drawing

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Hybrid Couplers
3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Divider/Combiners



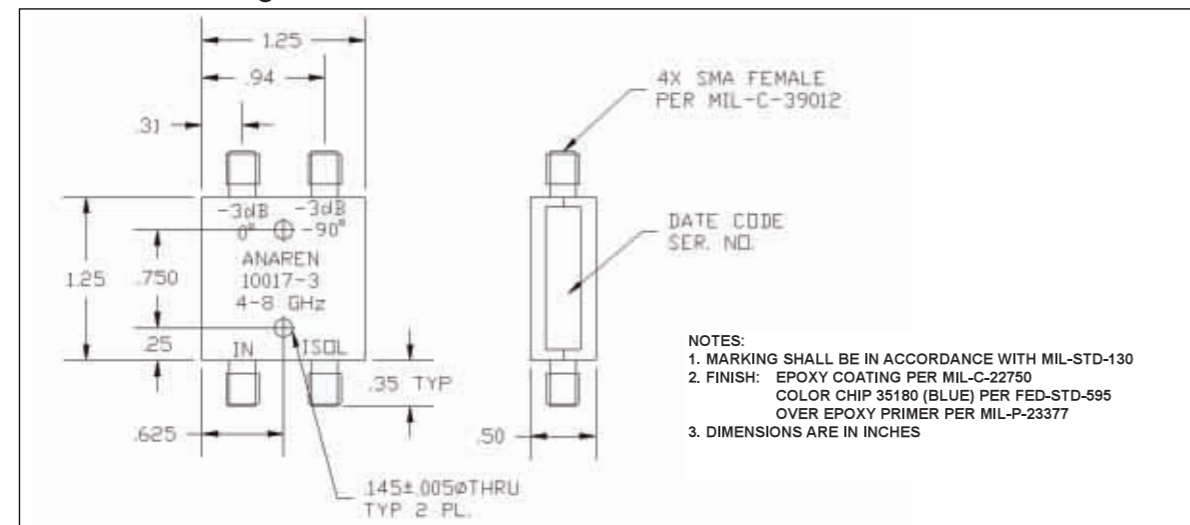
Features

- Military Grade
- 2-Way Power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR

Electrical Specifications			
Frequency GHz	Isolation dB Min/Typ	Insert. Loss dB Max	VSWR Max : 1
4.0 - 8.0	18/21	0.60	1.35
Amp. Bal. dB Max	Phase Bal. Degrees Max	Power Ave. CW Watts	
±0.50	±4.0	80	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class III requirements. Additional screening available for military and space applications.
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



- NOTES:
1. MARKING SHALL BE IN ACCORDANCE WITH MIL-STD-130
2. FINISH: EPOXY COATING PER MIL-C-22750
COLOR CHIP 35180 (BLUE) PER FED-STD-595
OVER EPOXY PRIMER PER MIL-P-23377
3. DIMENSIONS ARE IN INCHES

Hybrid Couplers
3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

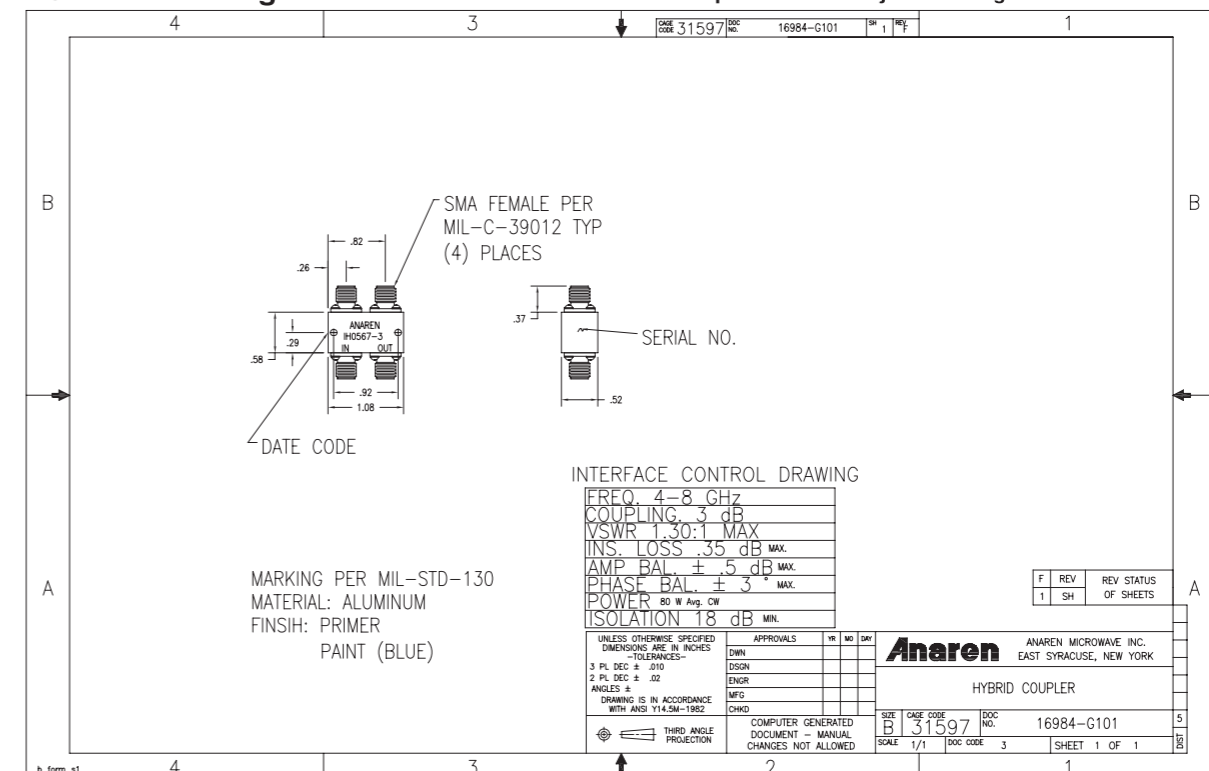
Features

- Military Grade
- 4.0 – 8.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



Model 10029-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

- Military Grade
- 4.5 – 18.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 1E0018-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

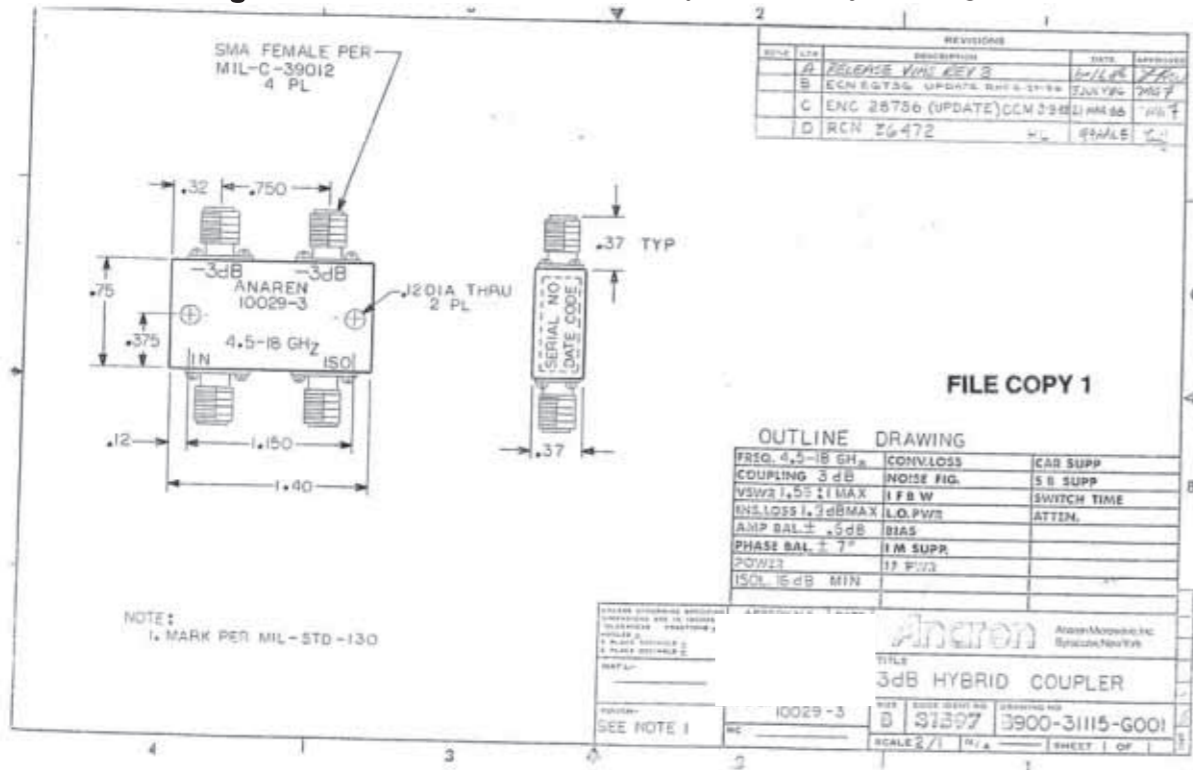
Features

- Military Grade
- 7.0 – 11.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



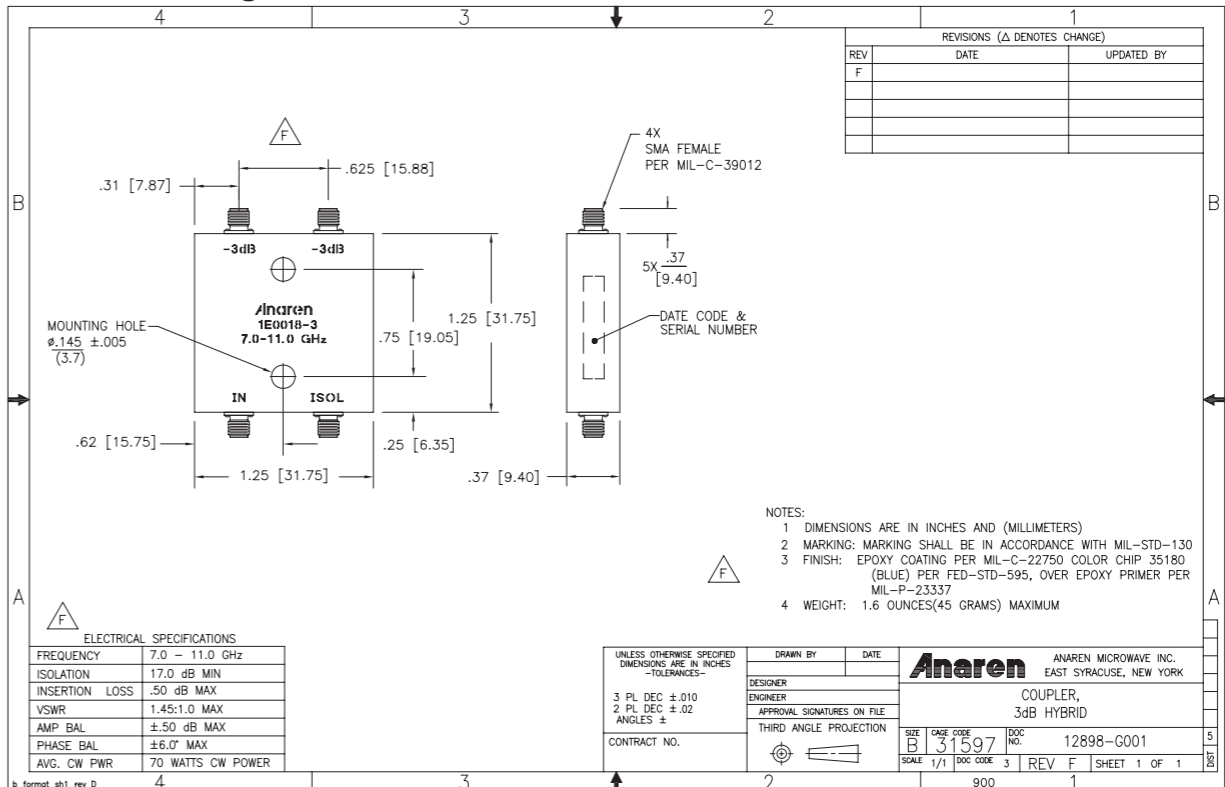
Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 1J0770-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

Features

- Military Grade
- 7.5 – 18.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 10018-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

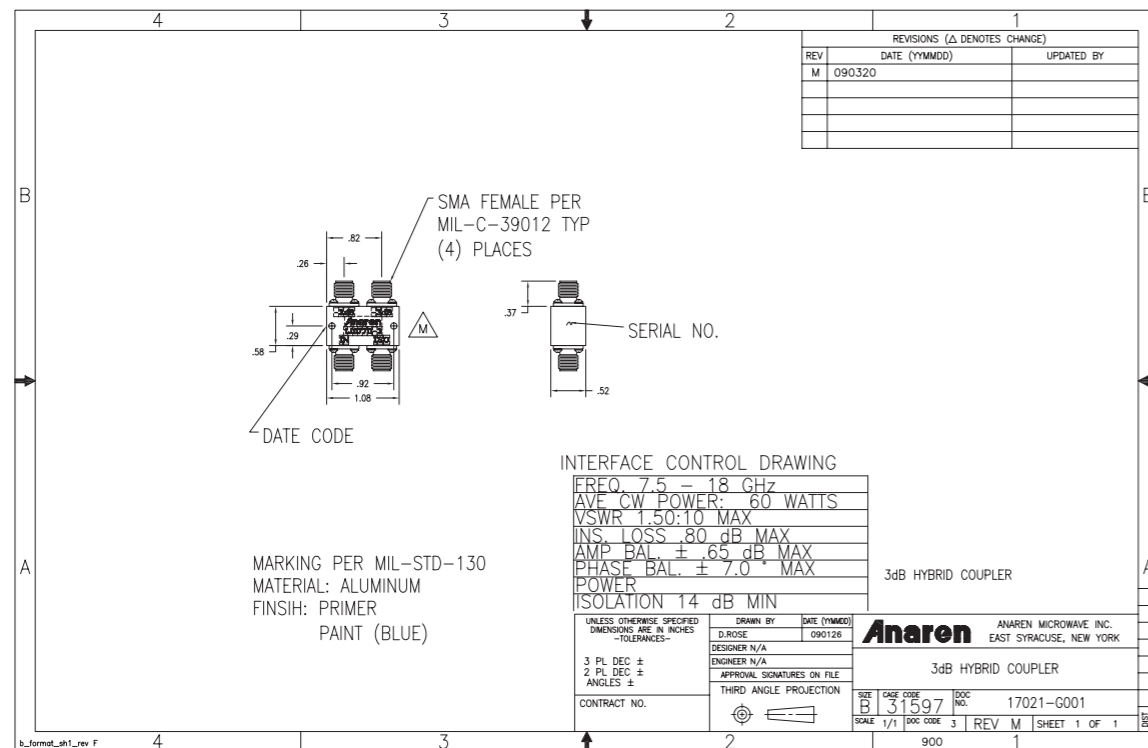
Features

- Military Grade
- 8.0 – 12.4 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



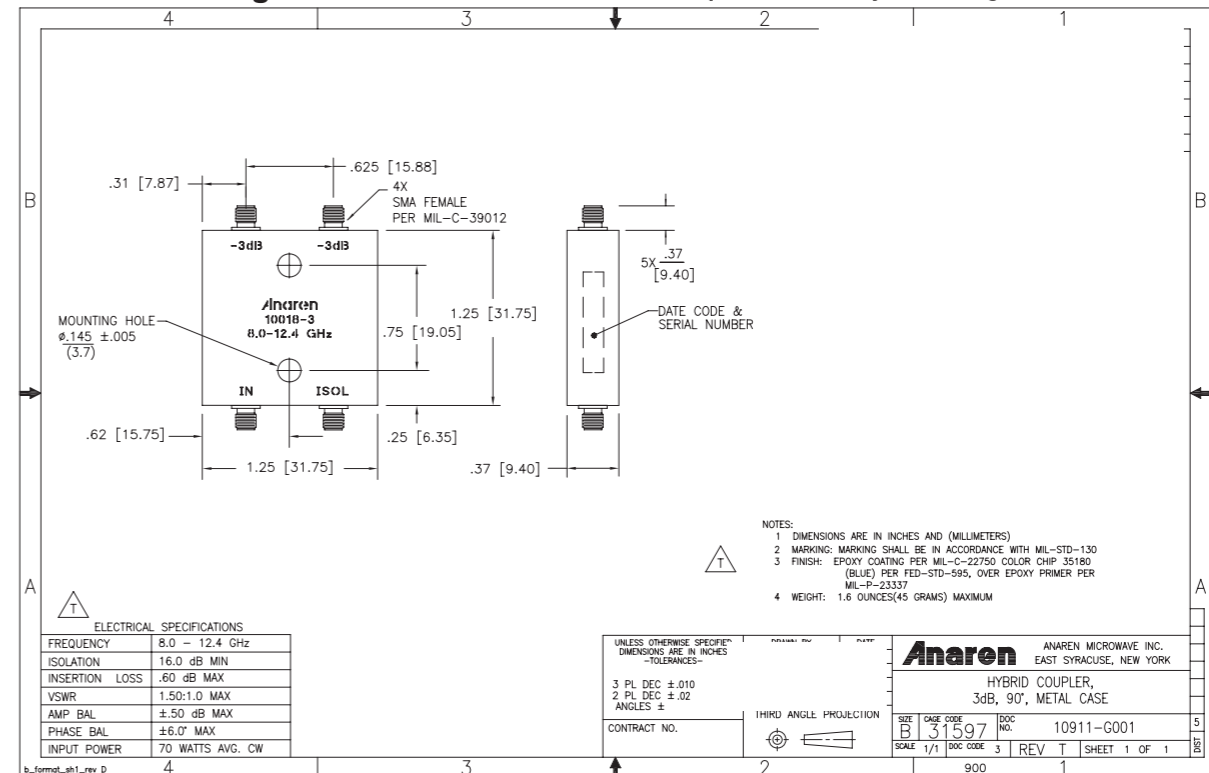
Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



Outline Drawing

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Model 1H0568-3



Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

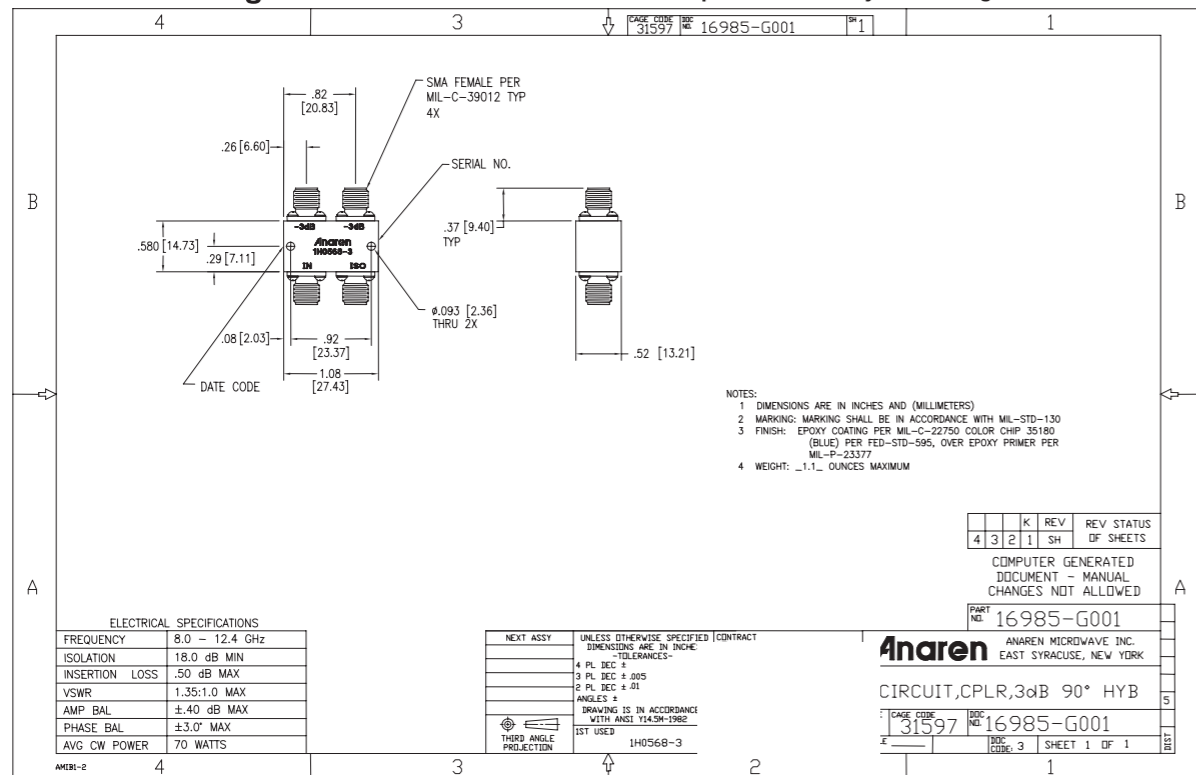
Features

- Military Grade
- 8.0 – 12.4 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 1H0569-3

Hybrid Couplers 3 dB, 90°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Phasing Networks
- Dividers/Combiners

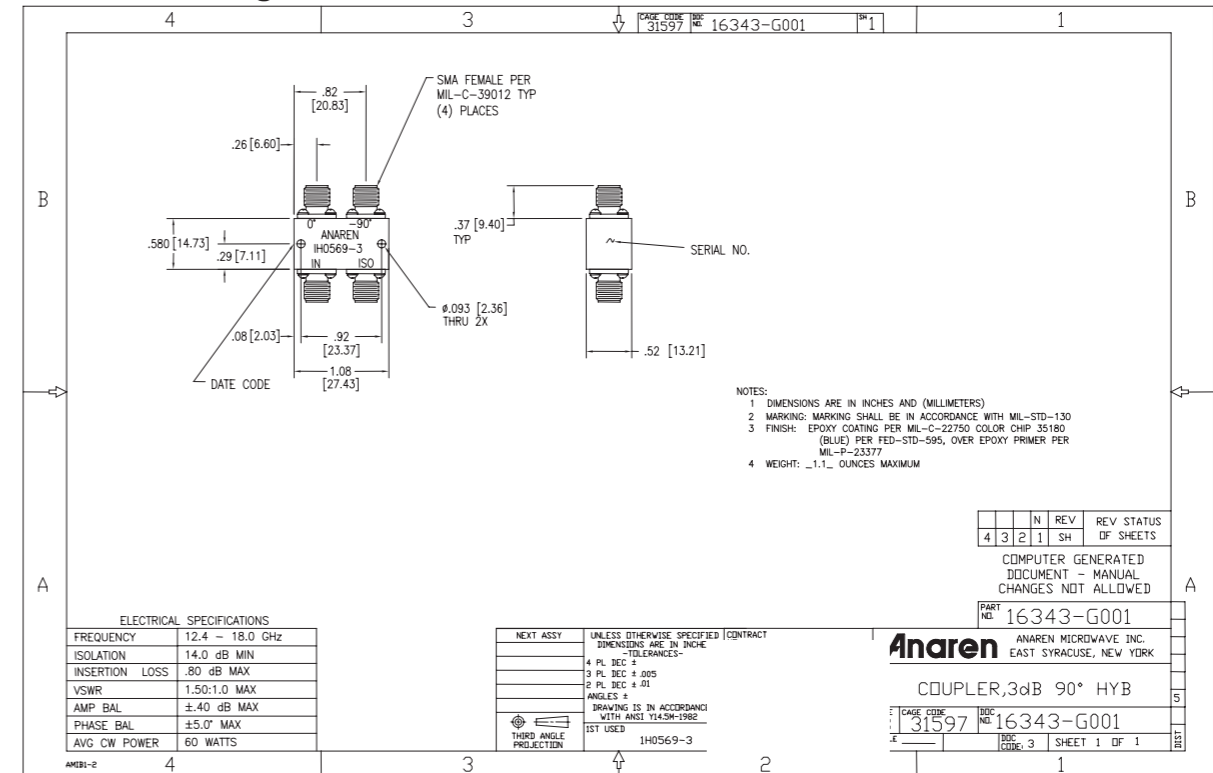
Features

- Military Grade
- 12.4 – 18.0 GHz
- 2-Way power Split
- Quadrature
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

Electrical and Mechanical Specifications subject to change without notice.



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Model 30054



Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

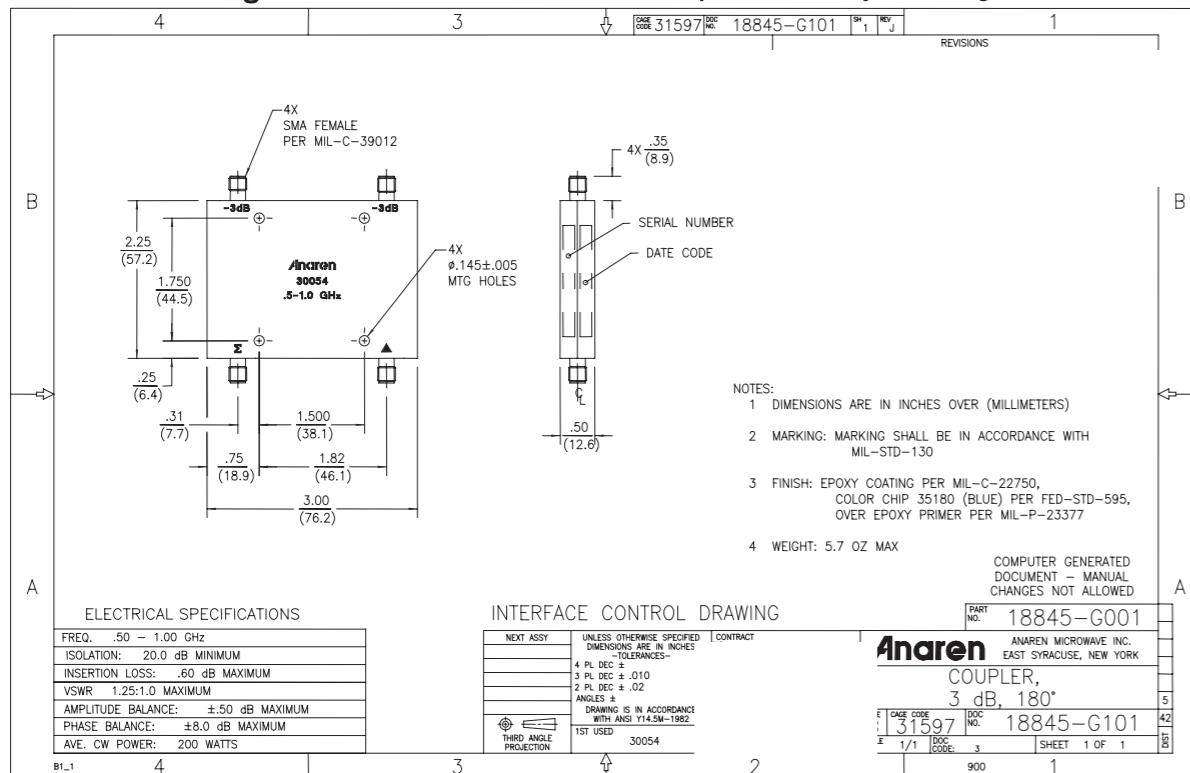
Features

- Military Grade
- 0.5 – 1.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 30110

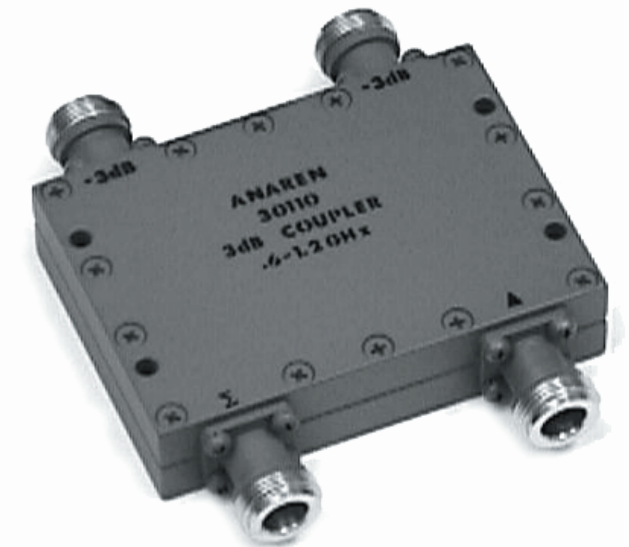
Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

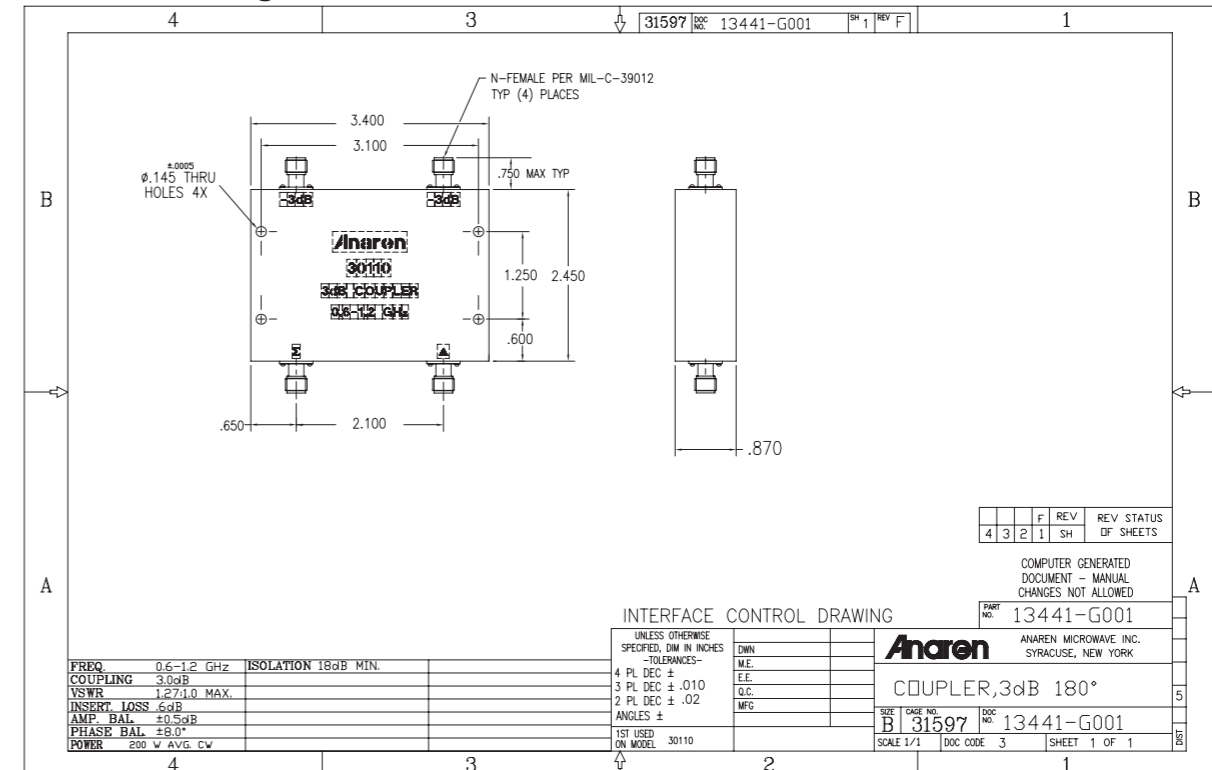
Features

- Military Grade
- 0.6 – 1.2 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 3A0055

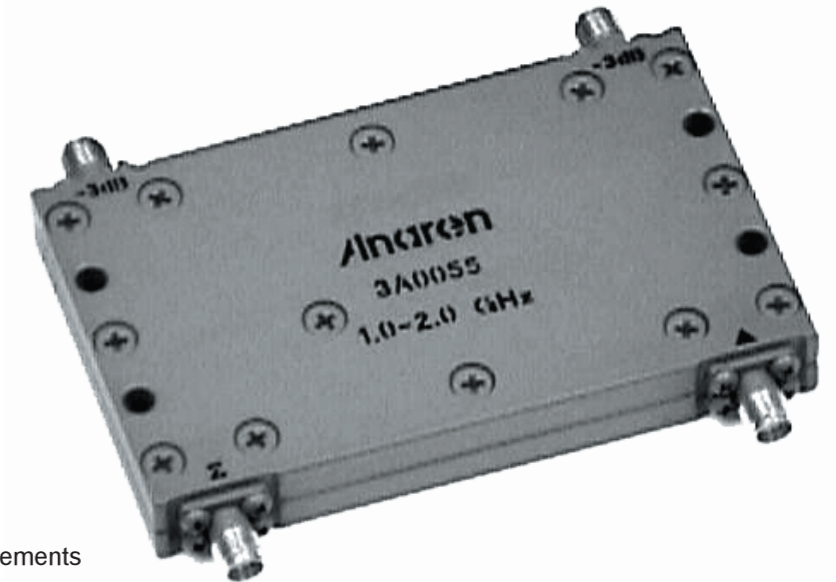
Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

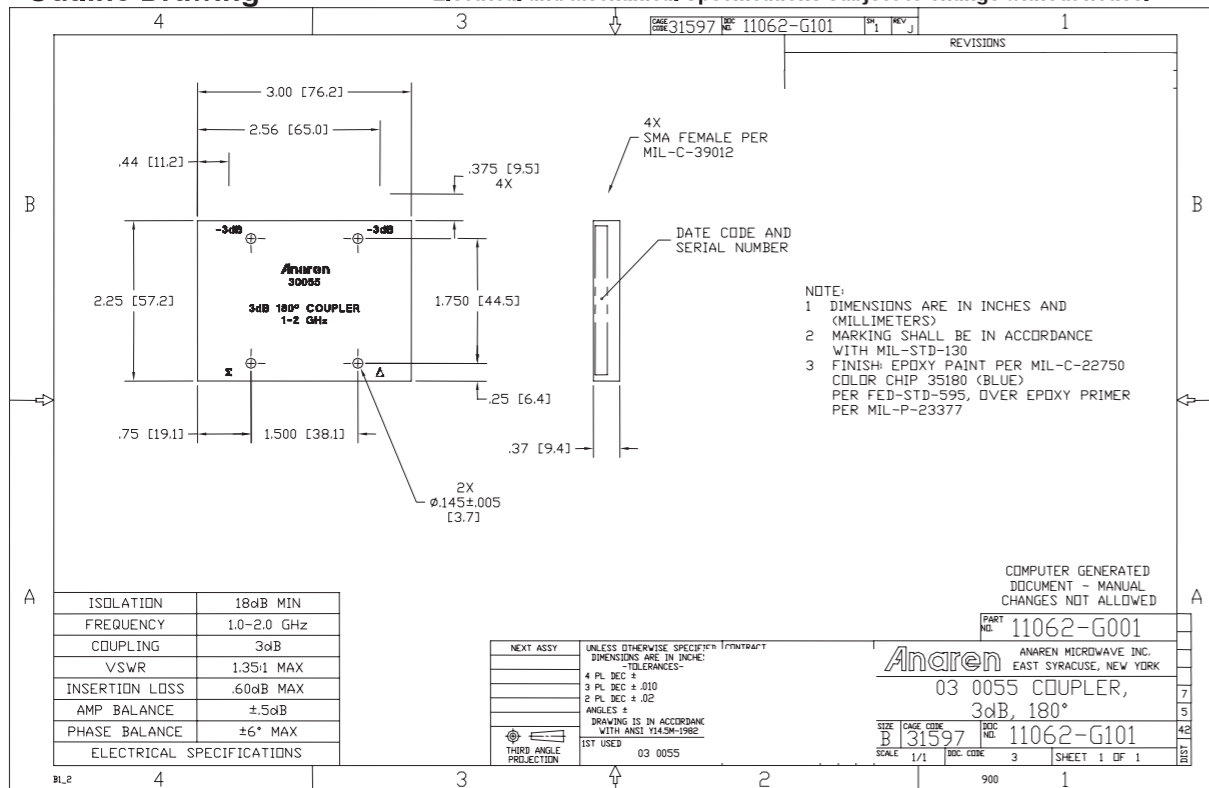
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



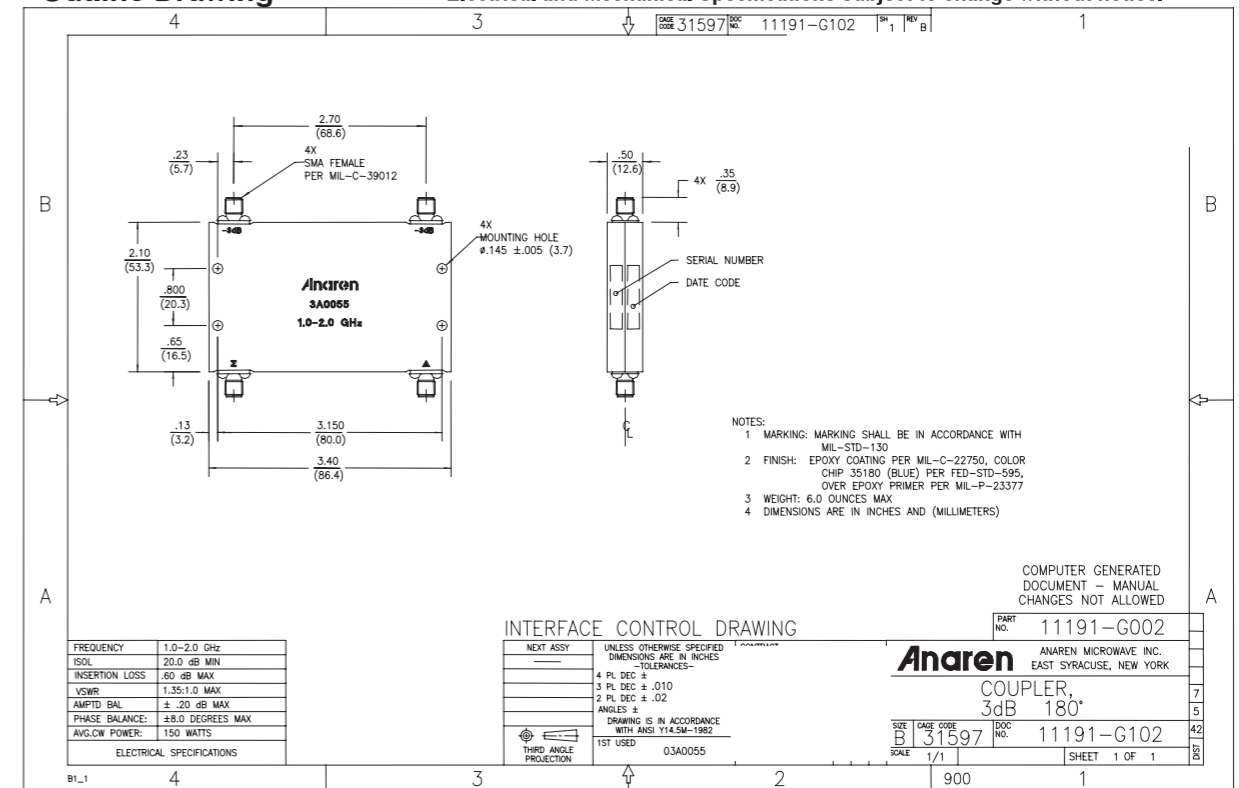
Outline Drawing

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Model 3A0200



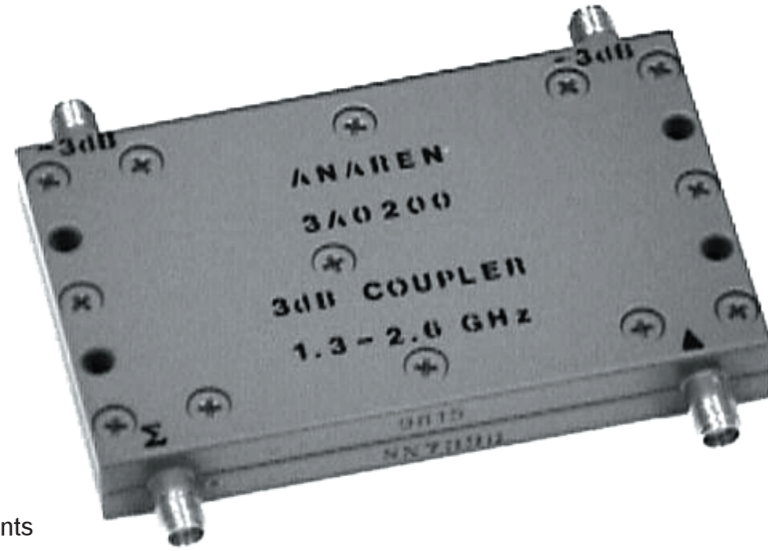
Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

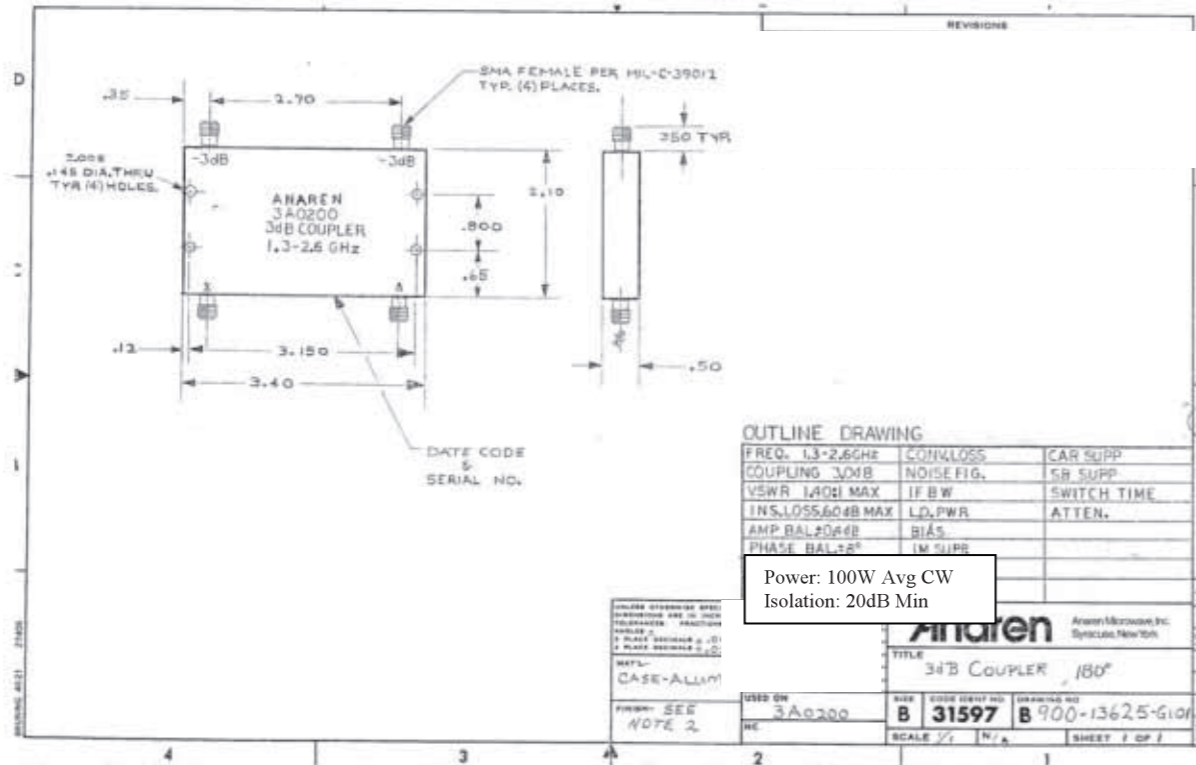
Features

- Military Grade
- 1.3 – 2.6 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 30056

Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

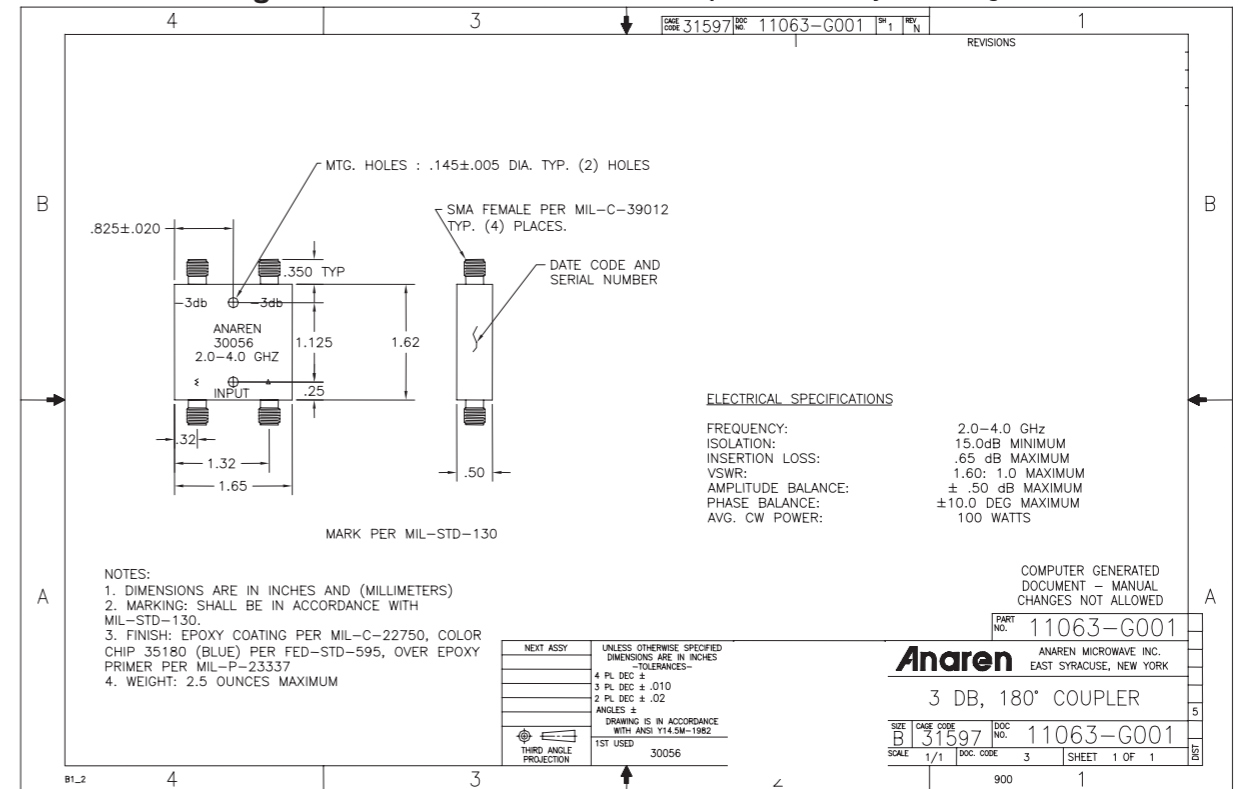
Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

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Model 3A0056



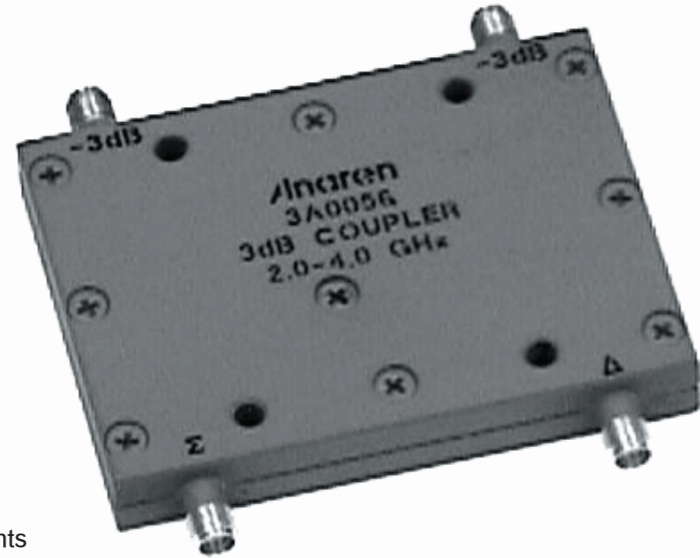
Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 30057

Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

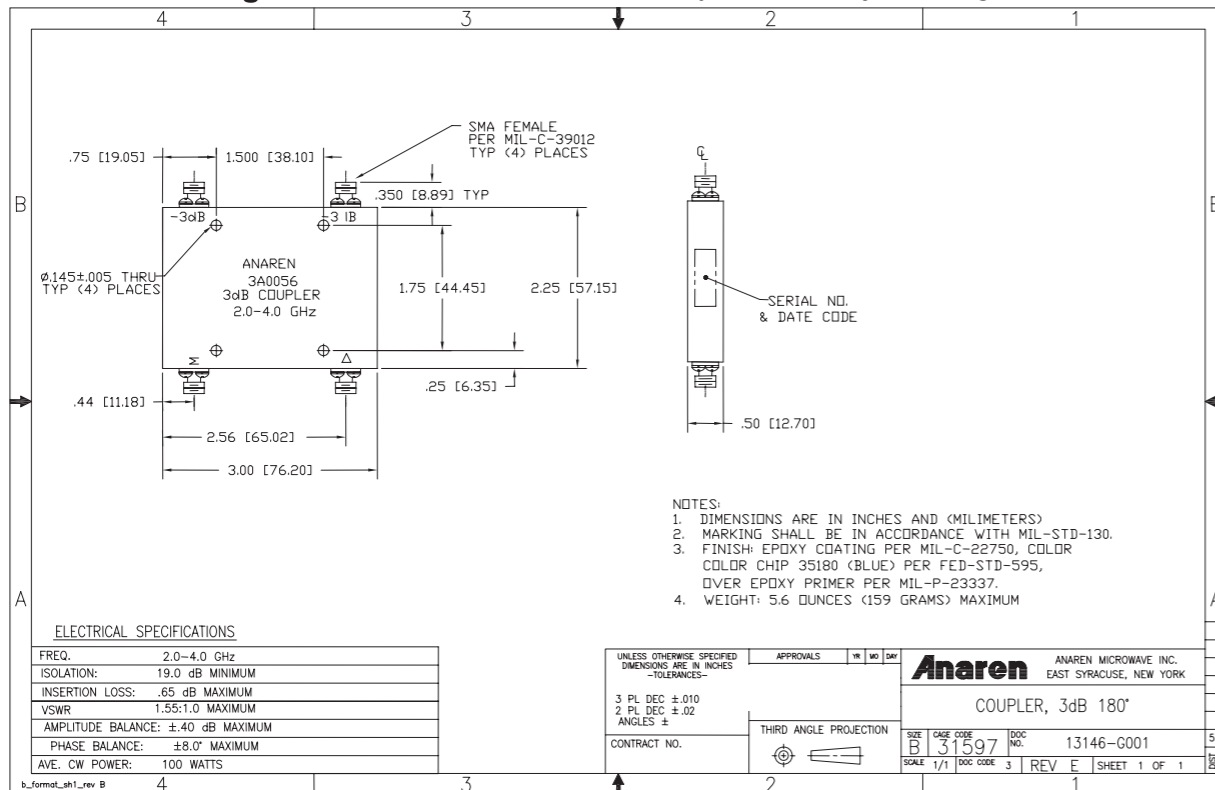
Features

- Military Grade
- 4.0 – 8.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



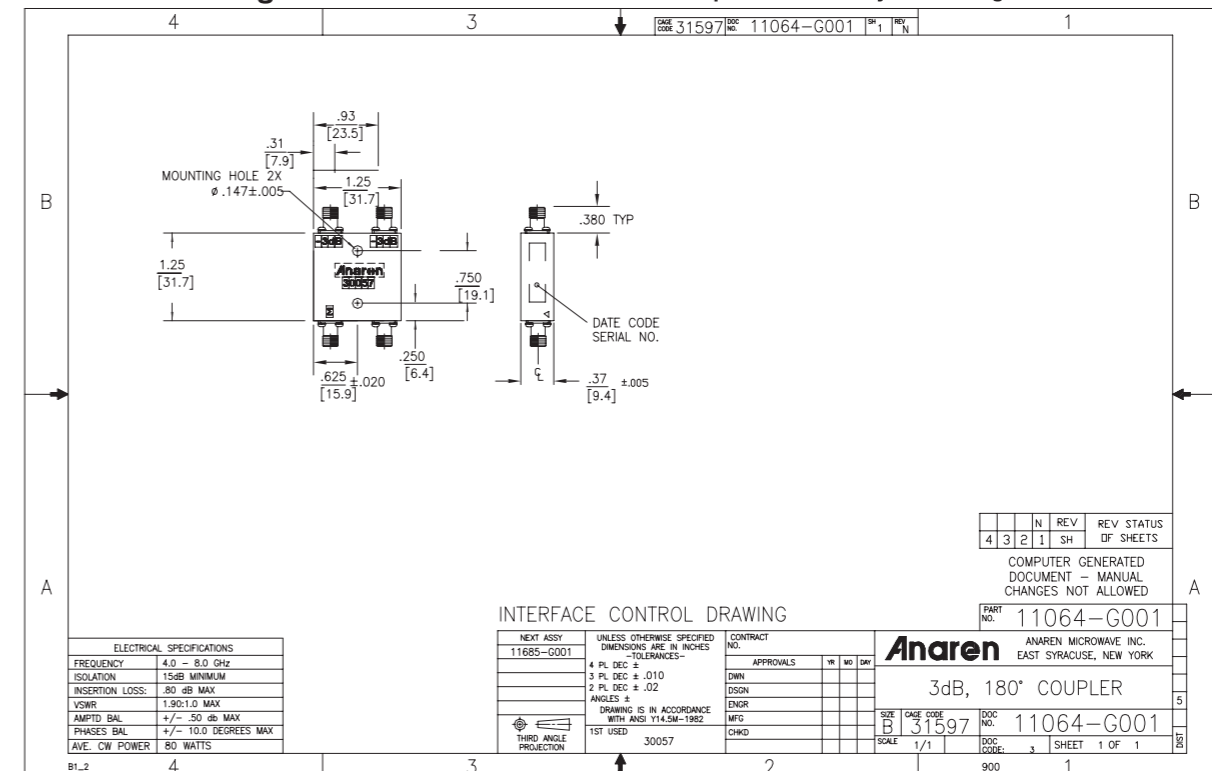
Outline Drawing

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Outline Drawing

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Model 30070



Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

Features

- Military Grade
- 6.0 – 18.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 30160

Hybrid Couplers 3 dB, 180°

Applications

- Balanced Mixers
- Antenna Feed Networks
- Image Reject Mixers
- Dividers/Combiners
- Single Sideband Modulators

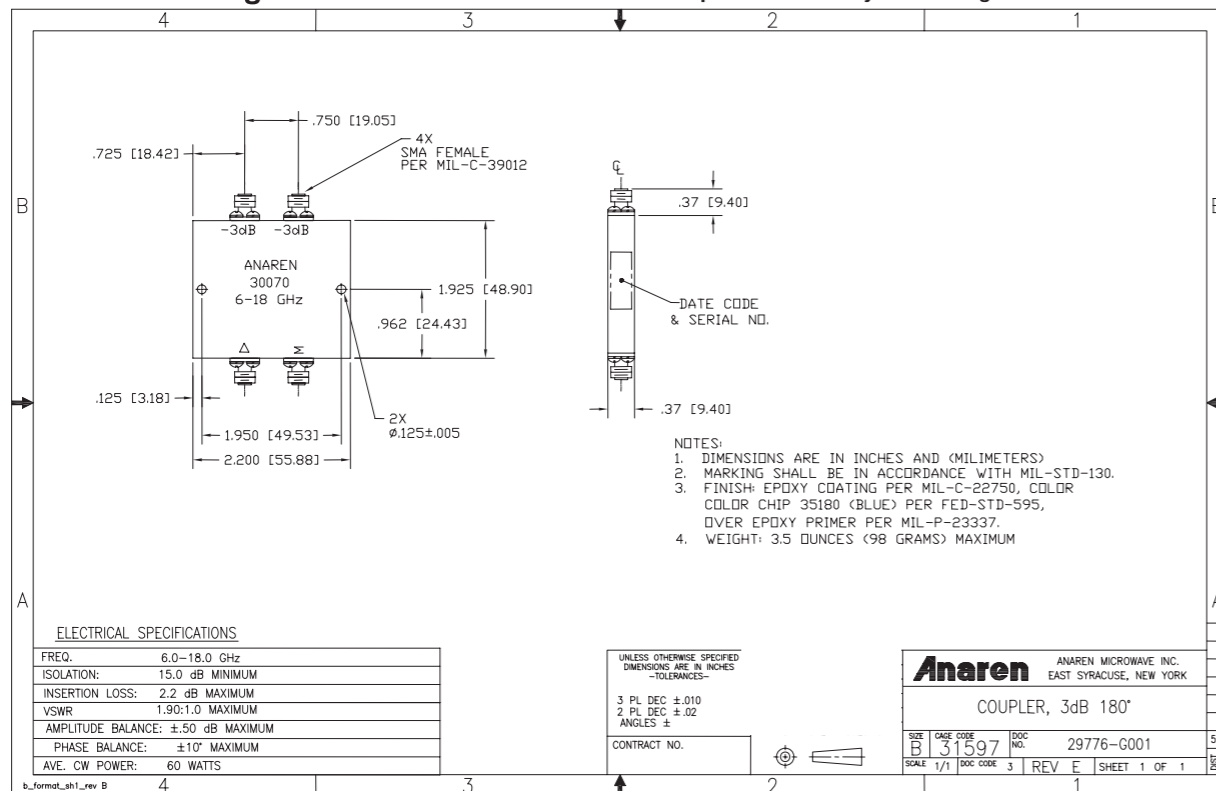
Features

- Military Grade
- 7.0 – 11.0 GHz
- 2-Way power Split
- 180 Degree
- Stainless Steel Connectors
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



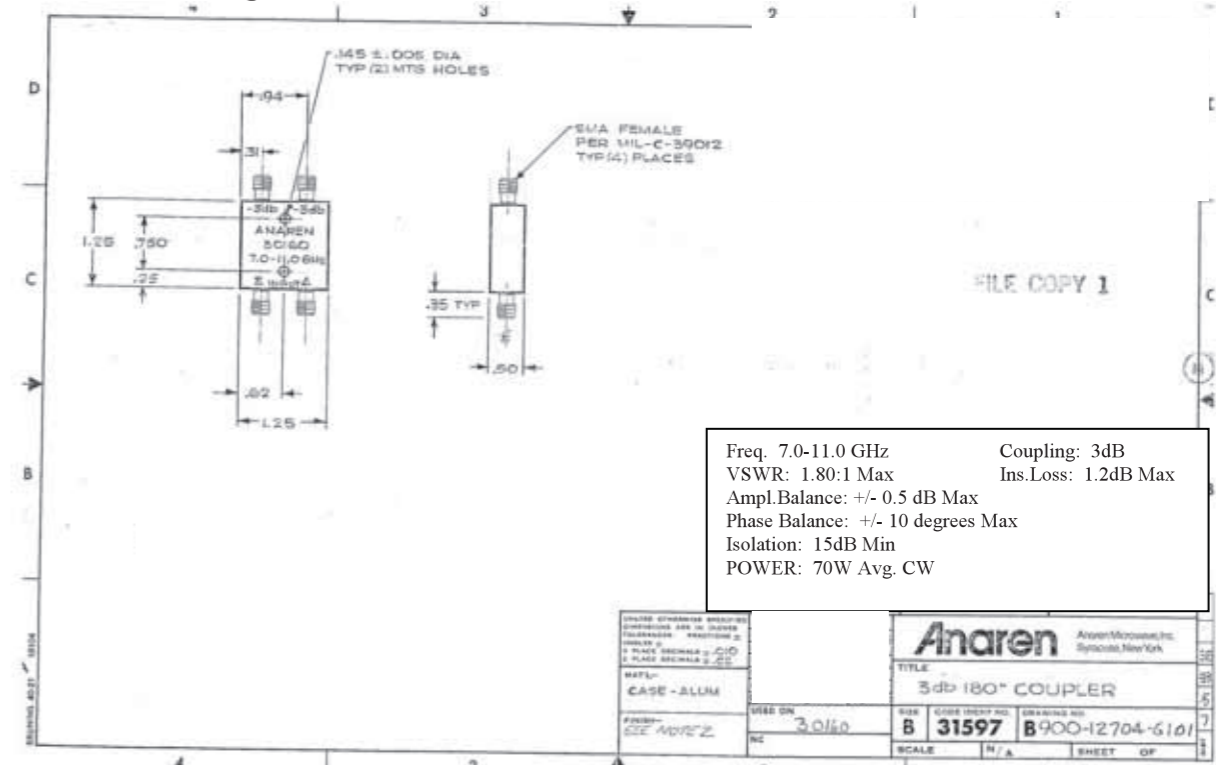
Outline Drawing

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Outline Drawing

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Combiners/Power Dividers Selection Matrix

Combiners/Dividers, no case									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Port Impedance (Ω)	Return Loss (VSWR)	Insertion Loss (dB)	Amplitude Balance (+/- dB)	Phase Balance (+/- °)	Isolation (dB)
40170	0.7 - 1.4	100	3 x 0.9	50	1.3	0.6	1	3	18
40600	0.965 - 1.565	100	3 x 0.9	50	1.3	0.6	0.9	3	20

Power Dividers, 2-way									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation (dB) Min	Insertion Loss (dB) Max	Input VSWR Max:1	Output VSWR Max:1	Amplitude Balance (dB) Max	Phase Balance (degrees) Max
40260	0.225 - 0.4	10	3.75 x 2.75	20	0.3	1.2	1.2	0.4	2
40263	0.25 - 0.5	10	3.75 x 2.75	20	0.3	1.2	1.2	0.4	2
42000	0.5 - 2.0	10	3.75 x 2.75	20	0.5	1.3	1.2	0.4	2
41620	0.5 - 3.0	10	1.75 x 3.75	15	0.75	1.6	1.6	0.4	8
41180	0.7 - 1.4	10	1.45 x 3	20	0.3	1.25	1.25	0.4	6
40255	1.0 - 2.0	10	3.92 x 2.65	20	0.3	1.3	1.3	0.4	4
40265	1.0 - 2.0	10	3.4 x 1.25	20	0.3	1.25	1.25	0.4	6
4J0265	1.0 - 2.0	10	3 x 1.45	20	0.3	1.25	1.25	0.4	6
40710	1.0 - 2.6	10	3.75 x 2.75	18	0.5	1.3	1.2	0.4	8
42010	1.0 - 4.0	10	1.4 x 1.5	18	0.5	1.35	1.2	0.4	3
40510	1.0 - 12.4	10	1.45 x 3	split specs	split specs	split specs	split specs	0.4	split specs
4E0265	1.5 - 3.0	10	3.4 x 1.25	20	0.3	1.25	1.25	0.4	6
40256	2.0 - 4.0	10	2.12 x 1	20	0.3	1.3	1.3	0.4	6
40266	2.0 - 4.0	10	1.25 x 2.1	20	0.3	1.3	1.3	0.4	6
4J0266	2.0 - 4.0	10	3 x 1.45	20	0.4	1.35	1.25	0.4	4
42020	2.0 - 8.0	10	1 x 1.5	split specs	split specs	split specs	split specs	0.4	split specs
41130	2.0 - 18.0	10	1.45 x 3	split specs	split specs	split specs	split specs	split specs	split specs
42100	2.0 - 18.0	10	1.575 x 1	split specs	split specs	split specs	split specs	split specs	split specs
4A0256	3.6 - 4.3	10	2 x 1.53	20	0.3	1.37	1.3	0.2	2
40267	4.0 - 8.0	10	1 x 1.5	18	0.7	1.6	1.6	0.4	6
42030	4.0 - 12.0	10	1 x 1	18	0.6	1.5	1.4	0.4	8
42040	6.0 - 18.0	10	1 x 0.75	17	split specs	split specs	split specs	0.5	10
41640	7.0 - 11.0	10	1 x 1.2	16	0.7	1.8	1.8	0.4	8
41690	7.0 - 18.0	10	1 x 1.2	split specs	split specs	split specs	split specs	split specs	split specs
40268	8.0 - 12.4	10	1 x 1.2	16	0.8	1.8	1.8	0.4	8
40269	12.4 - 18.0	10	1 x 1.2	14	1.2	2	2	0.5	10

Power Dividers, 3-way									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation (dB) Min	Insertion Loss (dB) Max	Input VSWR Max:1	Output VSWR Max:1	Amplitude Balance (dB) Max	Phase Balance (degrees) Max
43000	0.5 - 2.0	10	5.53 x 0.95	split specs	0.5	split specs	split specs	split specs	3
43020	2.0 - 6.0	10	0.95 x 2.4	17	0.5	1.4	1.5	0.3	6
43040	6.0 - 18.0	10	1 x 1.51	split specs	split specs	split specs	split specs	split specs	split specs

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Combiners/Power Dividers Selection Matrix

Power Dividers, 4-way									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation (dB) Min	Insertion Loss (dB) Max	Input VSWR Max:1	Output VSWR Max:1	Amplitude Balance (dB) Max	Phase Balance (degrees) Max
44000	0.5 - 2.0	17	2.4 x 4	20	1	1.5	1.3	0.6	6
40275	1.0 - 2.0	17	3.2 x 2.85	20	0.6	1.35	1.35	0.6	6
44010	1.0 - 4.0	17	2.4 x 2	18	1	1.5	1.35	0.6	6
40276	2.0 - 4.0	17	2.8 x 2.4	18	0.6	1.35	1.35	0.6	6
44020	2.0 - 8.0	17	2 x 1.75	16	1.2	1.55	1.45	0.6	6
44100	2.0 - 18.0	17	2 x 1.75	split specs	split specs	split specs	split specs	split specs	split specs
4A0456	3.6 - 4.3	17	4 x 2.75	20	0.5	1.37	1.3	0.2	3
44040	6.0 - 18.0	17	2 x 1.03	17	1.6	1.78	1.5	0.6	12
4A0279	7.0 - 18.0	17	2.5 x 2	14	2	*	2.2	2	1
40278	8.0 - 12.4	17	2.5 x 2	16	1.2	1.85	1.85	0.8	12
40279	12.4 - 18.0	17	2.5 x 2	14	2	2	2	0.8	24

Power Dividers, 8-way									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation (dB) Min	Insertion Loss (dB) Max	Input VSWR Max:1	Output VSWR Max:1	Amplitude Balance (dB) Max	Phase Balance (degrees) Max
4A0286	2.0 - 4.0	25	5.2 x 2.5	18	1	1.6	1.4	0.8	10
41730	2.0 - 18.0	25	5.2 x 5	split specs	split specs	2.5	2.5	split specs	20
40287	4.0 - 8.0	25	5.2 x 2.5	17	2	2	1.5	1	12
4A0857	5.7 - 6.5	25	8 x 1.75	20	0.8	1.4	1.3	0.4	6
40288	7.0 - 12.4	25	5.2 x 2.5	15	2	2	1.7	1	16



Model 40170

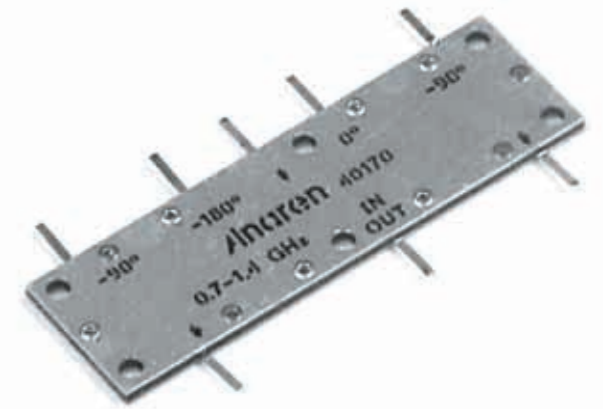
Combiner/Dividers 4 - Way

Applications

- Microstrip Circuits
- LO Networks
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

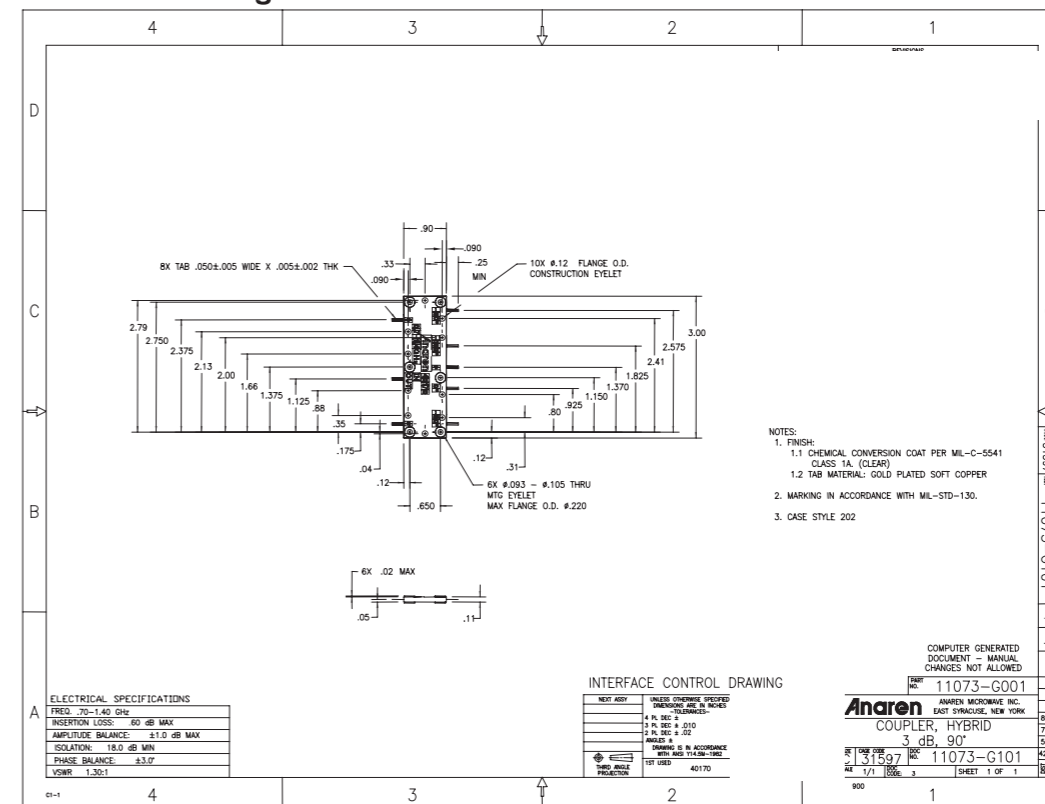
Features

- 0.7 - 1.4 GHz
- 4 - Way Power Split
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Testing is done at ambient temperature only. Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 40600



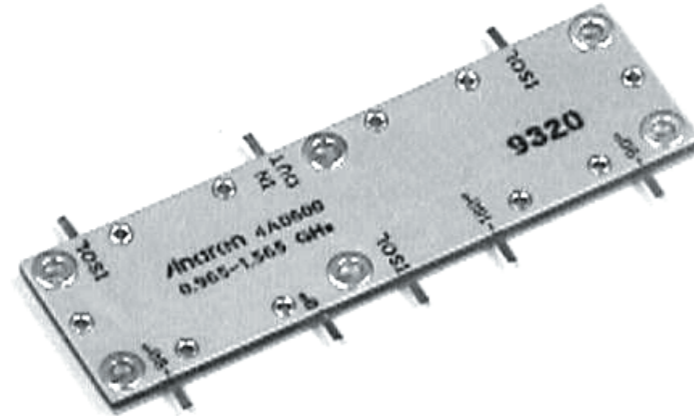
Combiner/Dividers 4 - Way

Applications

- Microstrip Circuits
- LO Networks
- Dividers/Combiners
- Switch Networks
- Balanced Detectors
- Antenna Feeds

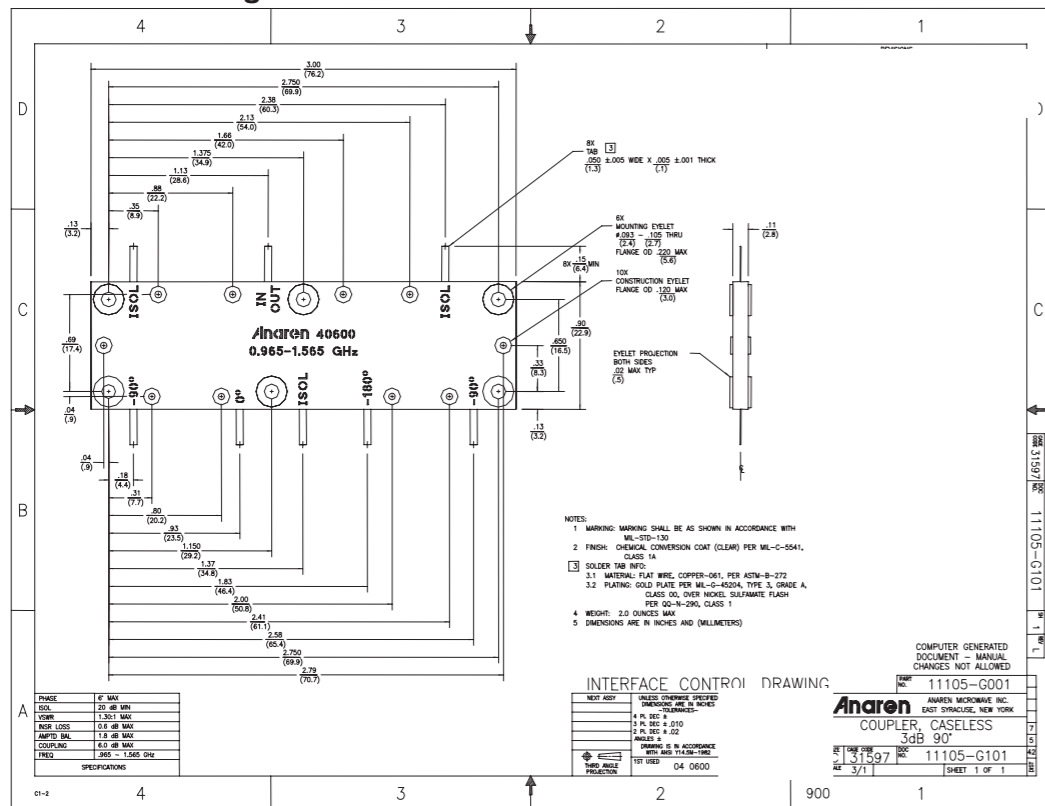
Features

- 0.965 – 1.565 GHz
- 4 – Way Power Split
- Reliable Performance
- Handles 100 Watts
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Anaren Power rating applies when solder tab/coupler interface has been conformally coated. Testing is done at ambient temperature only. Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 40260

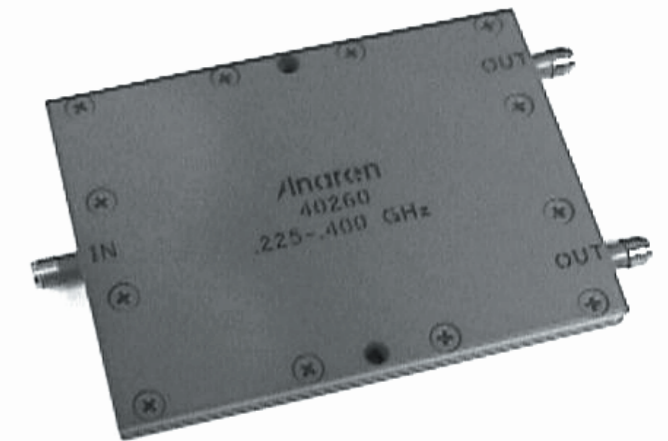
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

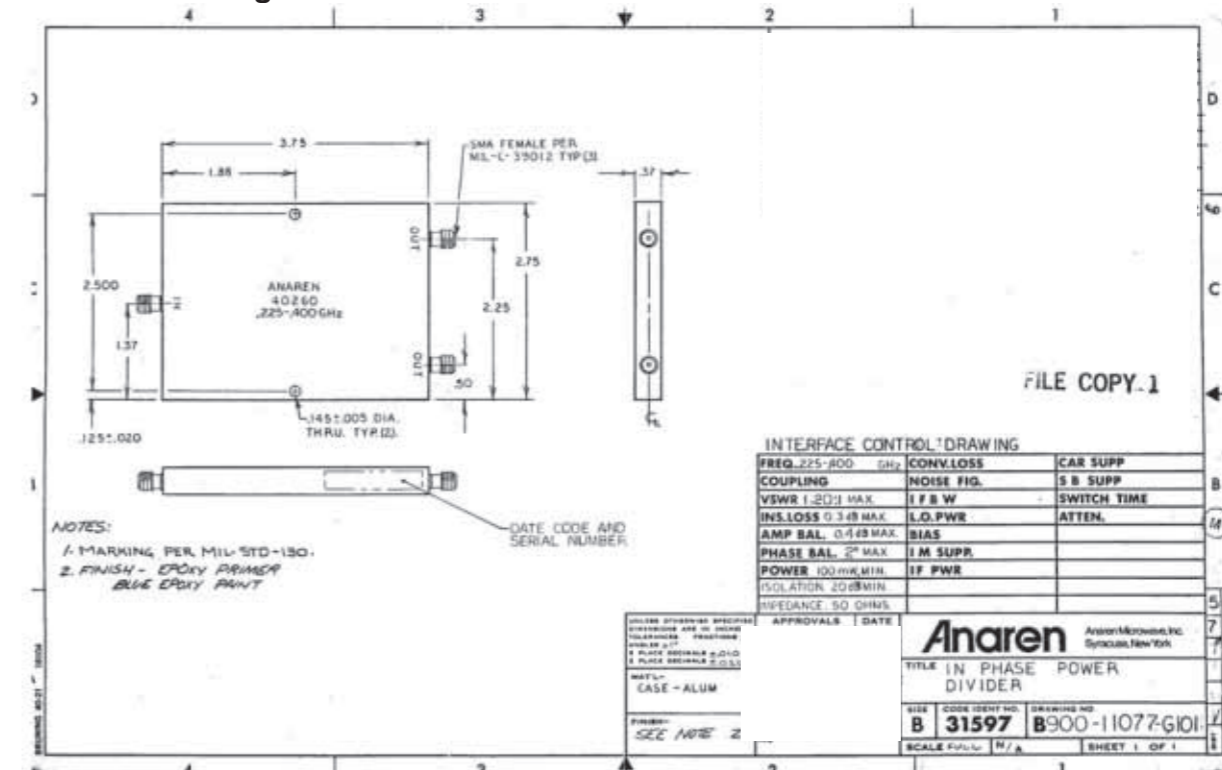
Features

- Military Grade
- 0.225 – 0.4 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 40263



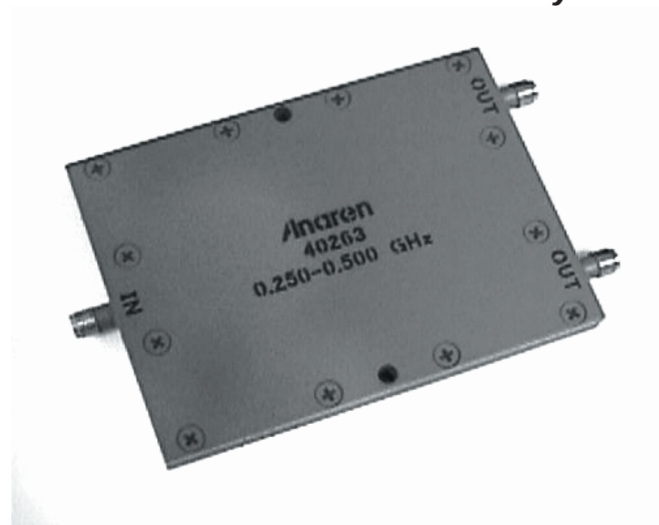
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

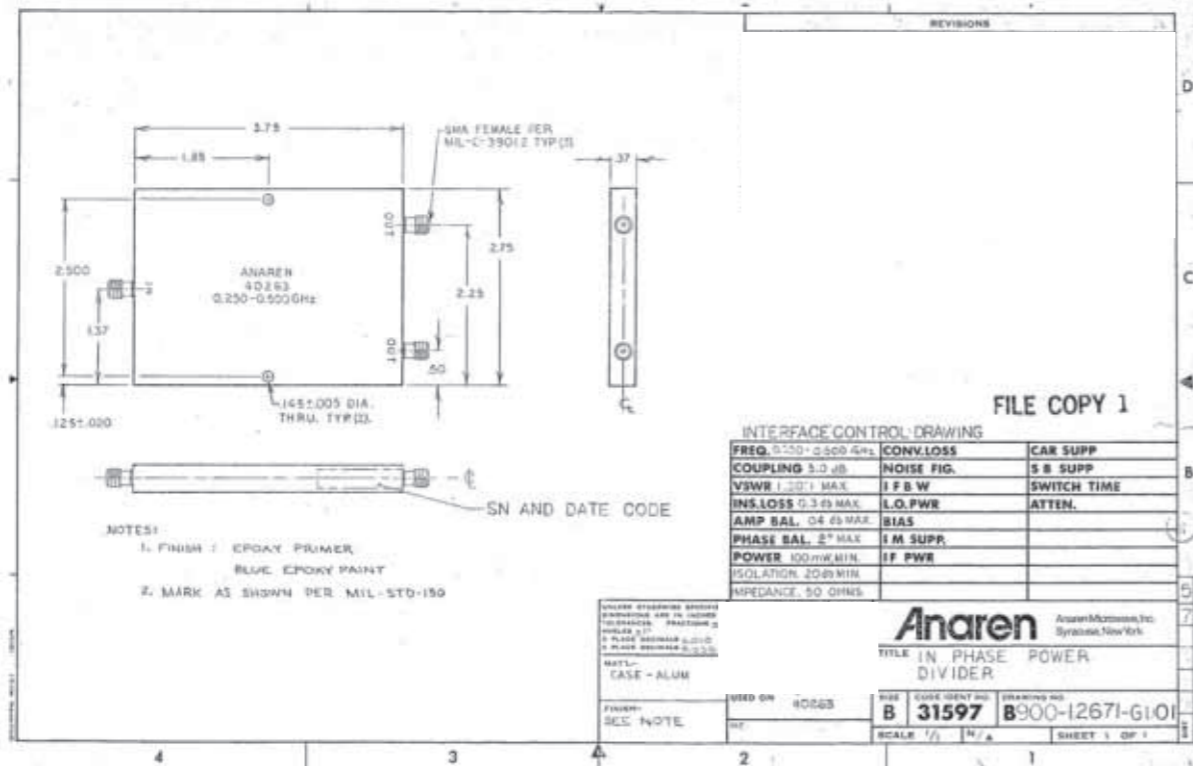
Features

- Military Grade
- 0.25 – 0.5 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 42000

Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

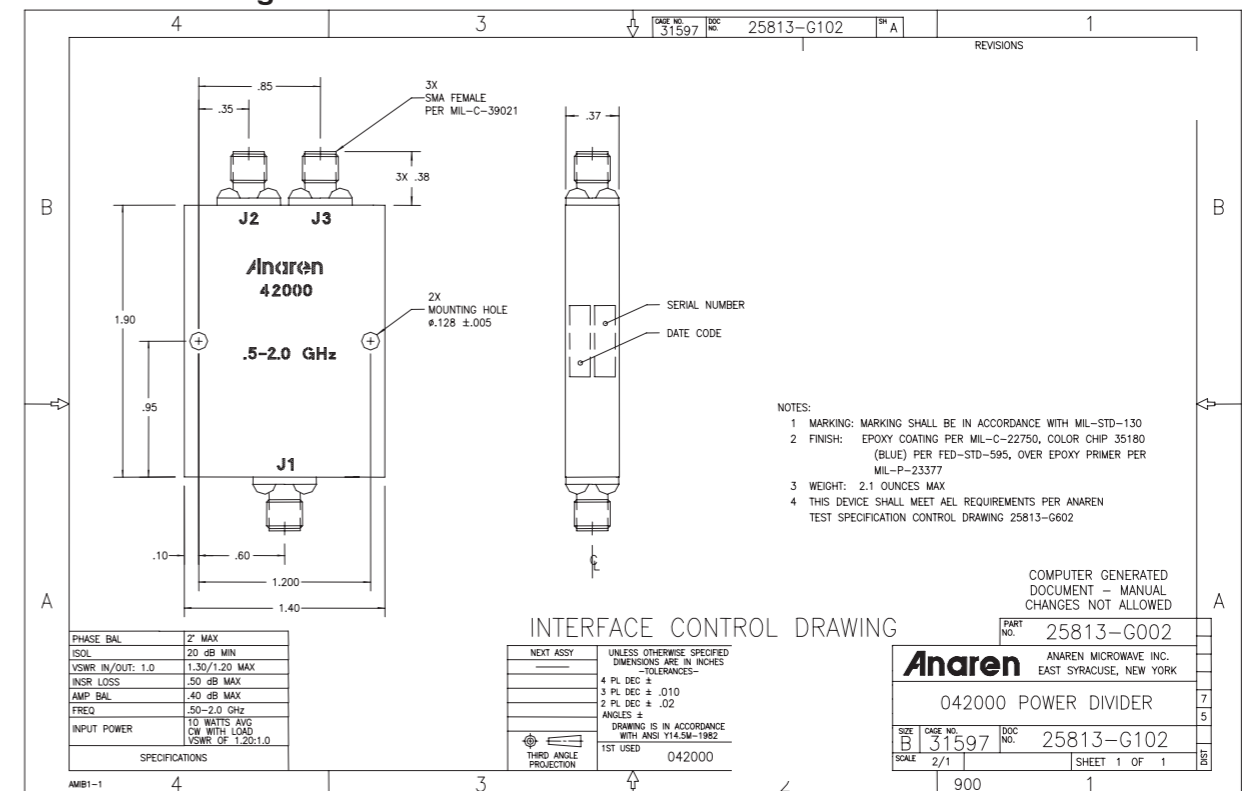
Features

- Military Grade
- 0.5 – 2.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



- NOTES:
- 1 MARKING: MARKING SHALL BE IN ACCORDANCE WITH MIL-STD-130
 - 2 FINISH: EPOXY COATING PER MIL-C-22750, COLOR CHIP 35180 (BLUE) PER FED-STD-595, OVER EPOXY PRIMER PER MIL-P-23377
 - 3 WEIGHT: 2.1 OUNCES MAX
 - 4 THIS DEVICE SHALL MEET AEL REQUIREMENTS PER ANAREN TEST SPECIFICATION CONTROL DRAWING 25813-G002

COMPUTER GENERATED DOCUMENT - MANUAL CHANGES NOT ALLOWED

PART NO. 25813-G002
ANAREN MICROWAVE INC.
EAST SYRACUSE, NEW YORK

042000 POWER DIVIDER

SIZE CASE NO. 31597 DOC NO. 25813-G102
SCALE 2/1 SHEET 1 OF 1

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Model 41620



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

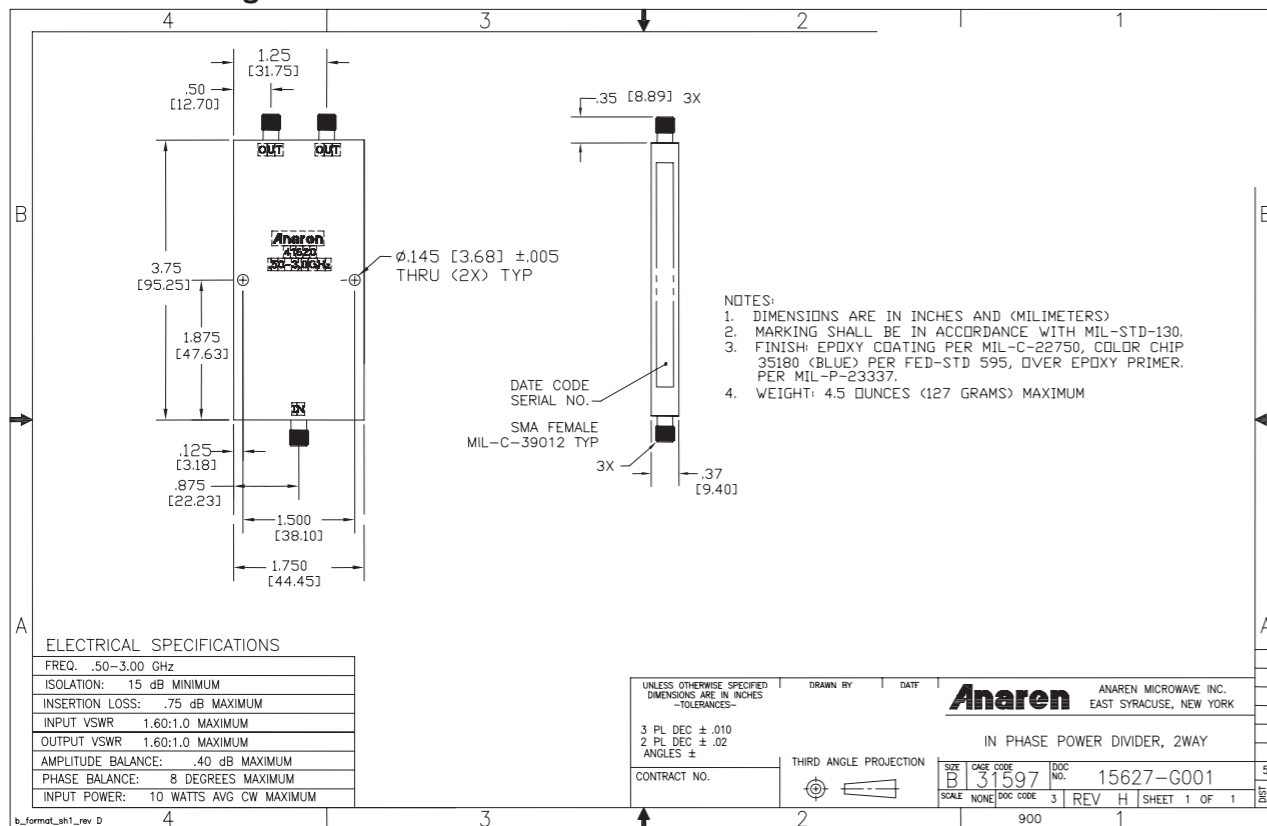
Features

- Military Grade
- 0.5 – 3.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 41180

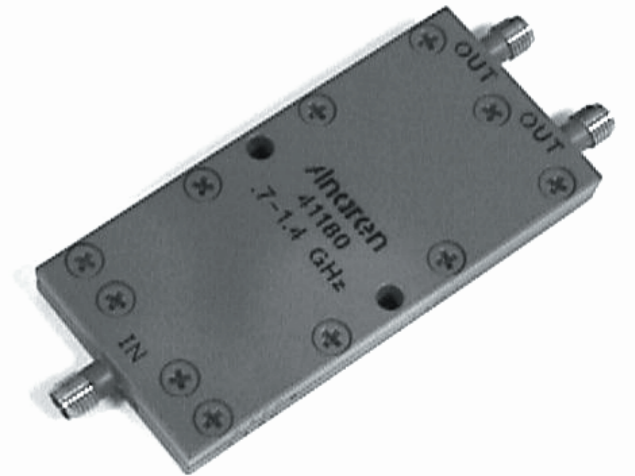
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

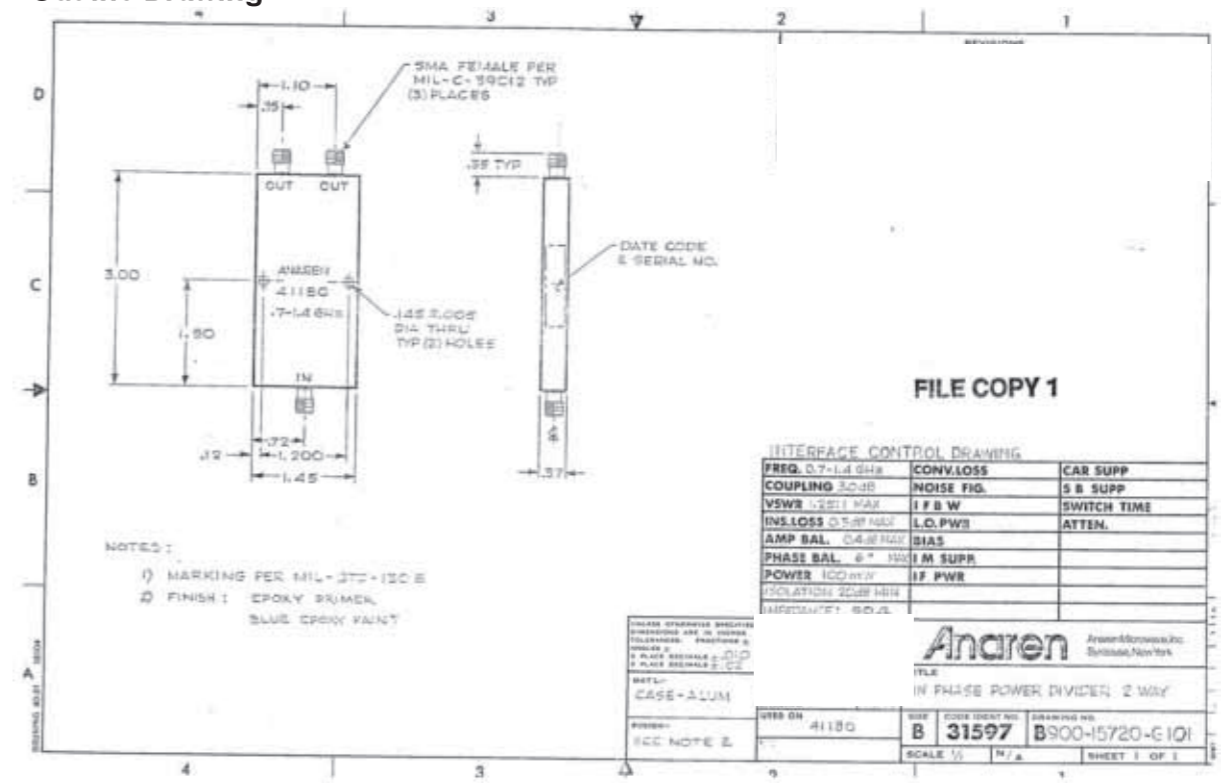
Features

- Military Grade
- 0.7 – 1.4 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 40255



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

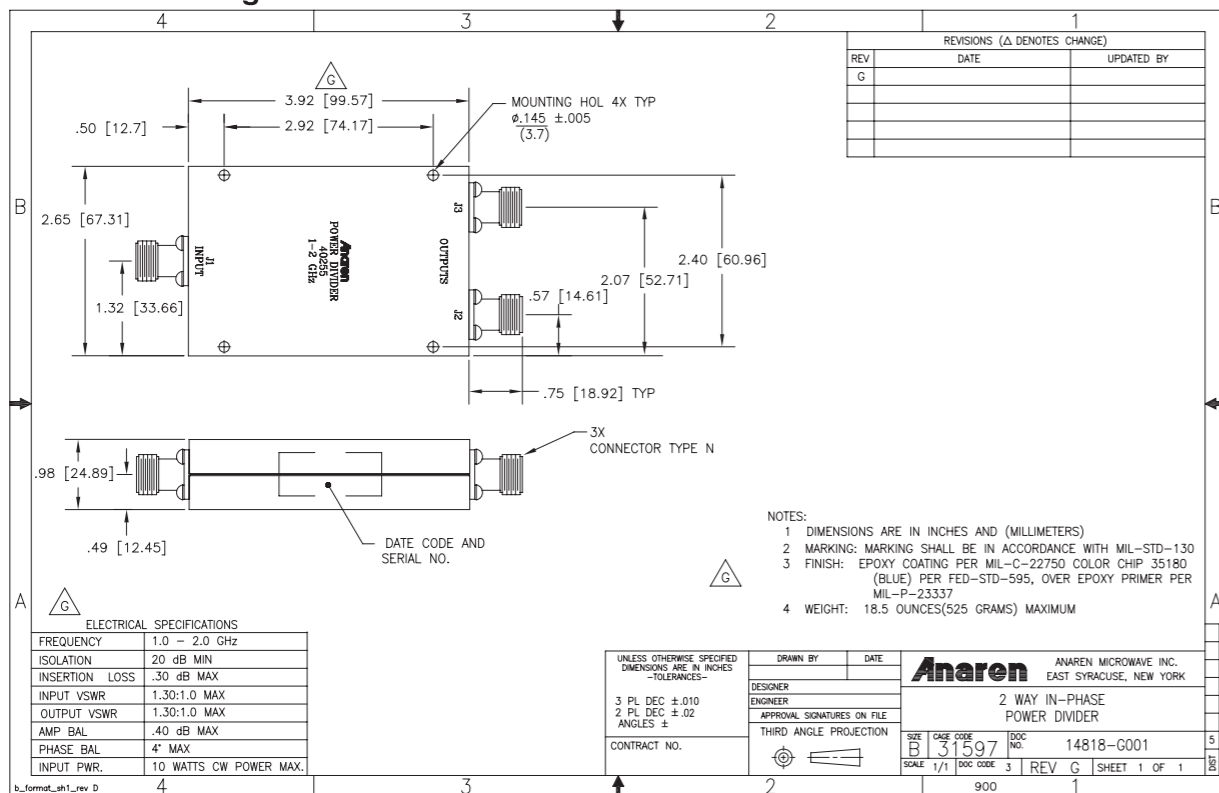
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 40265

Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

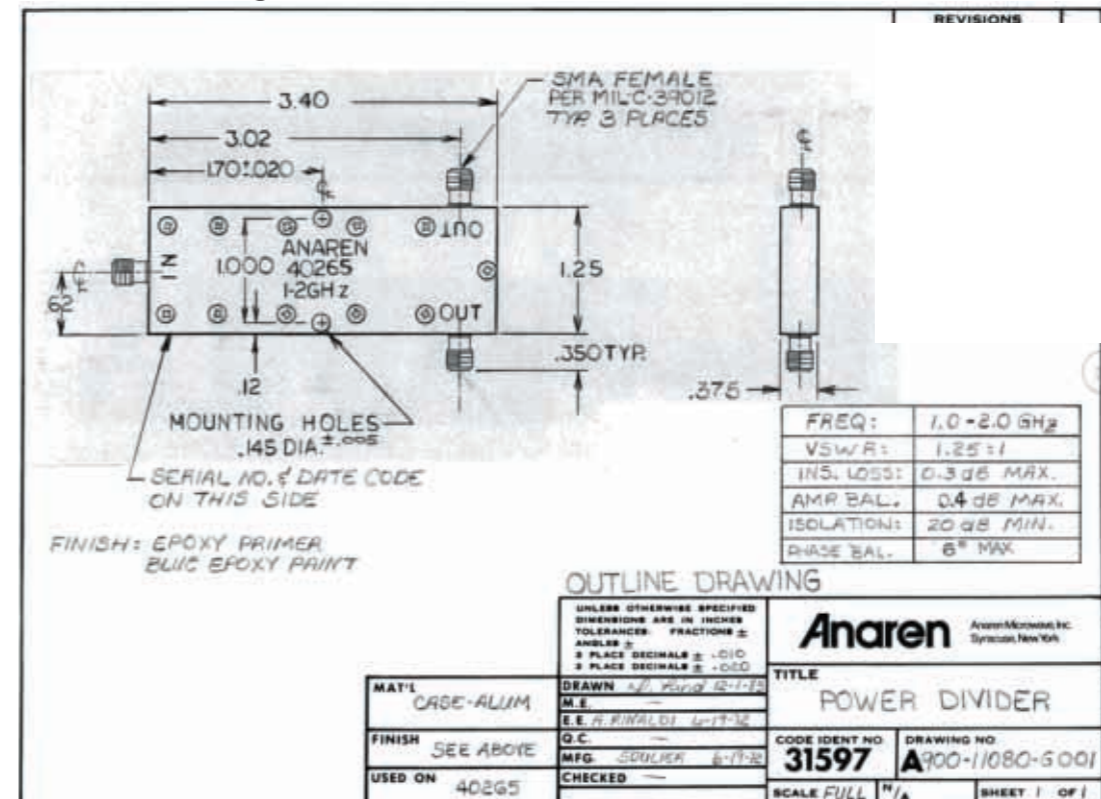
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 4J0265



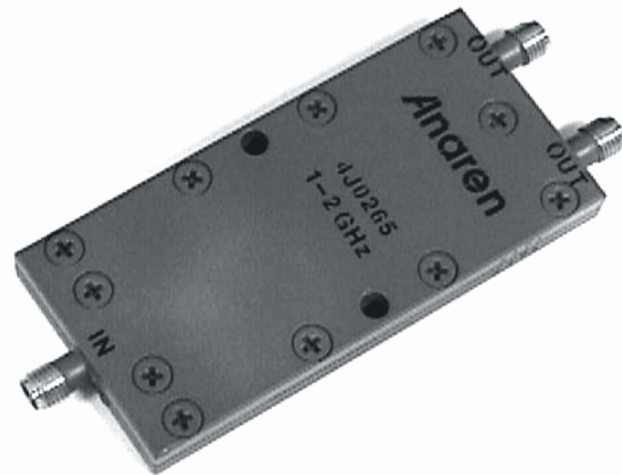
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

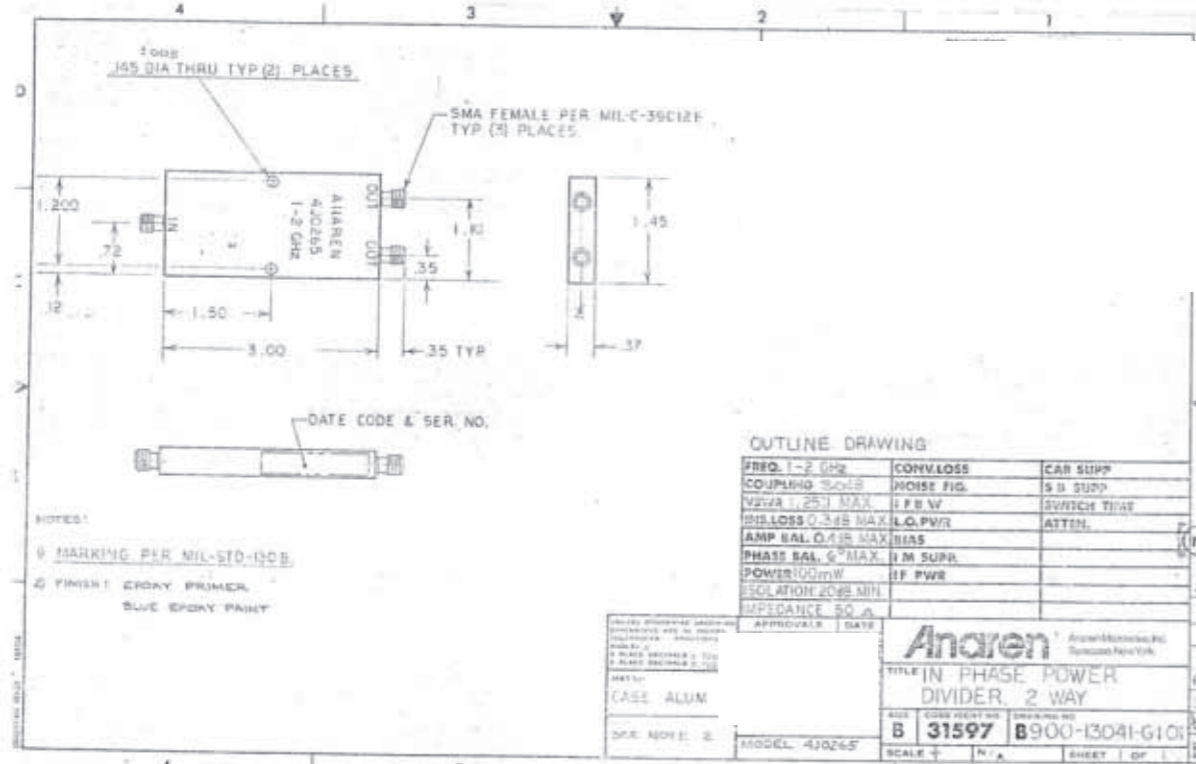
Features

- Military Grade
- 1.0 – 2.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 40710

Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

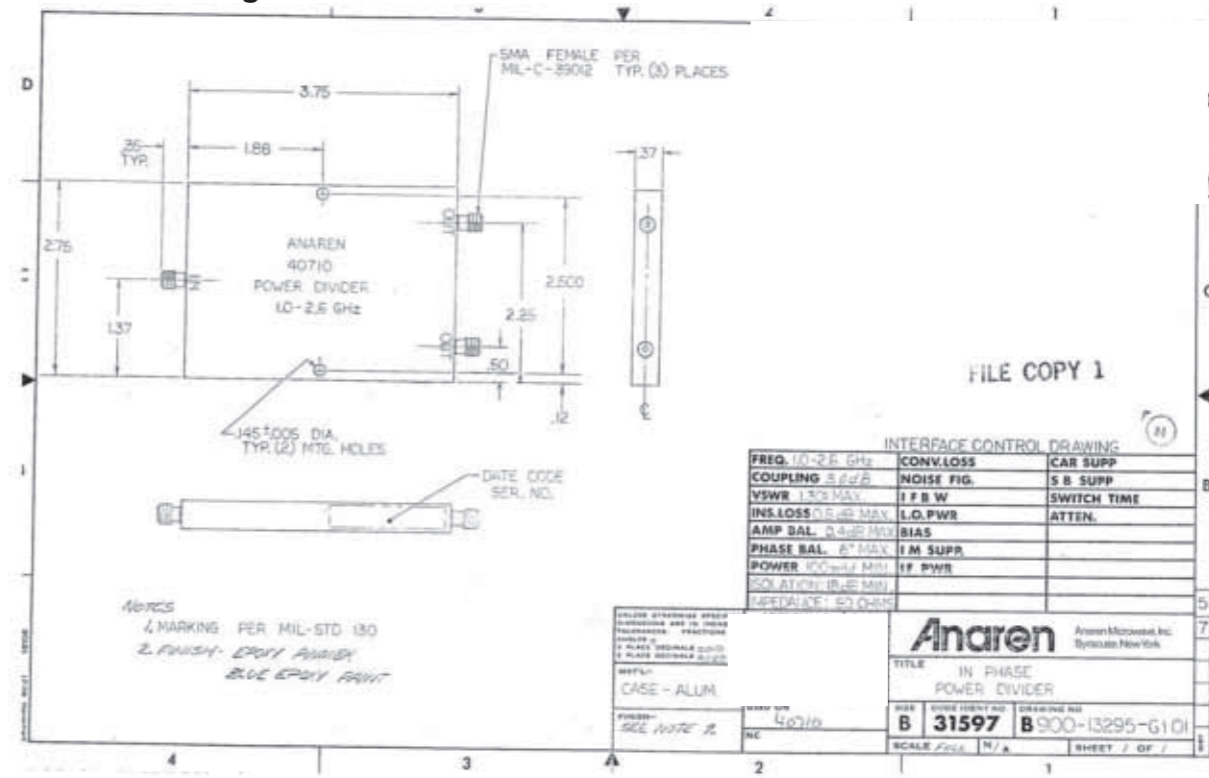
Features

- Military Grade
- 1.0 – 2.6 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 42010



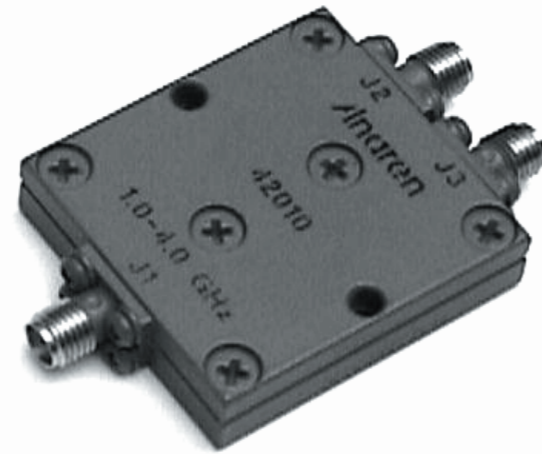
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

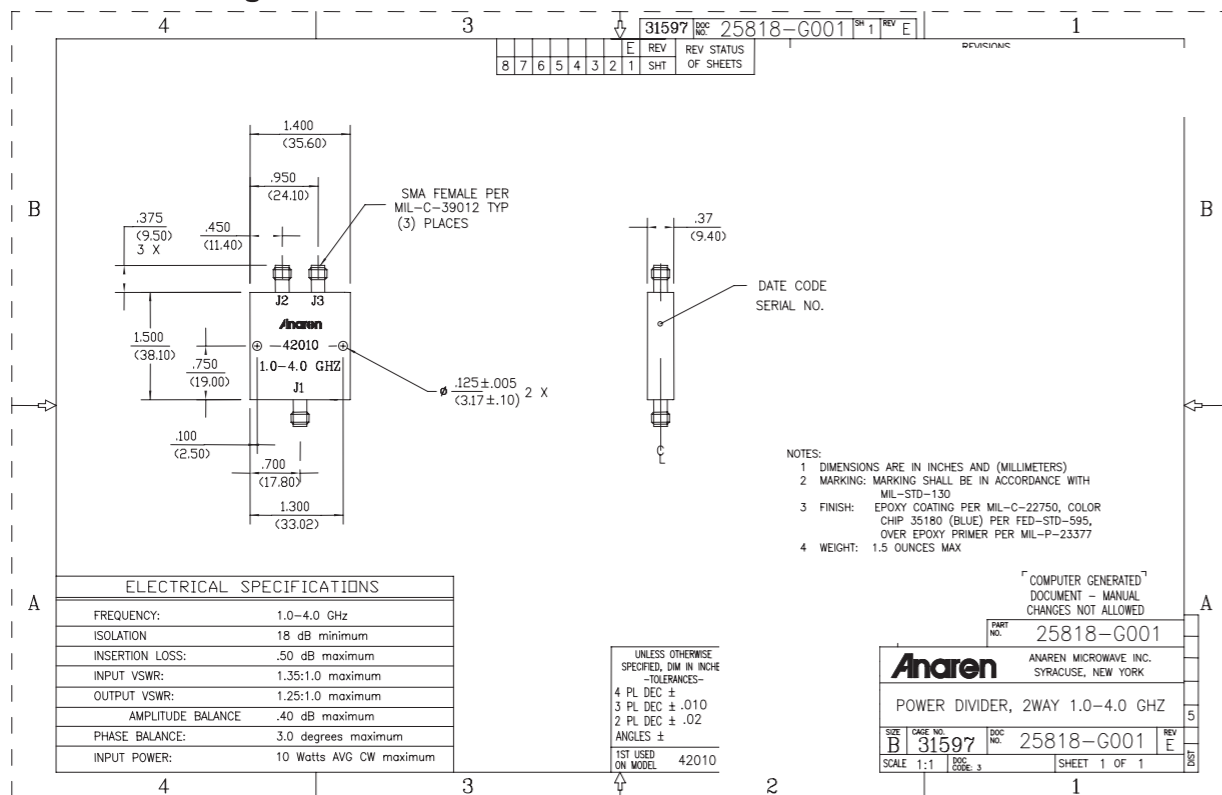
Features

- Military Grade
- 1.0 – 4.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 40510

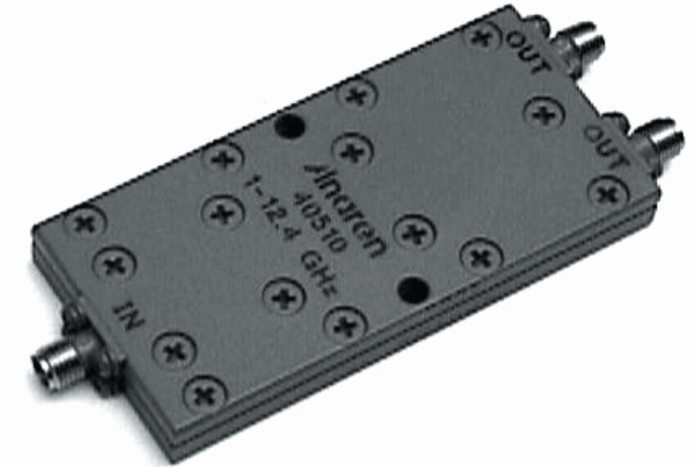
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

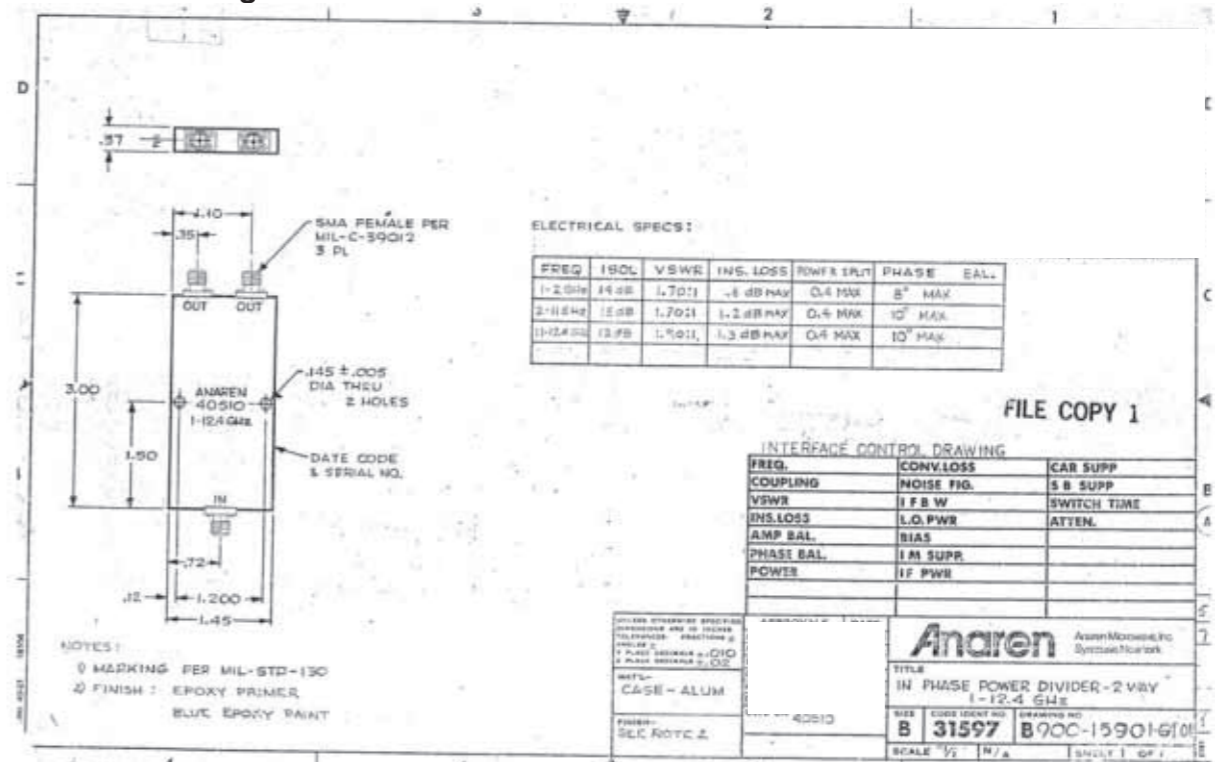
Features

- Military Grade
- 1.0 – 12.4 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 4E0265



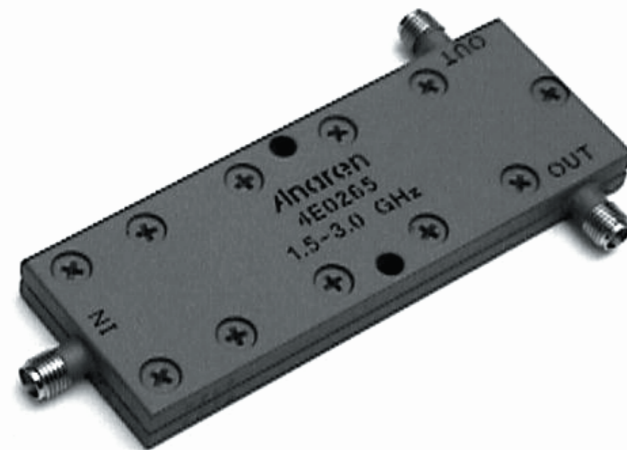
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 1.5 – 3.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 40256

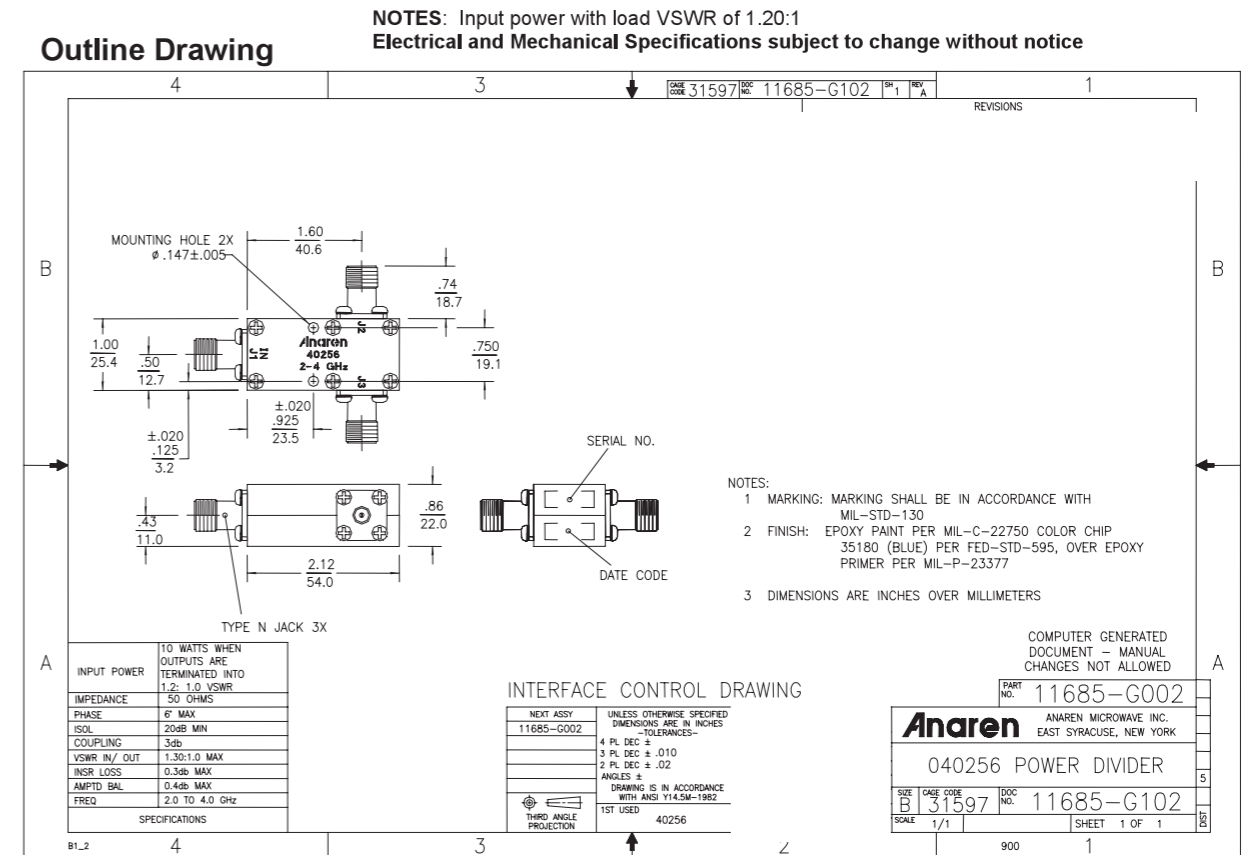
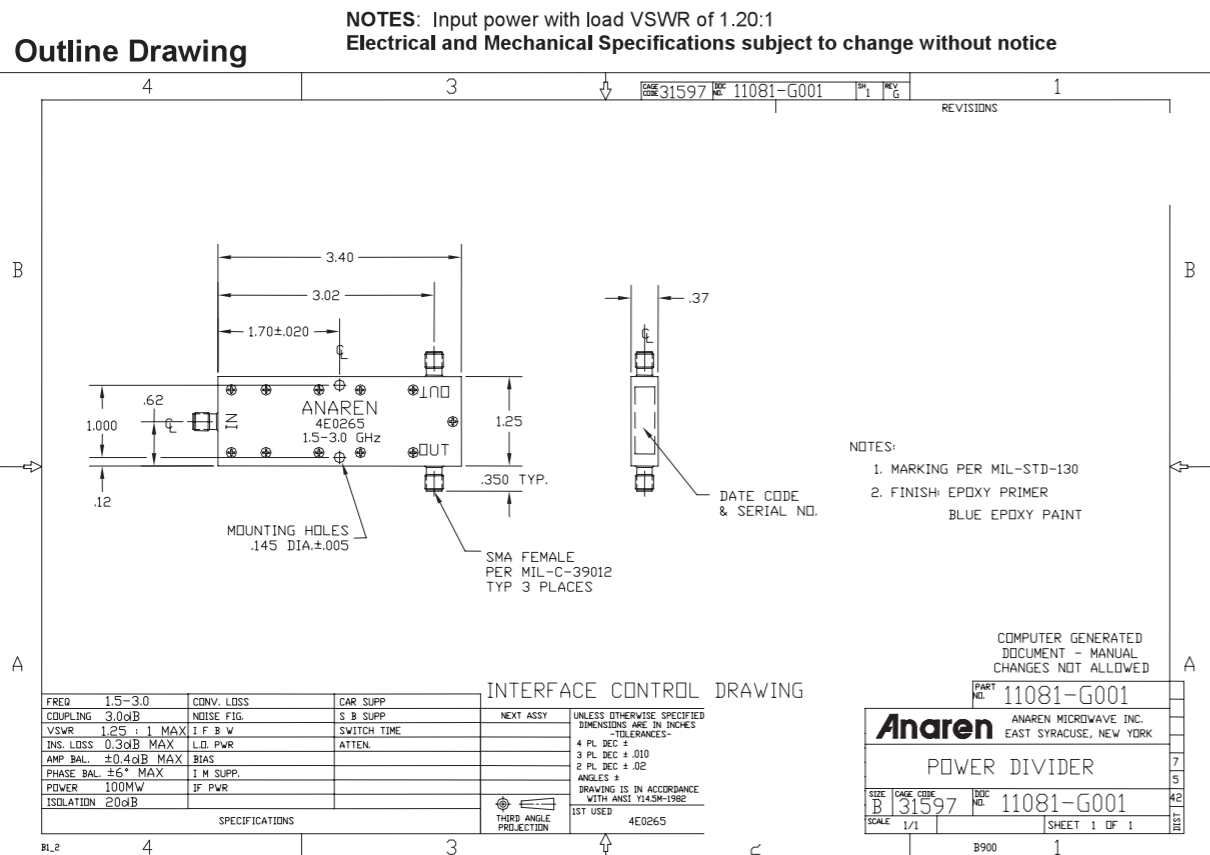
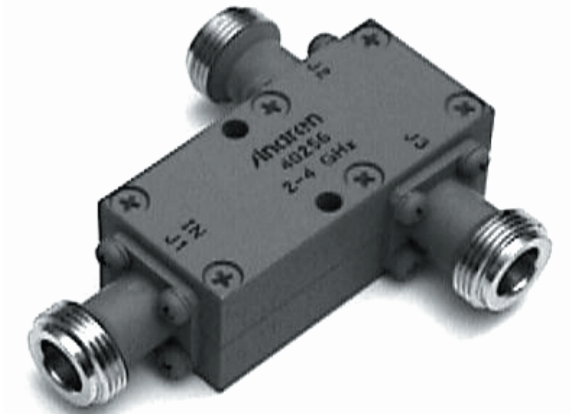
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



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Model 40266



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 4J0266

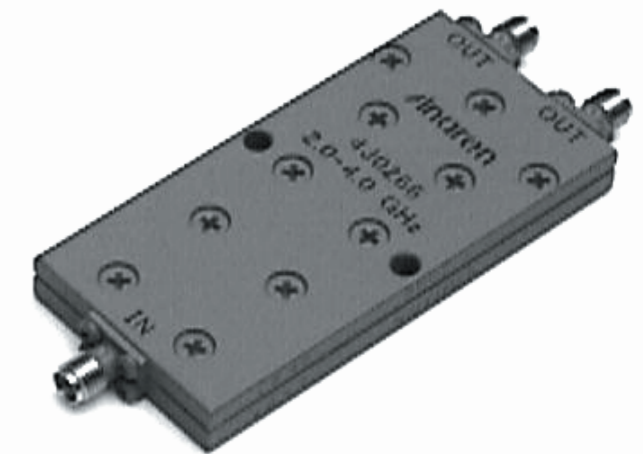
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

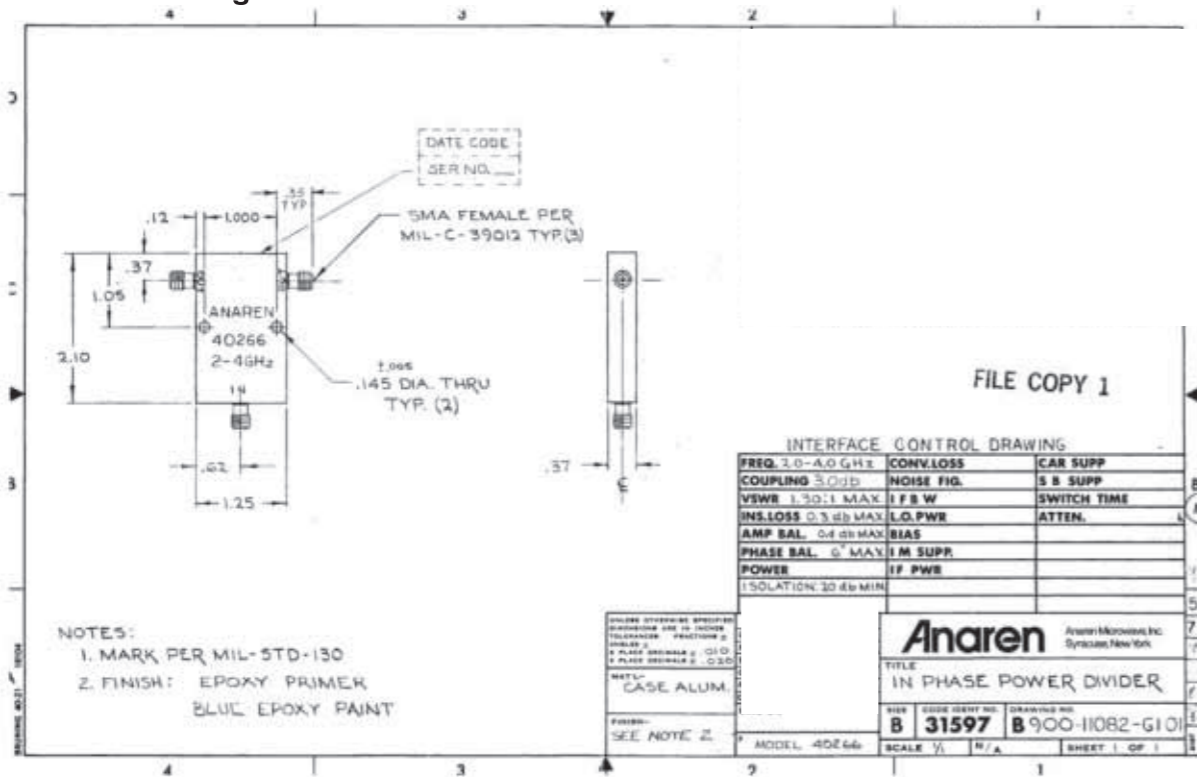
Features

- Military Grade
- 2.0 – 4.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

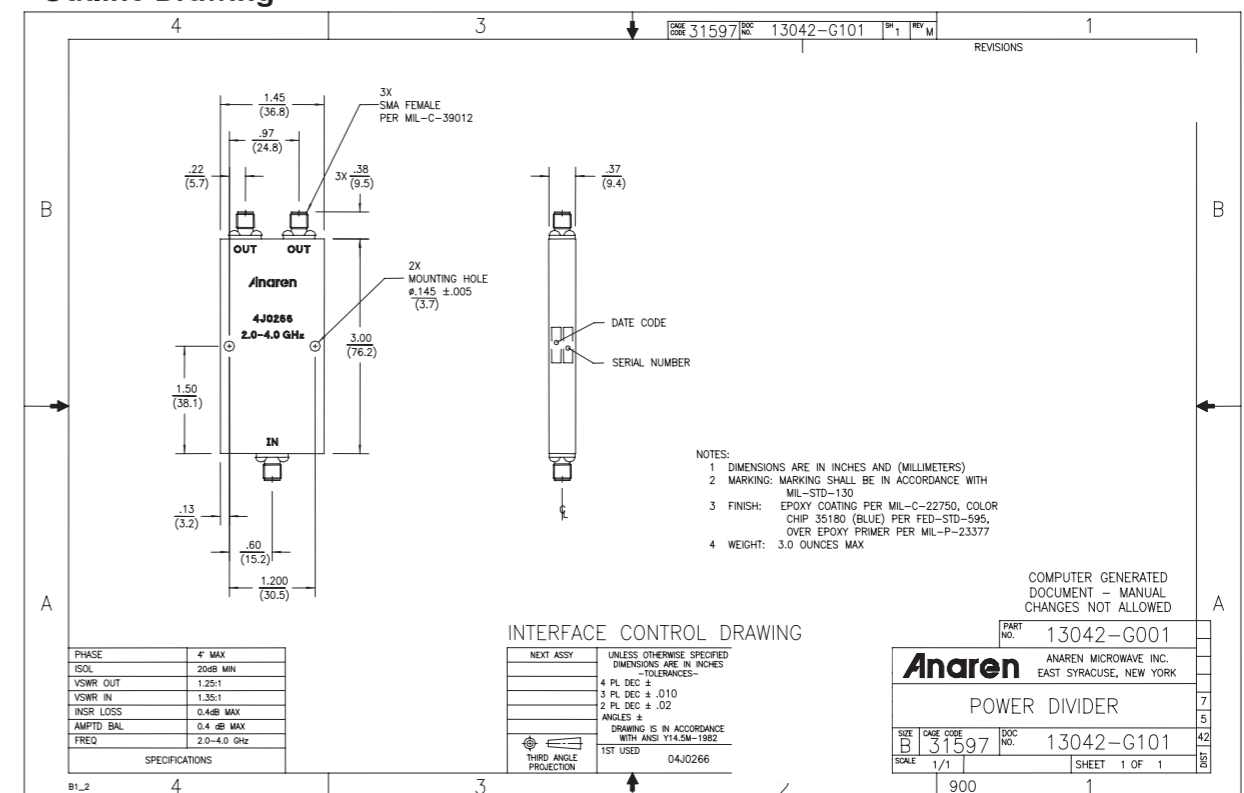


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Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
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Model 42020



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 2.0 – 8.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements

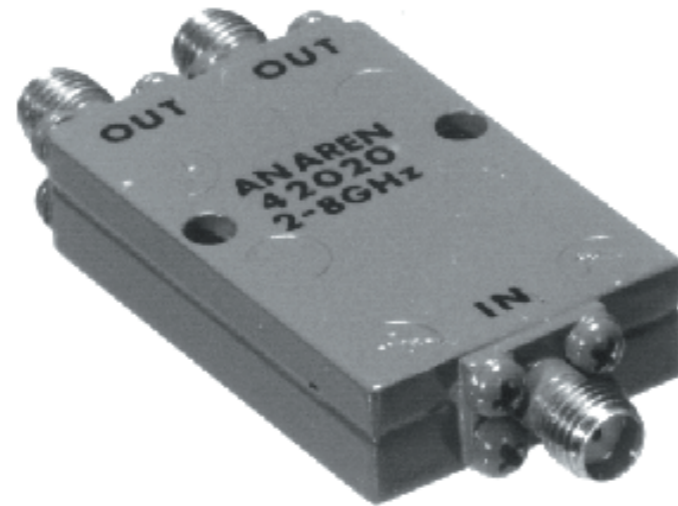


Photo shows old marking stencil, see drawing for current marking design.



Model 41130

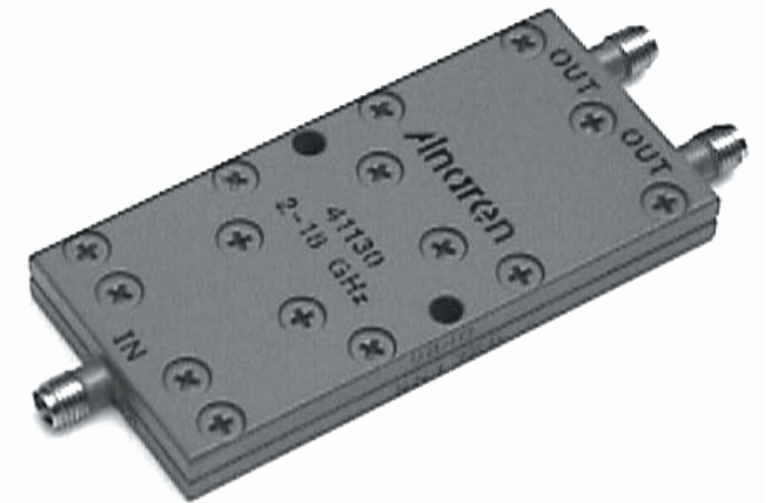
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

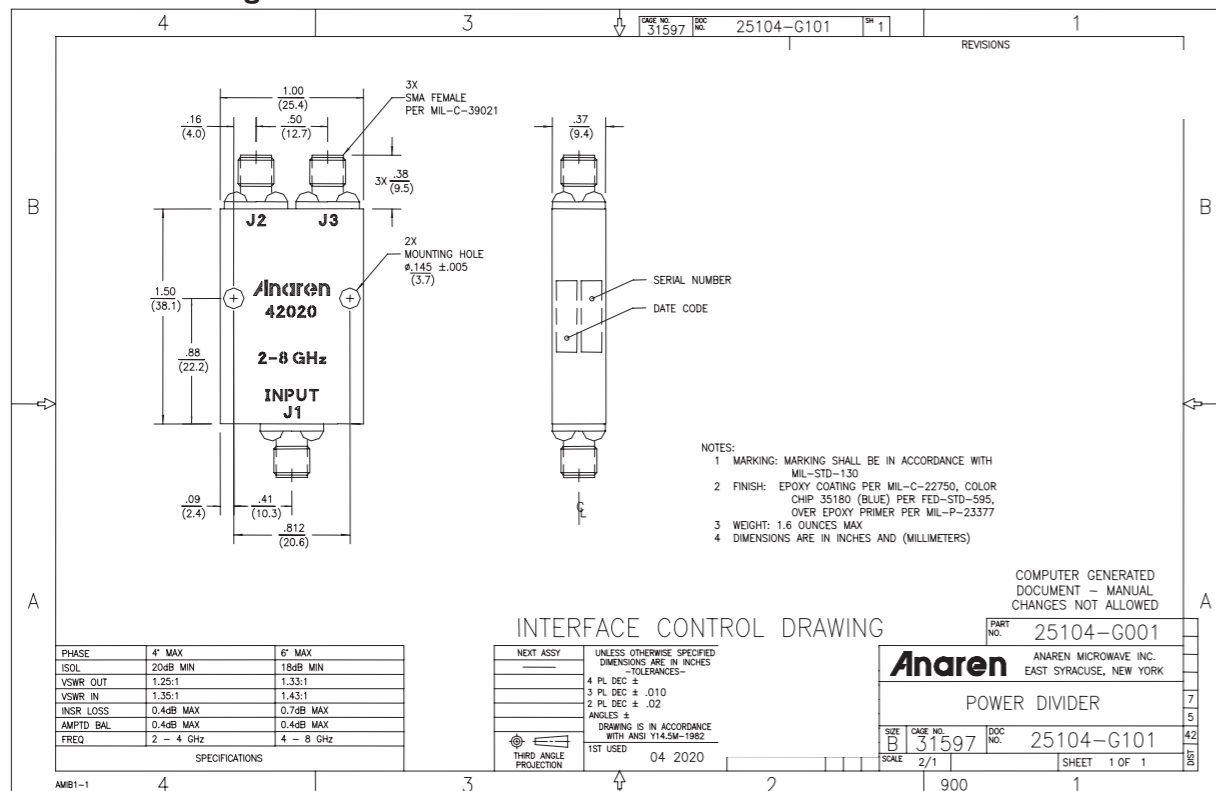
Features

- Military Grade
- 2.0 – 18.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



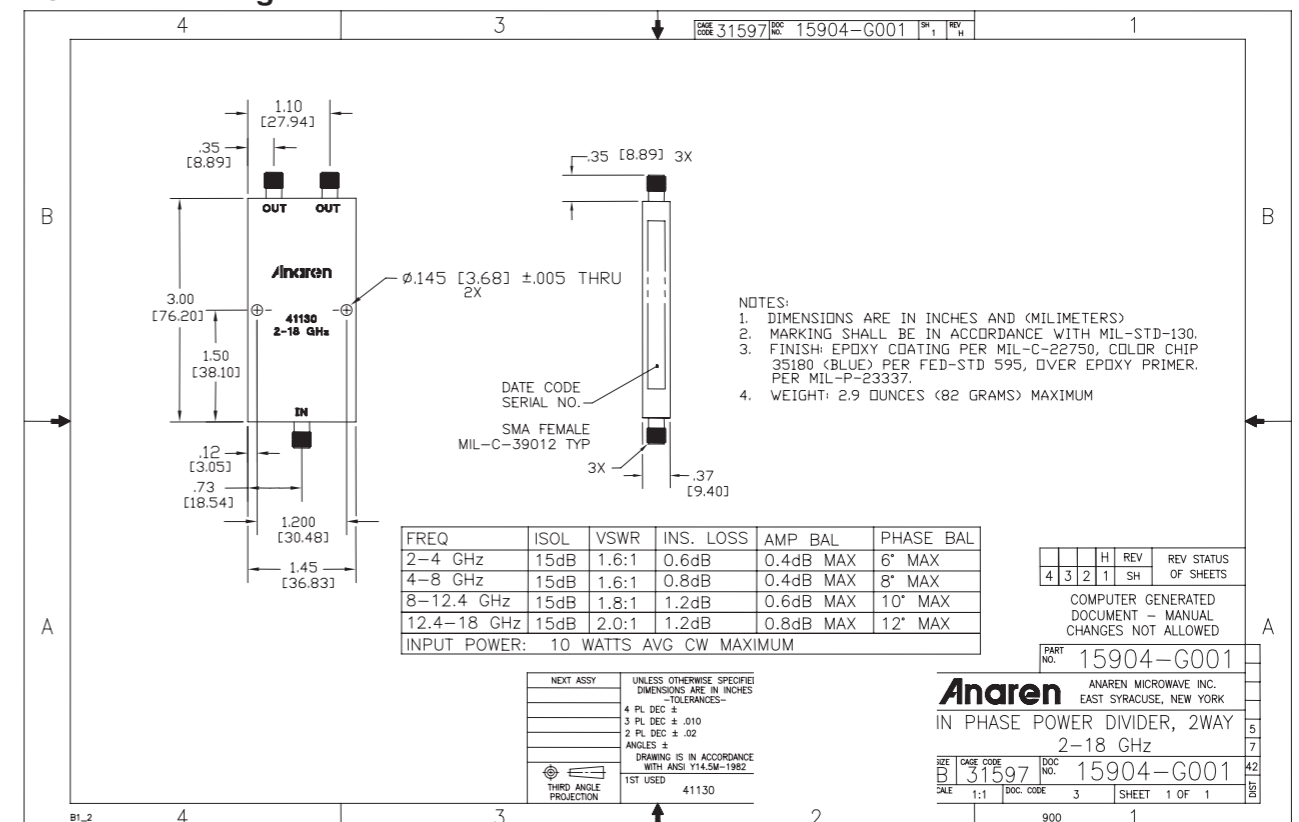
NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 42100



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

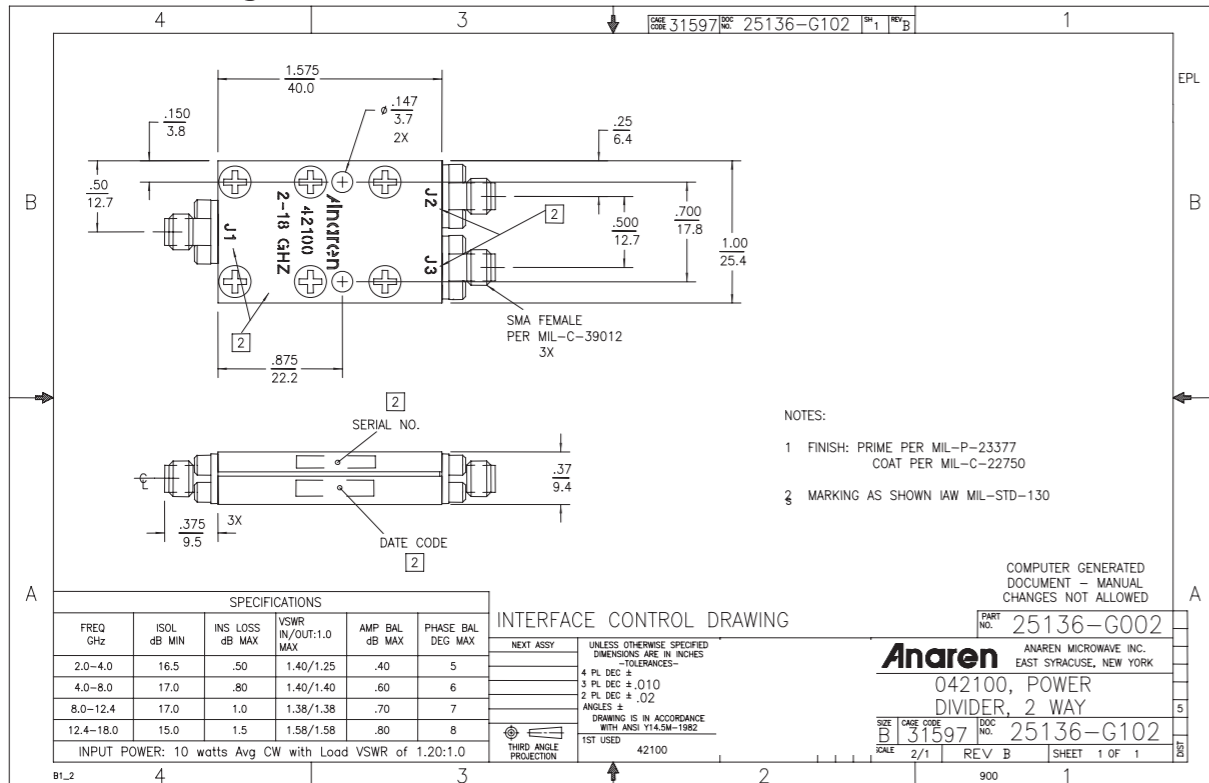
Features

- Military Grade
- 2.0 – 18.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 4A0256

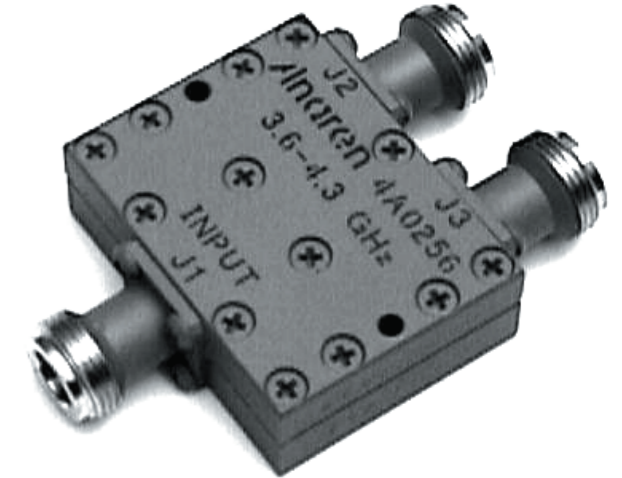
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

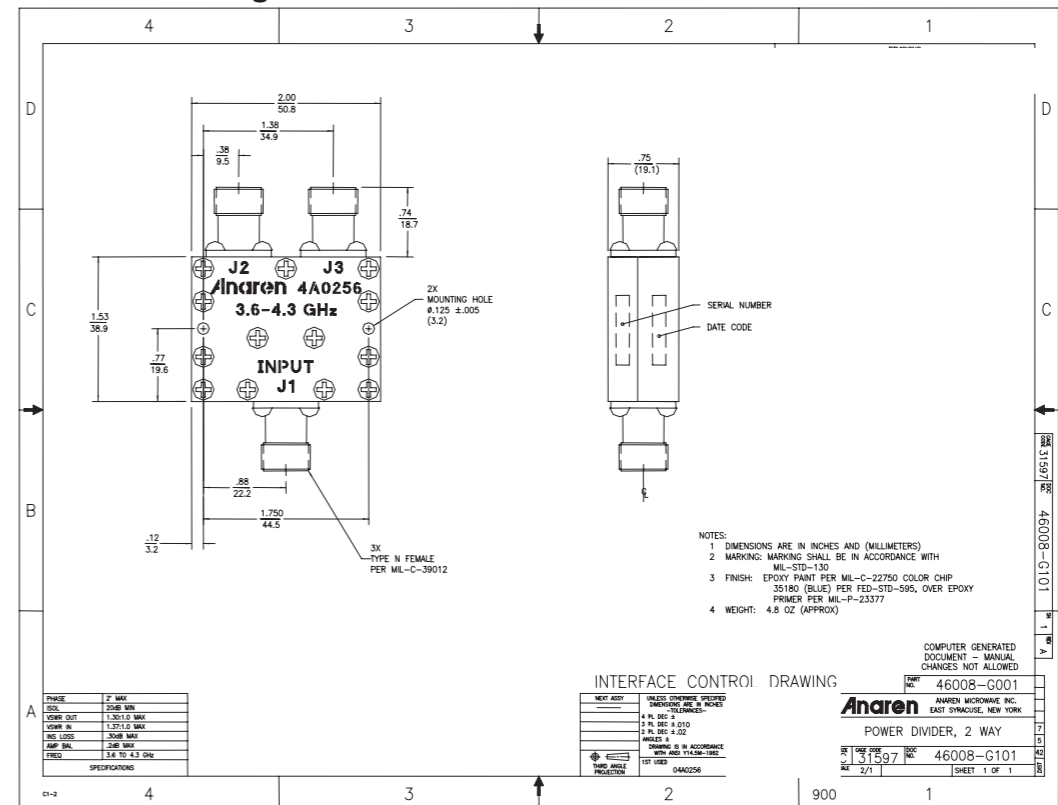
Features

- Military Grade
- 3.6 – 4.3 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 40267



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 4.0 – 8.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 42030

Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

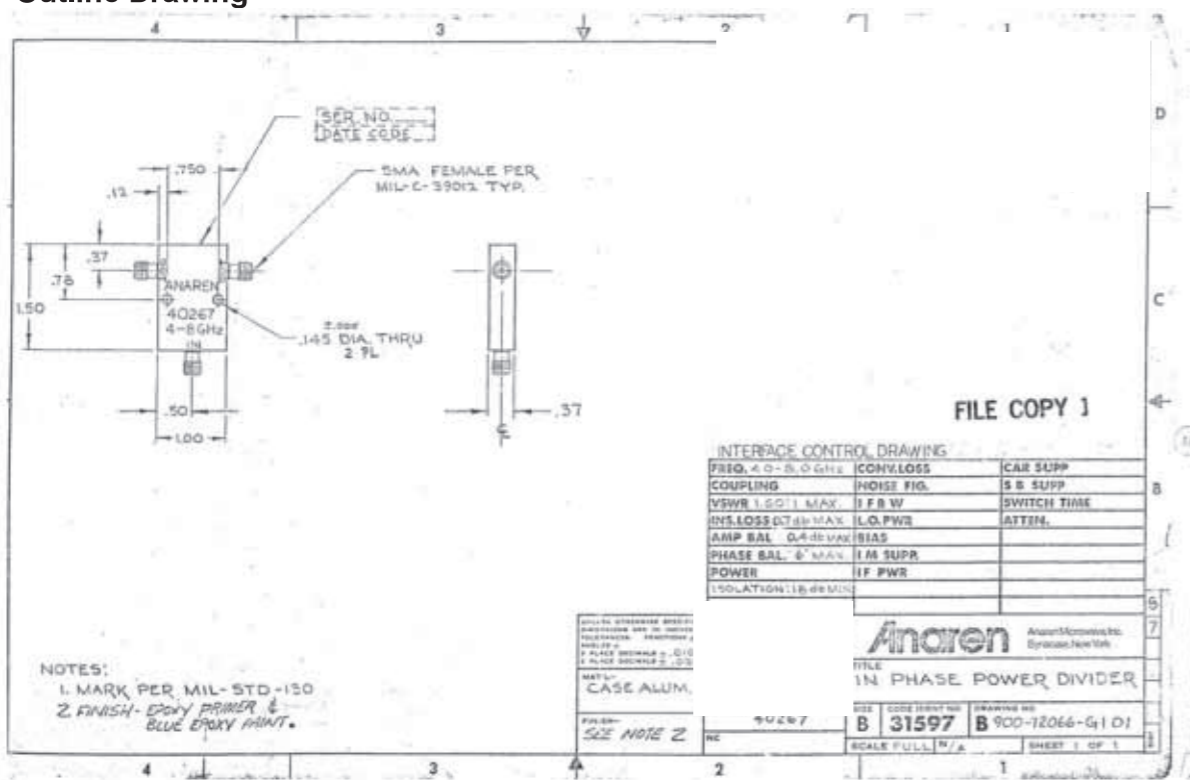
Features

- Military Grade
- 4.0 – 12.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



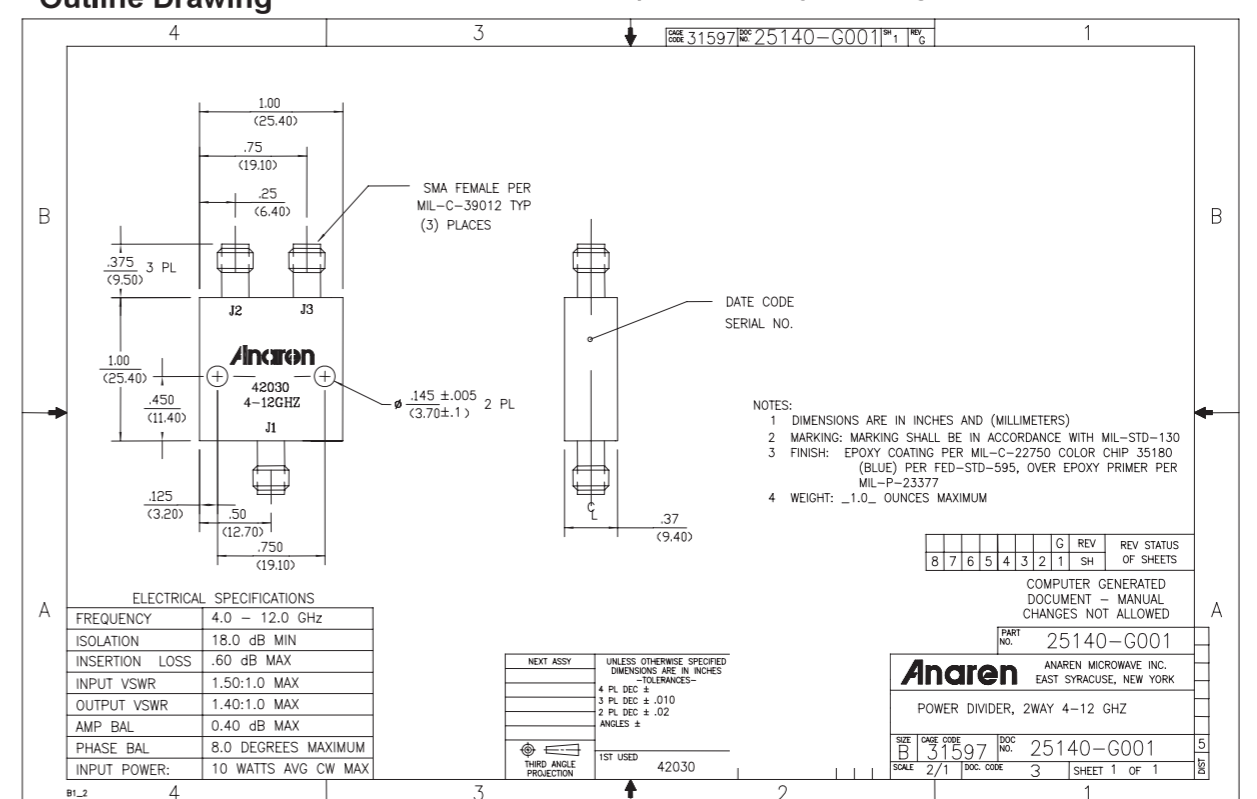
Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 42040



Power Dividers 2-Way



Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 6.0 – 18.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 41640

Power Dividers 2-Way



Applications

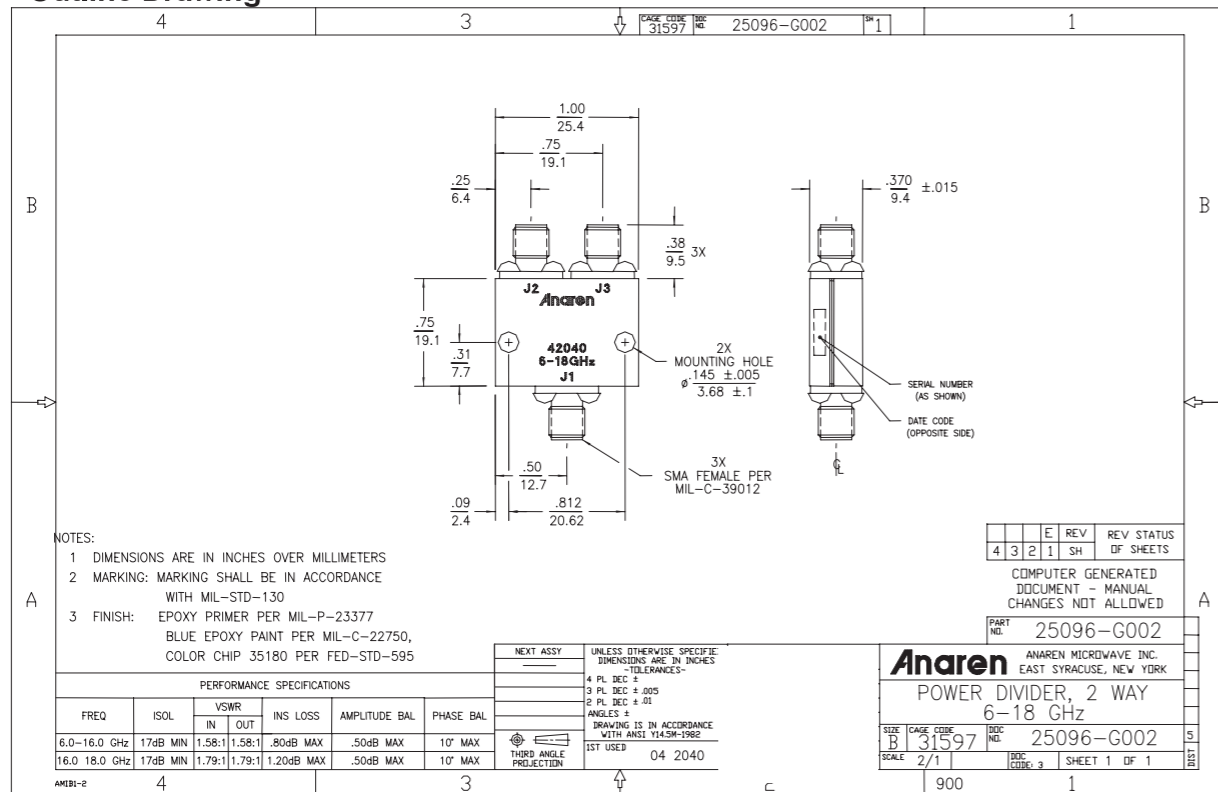
- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 7.0 – 11.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements

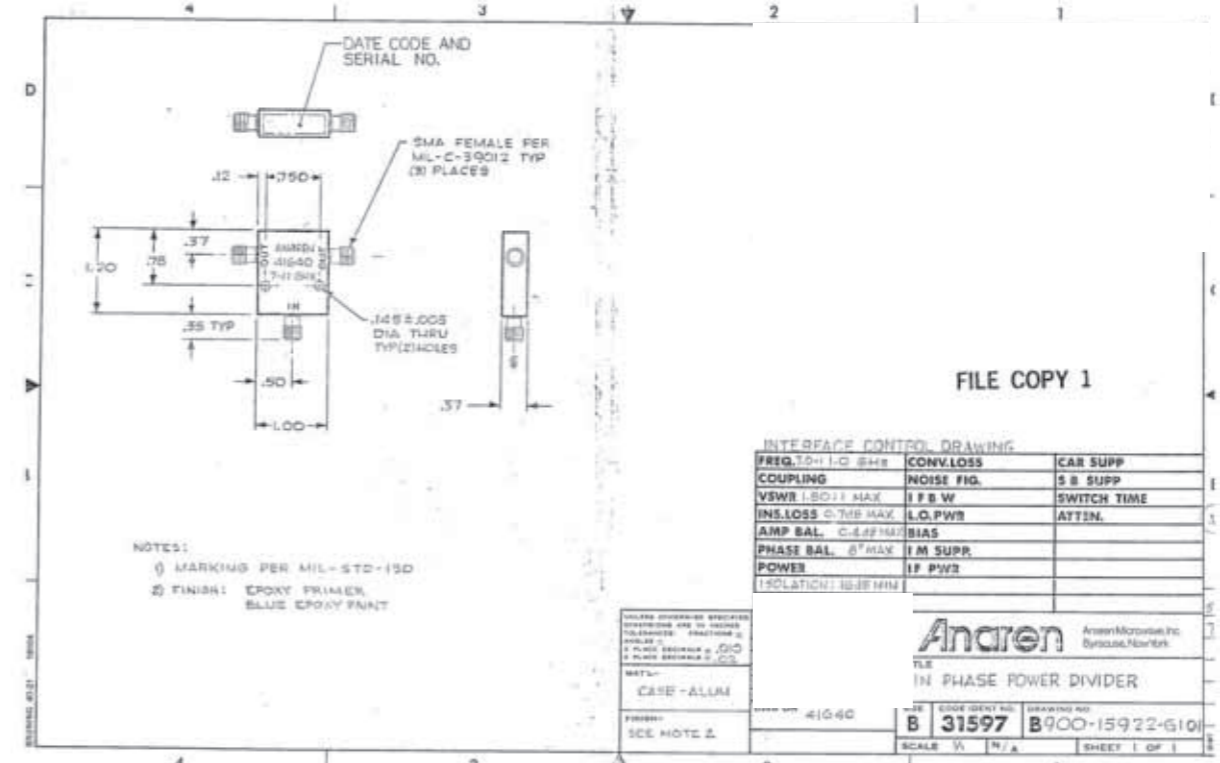
Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 41690



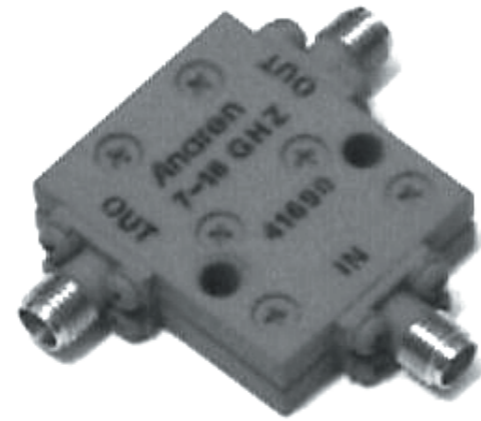
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 7.0 – 18.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 40268

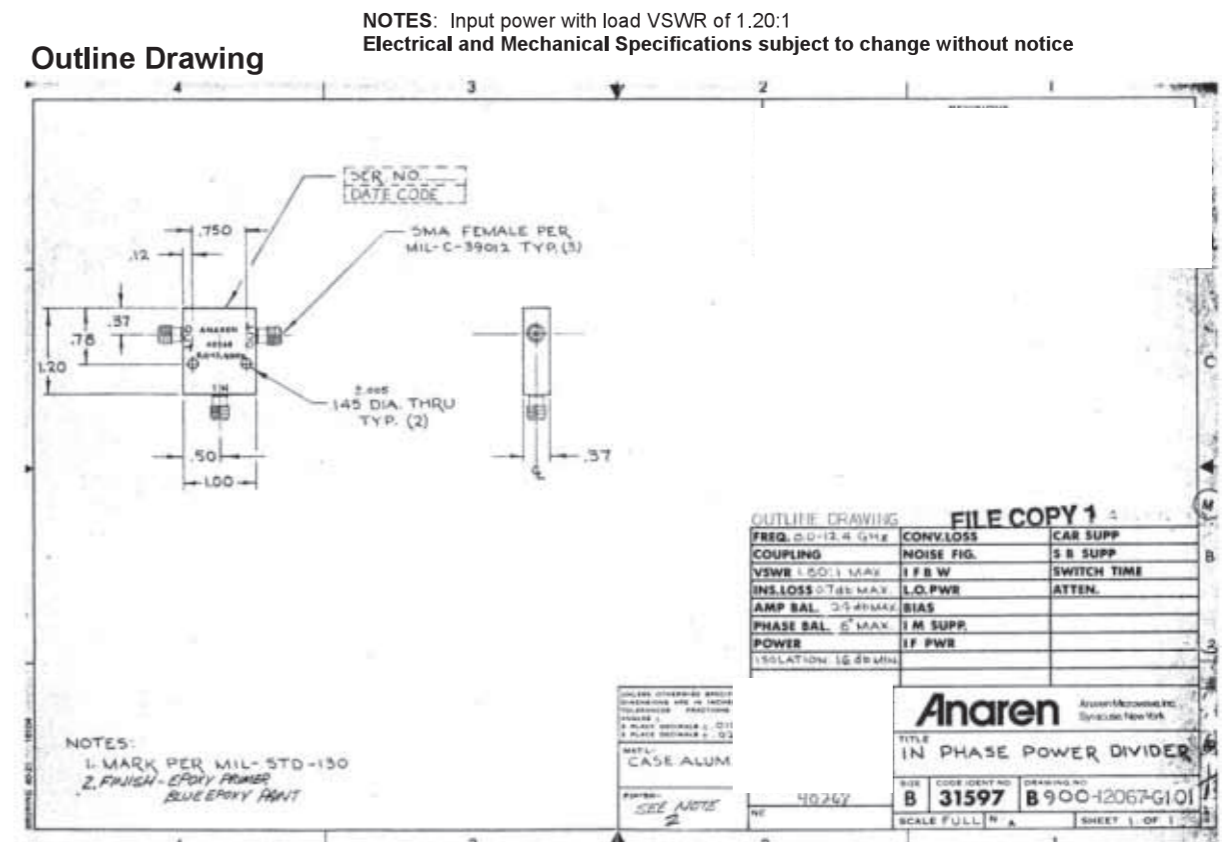
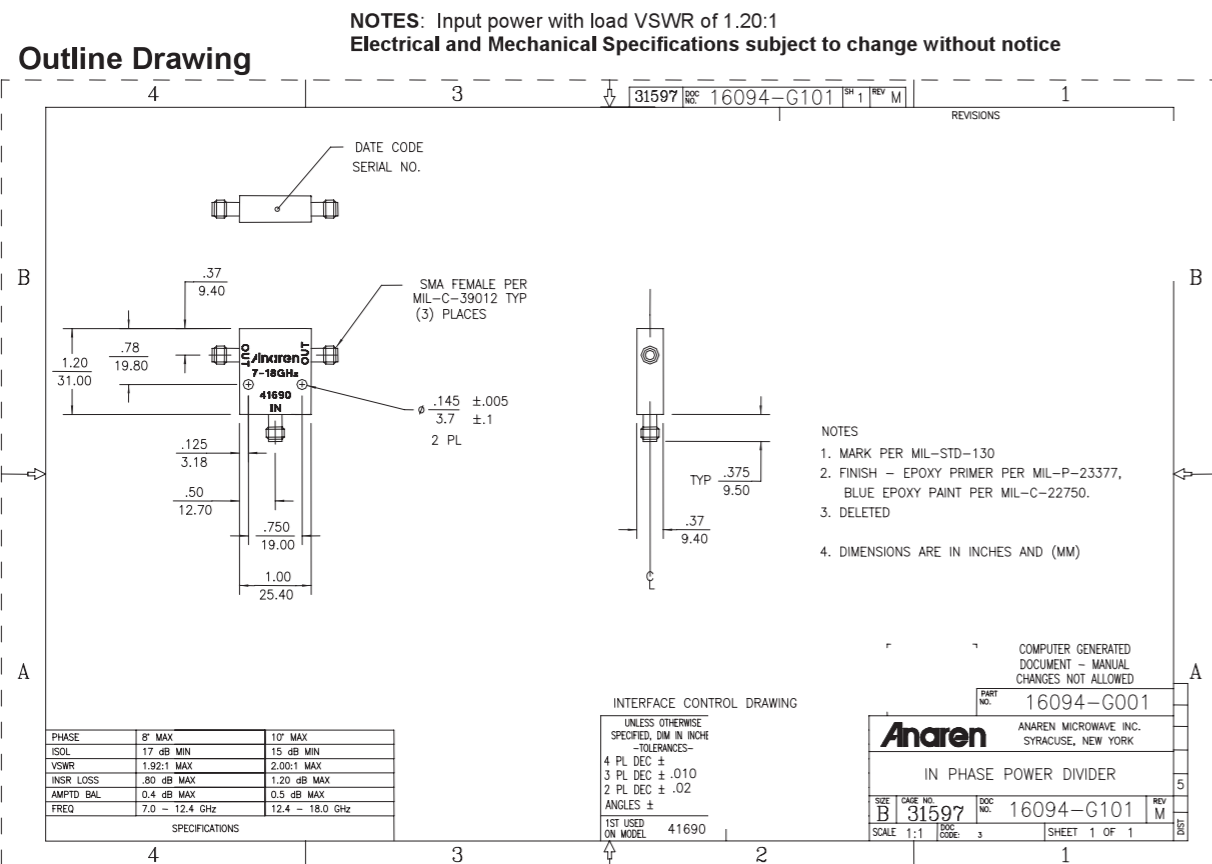
Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 8.0 – 12.4 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



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Model 40269



Power Dividers 2-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

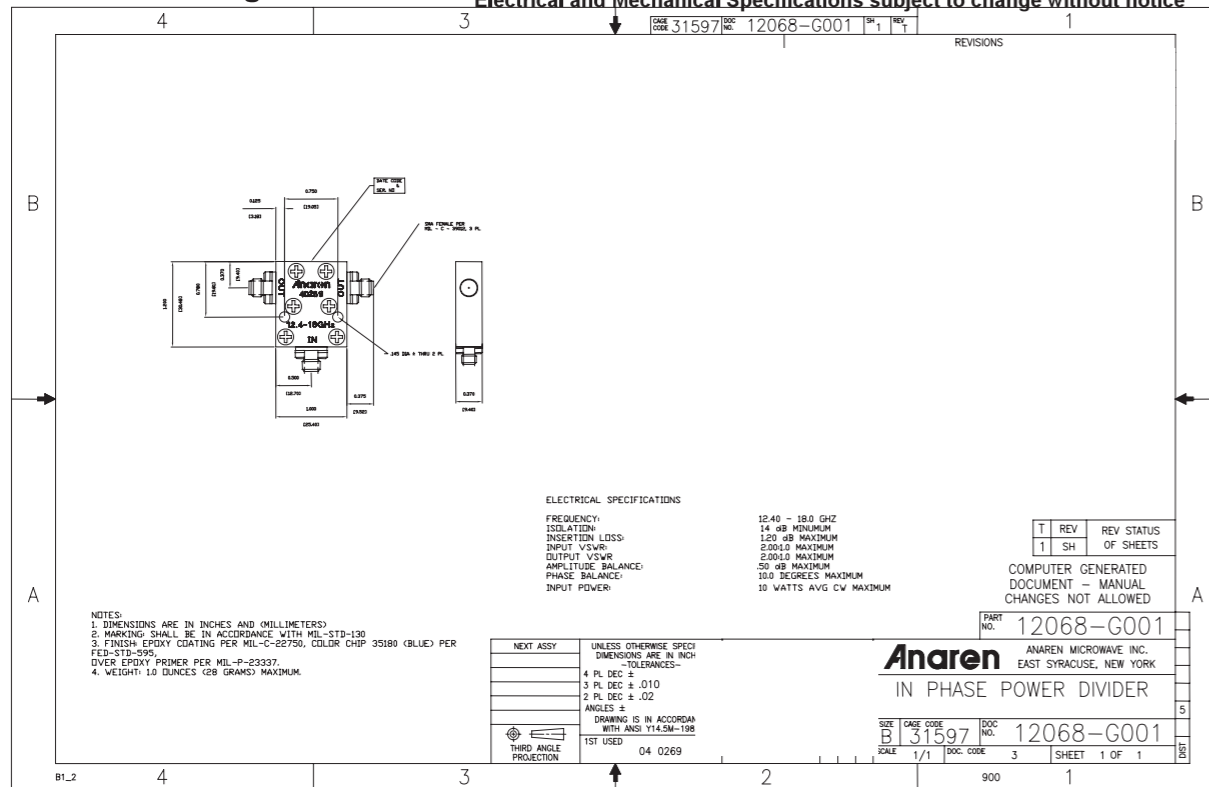
Features

- Military Grade
- 12.4 – 18.0 GHz
- 2-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 43000

Power Dividers 3-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

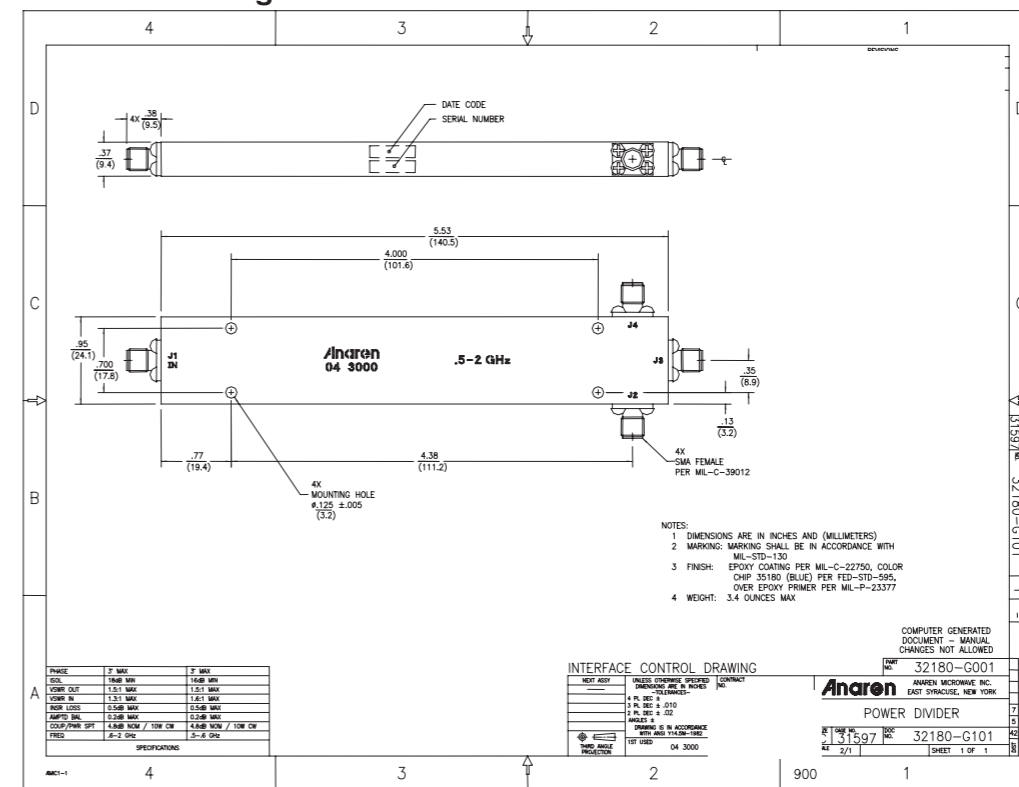
Features

- Military Grade
- 0.5 – 2.0 GHz
- 3-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 43020



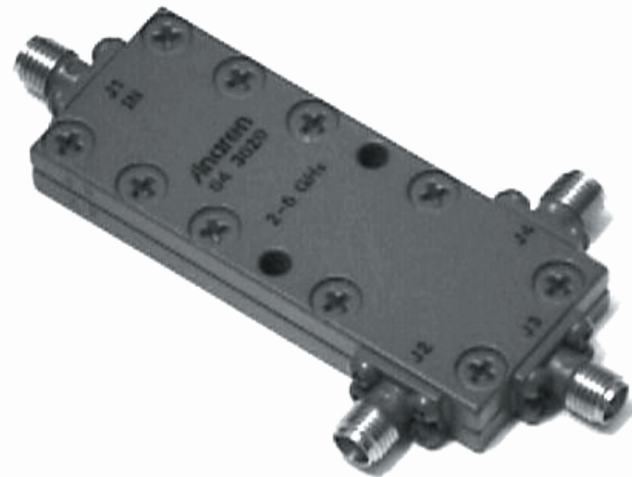
Power Dividers 3-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 2.0 – 6.0 GHz
- 3-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 43040

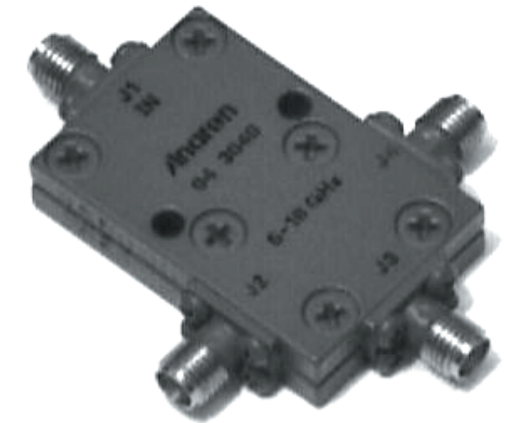
Power Dividers 3-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

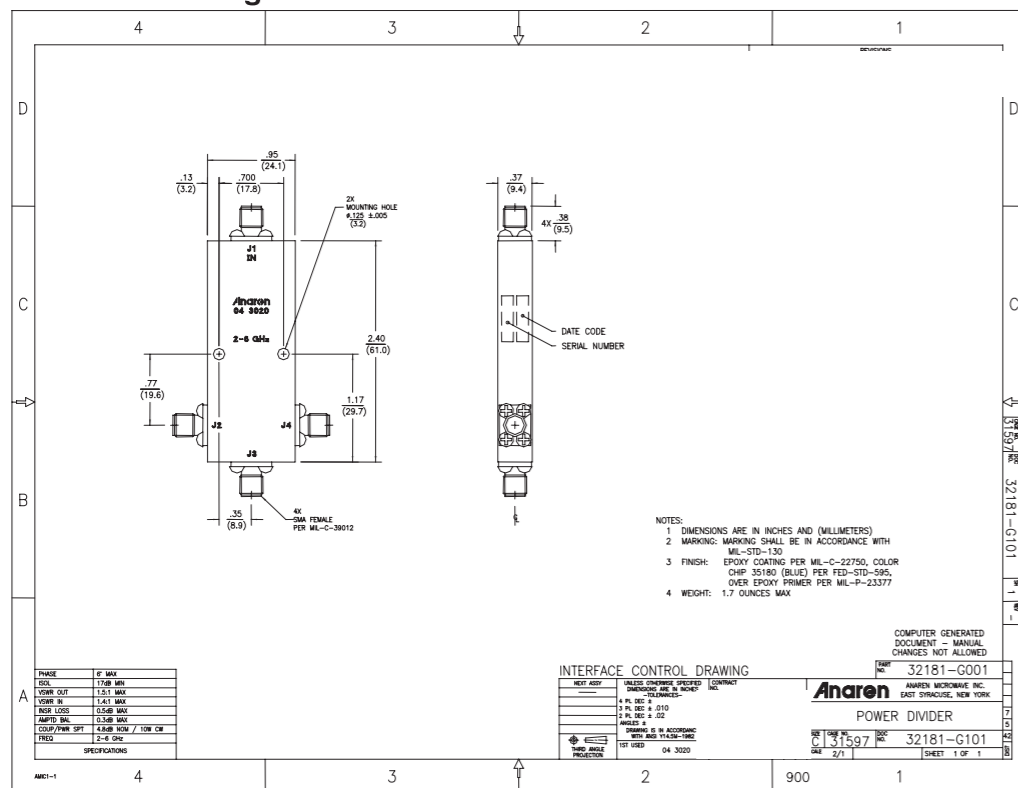
Features

- Military Grade
- 6.0 – 18.0 GHz
- 3-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



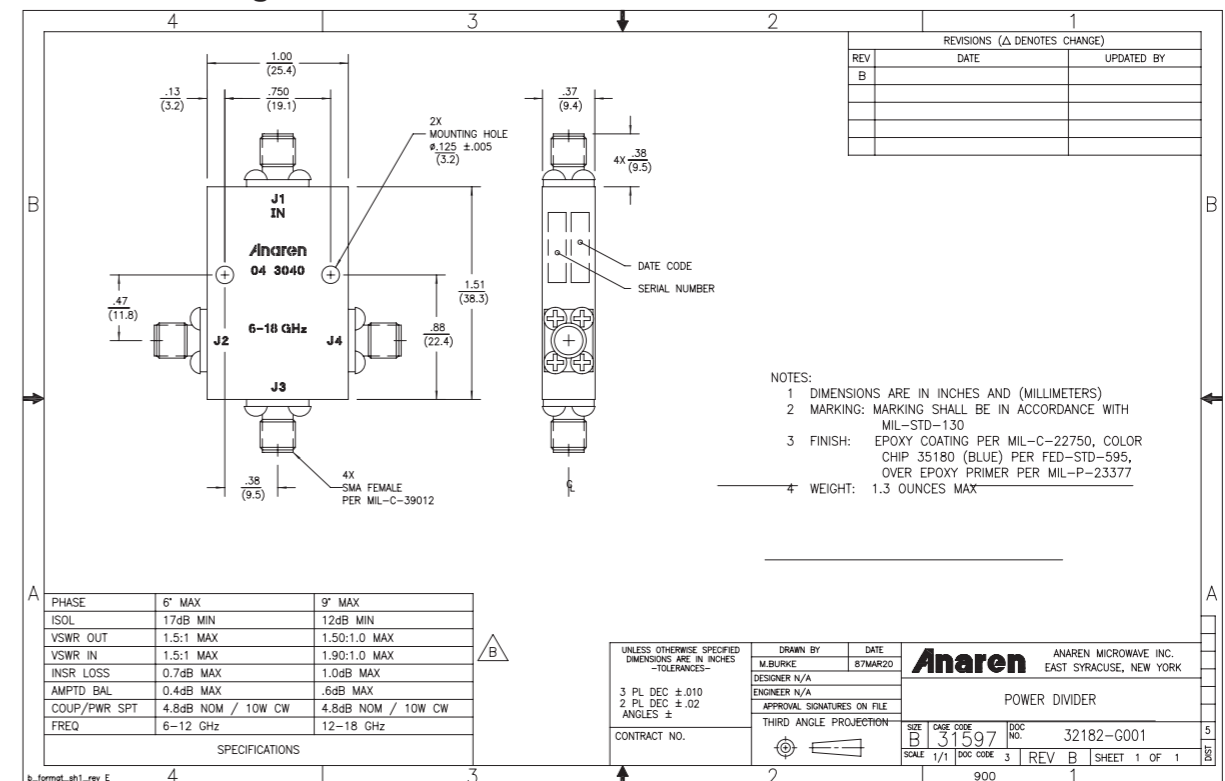
Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 44000



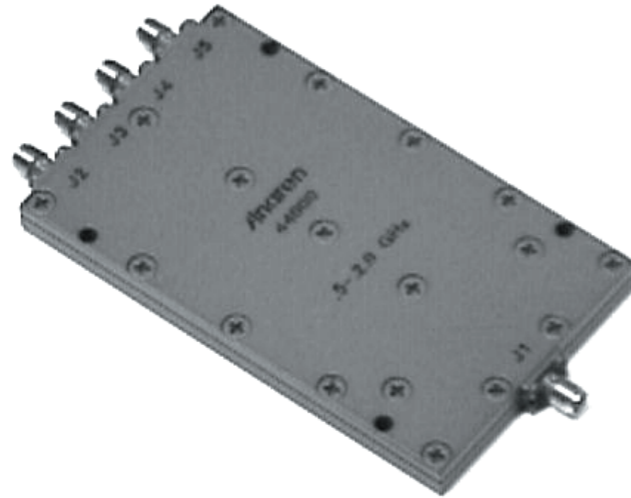
Power Dividers 4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

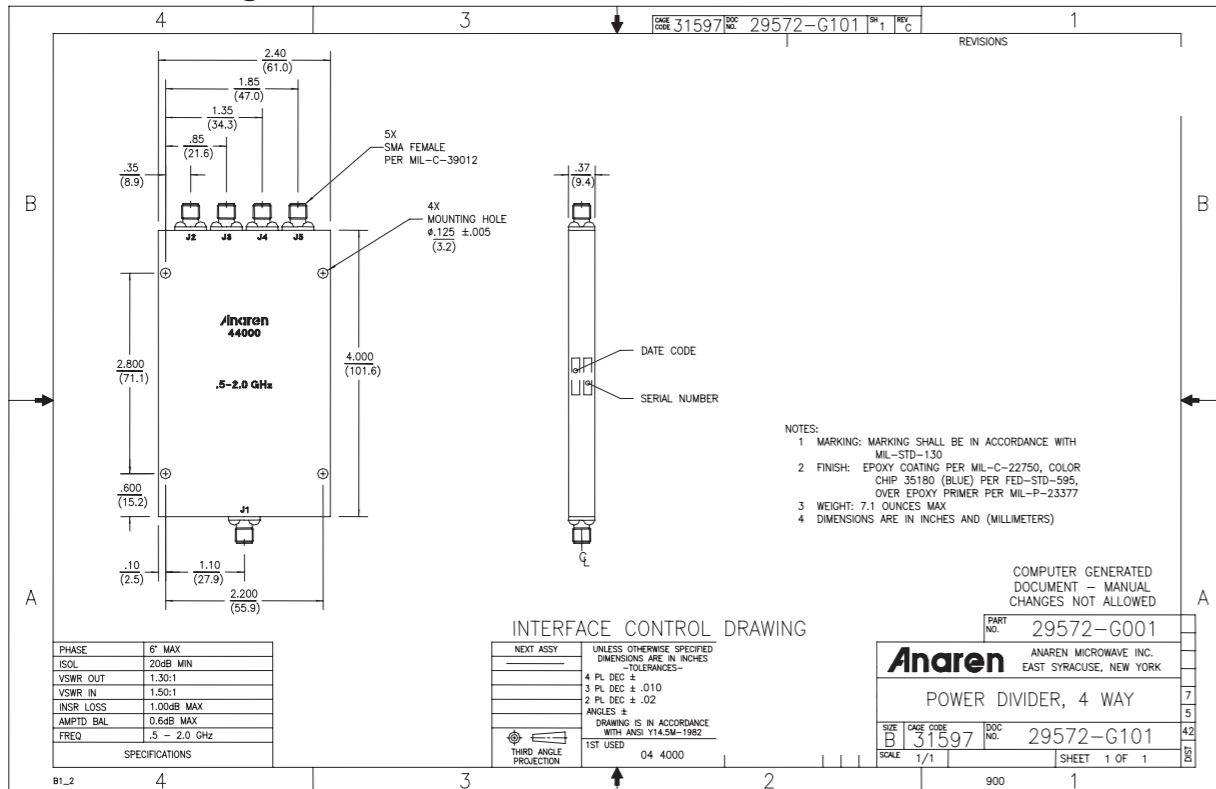
Features

- Military Grade
- 0.5 – 2.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Model 40275

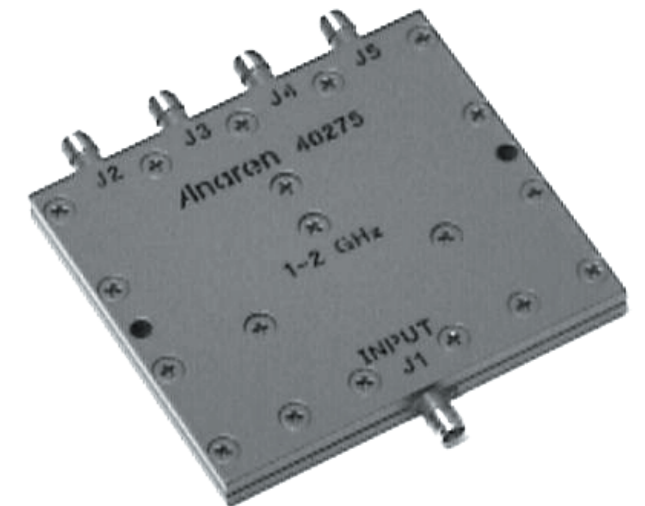
Power Dividers 4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

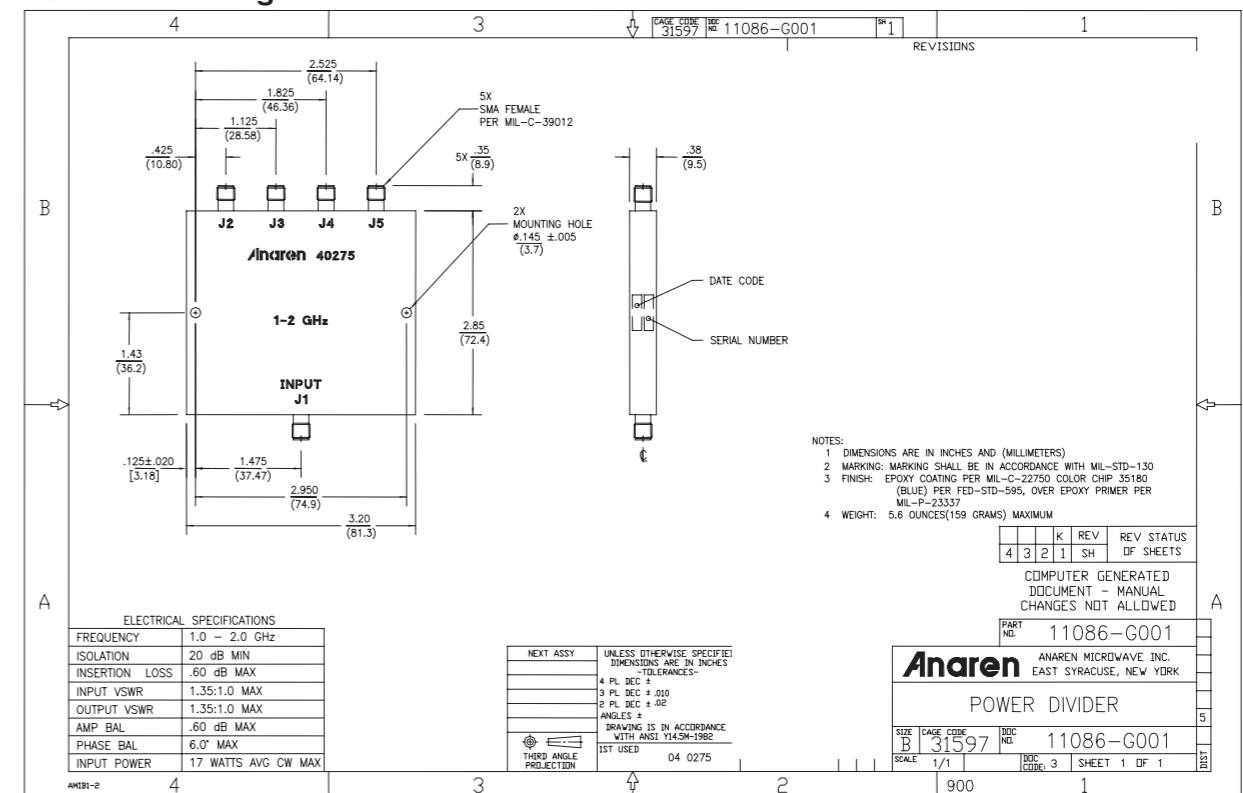
Features

- Military Grade
- 1.0 – 2.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 44020



Power Dividers 4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

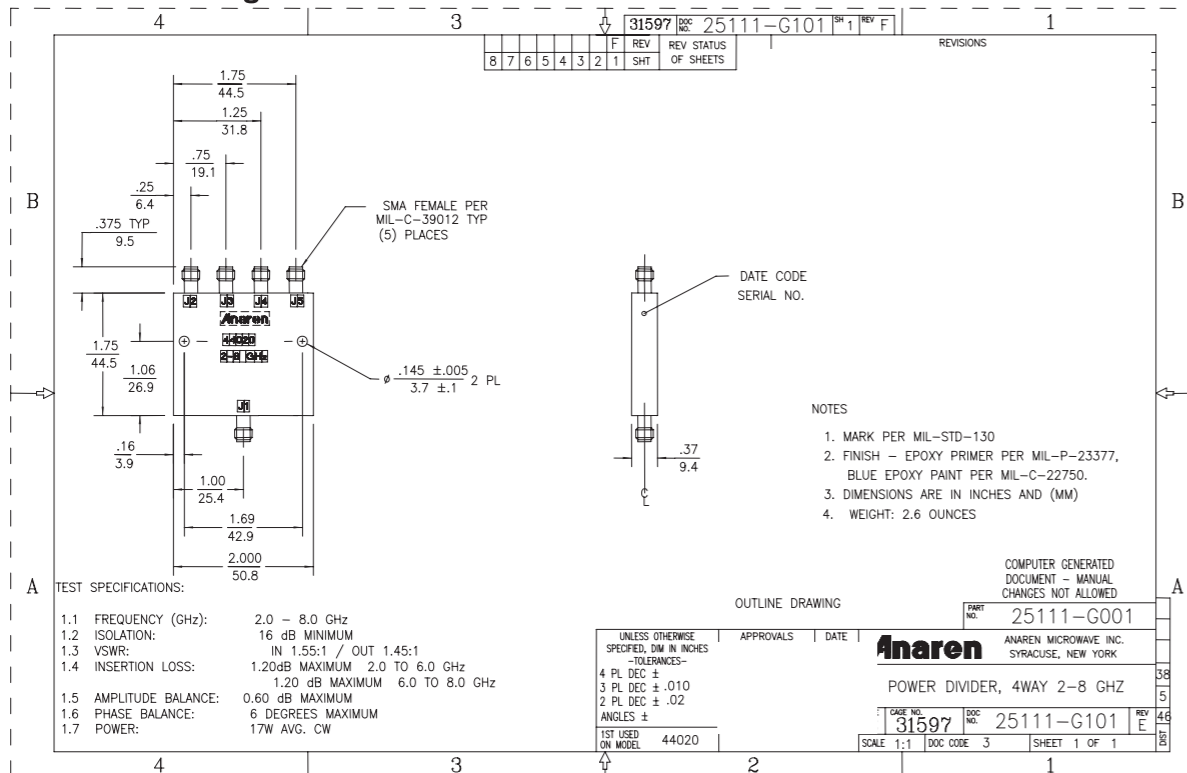
Features

- Military Grade
- 2.0 – 8.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 2 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Model 44100

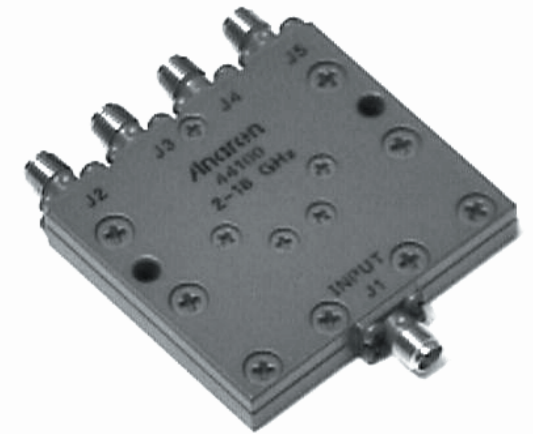
Power Dividers 4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

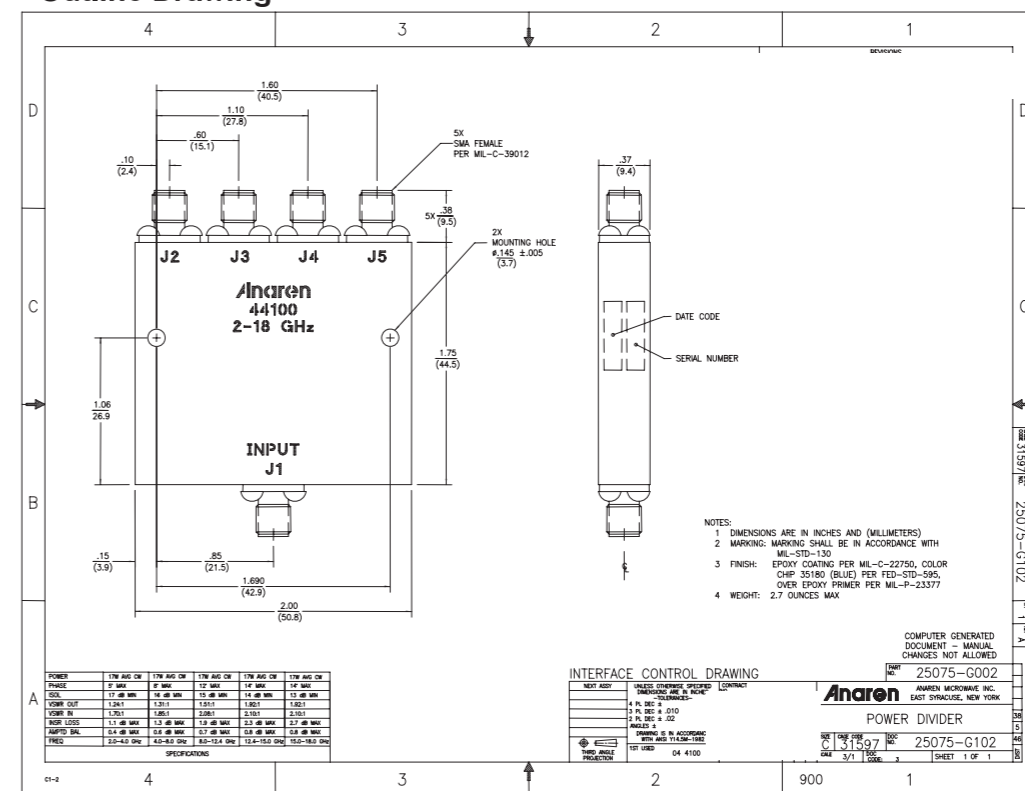
Features

- Military Grade
- 2.0 – 18.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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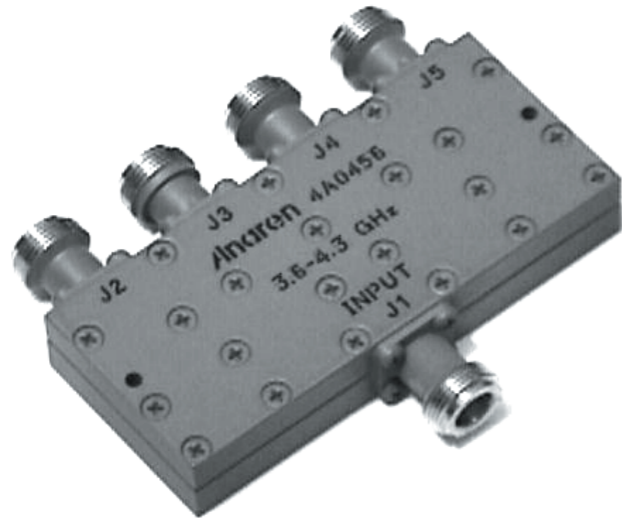


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Model 4A0456



Power Dividers 4-Way



Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 3.6 – 4.3 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 44040

Power Dividers 4-Way



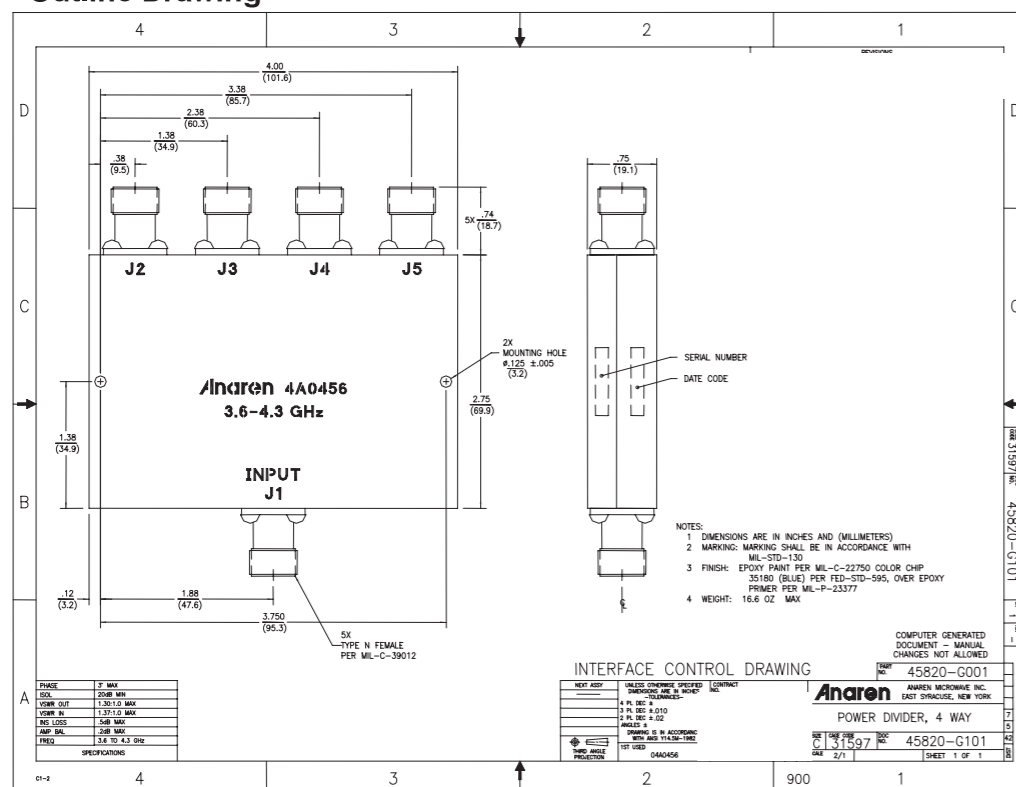
Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

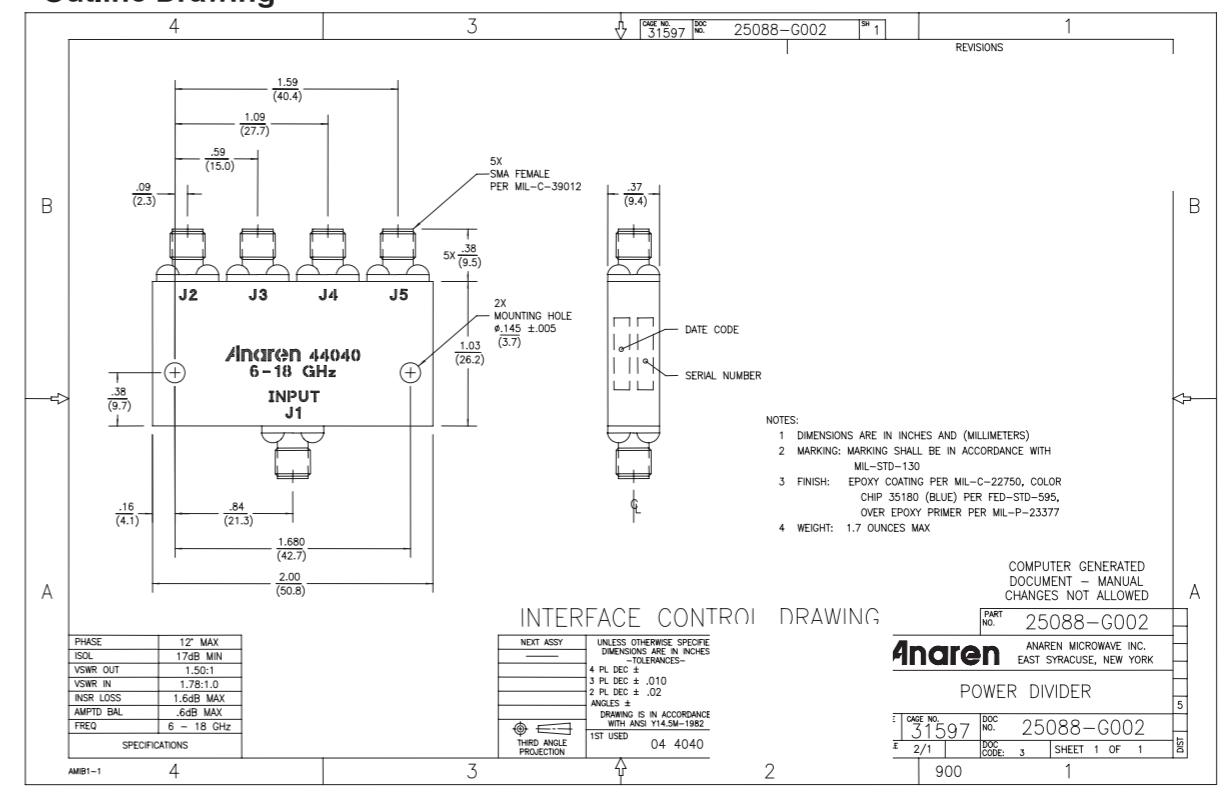
Features

- Military Grade
- 6.0 – 18.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements

Outline Drawing NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Outline Drawing NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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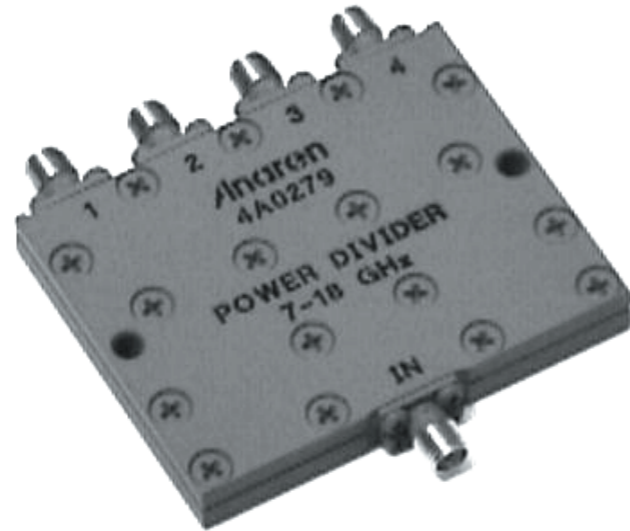
Power Dividers
4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

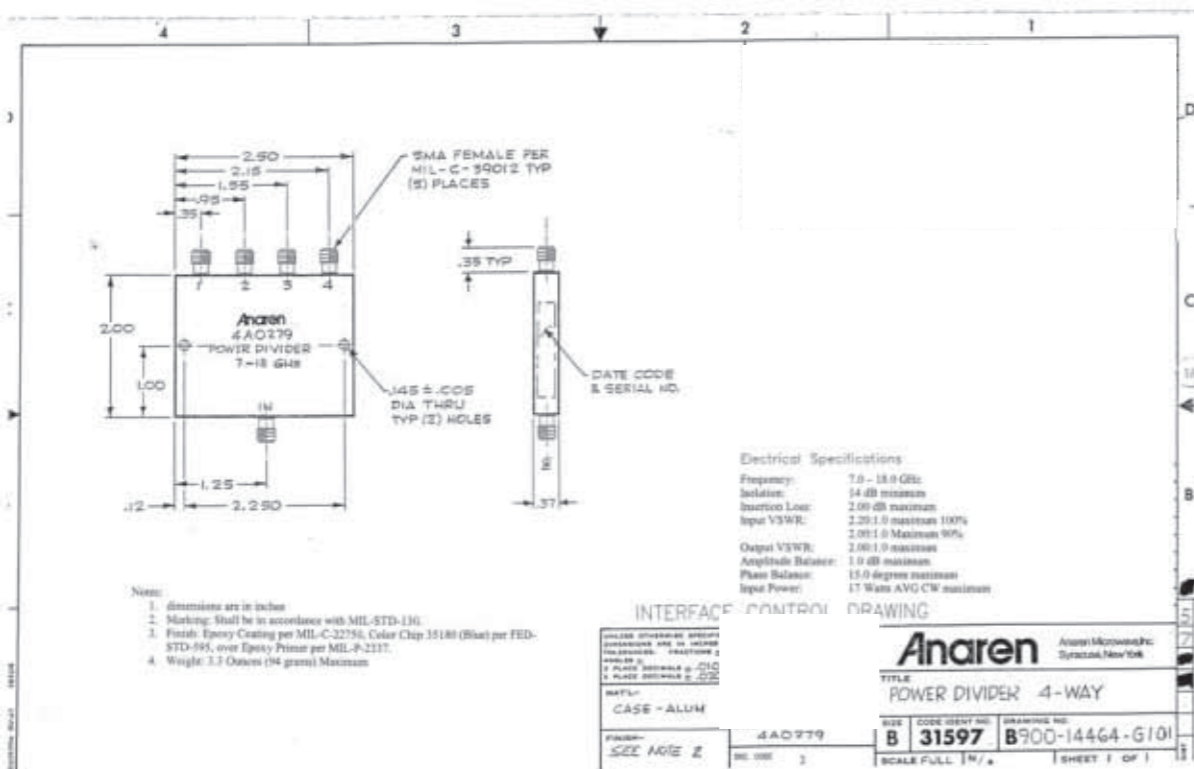
Features

- Military Grade
- 7.0 – 18.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



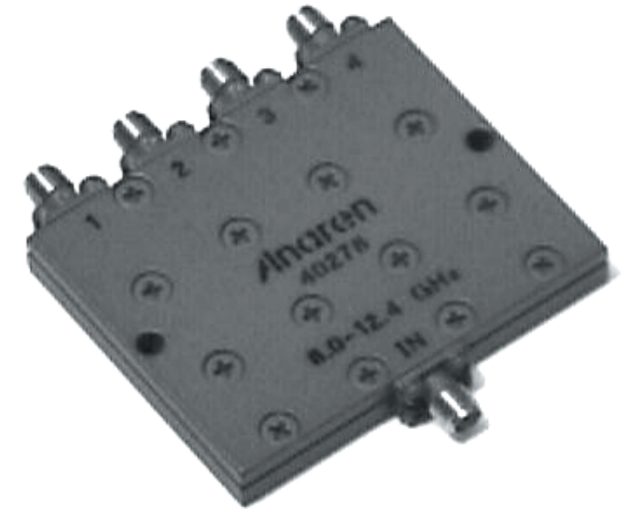
Power Dividers
4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

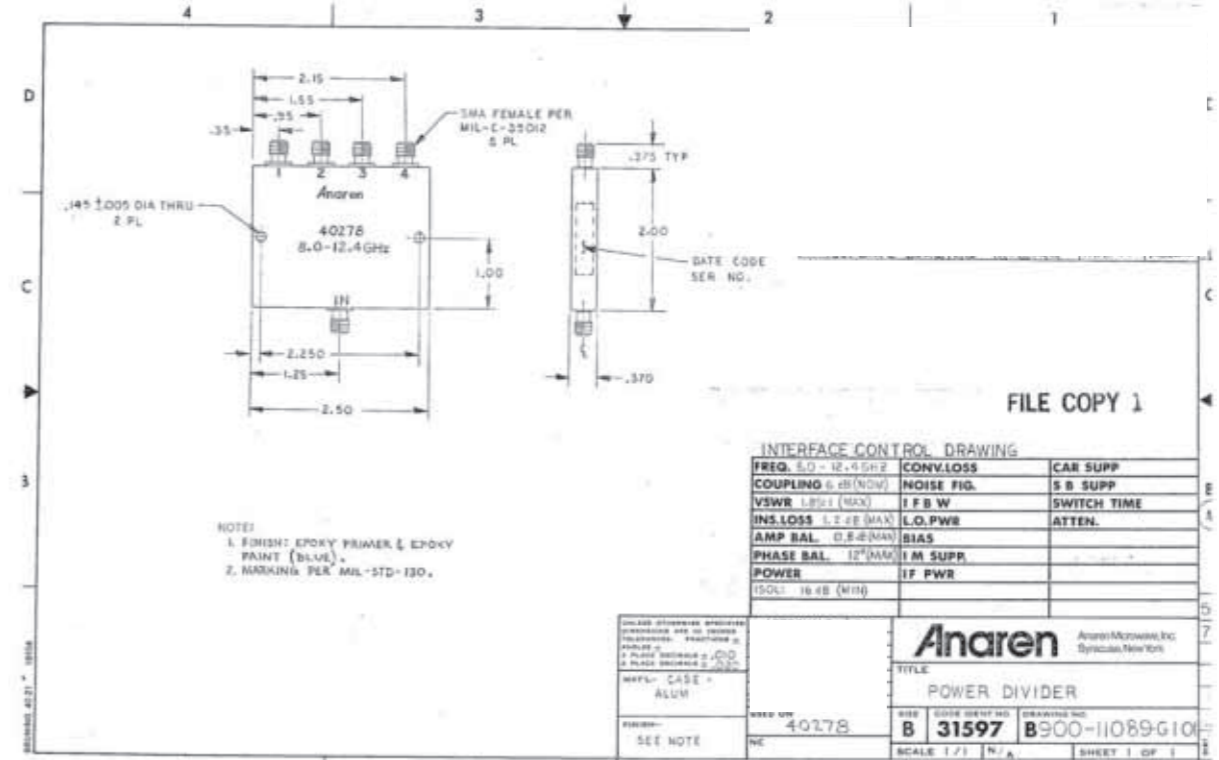
Features

- Military Grade
- 8.0 – 12.4 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Model 40279



Power Dividers 4-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

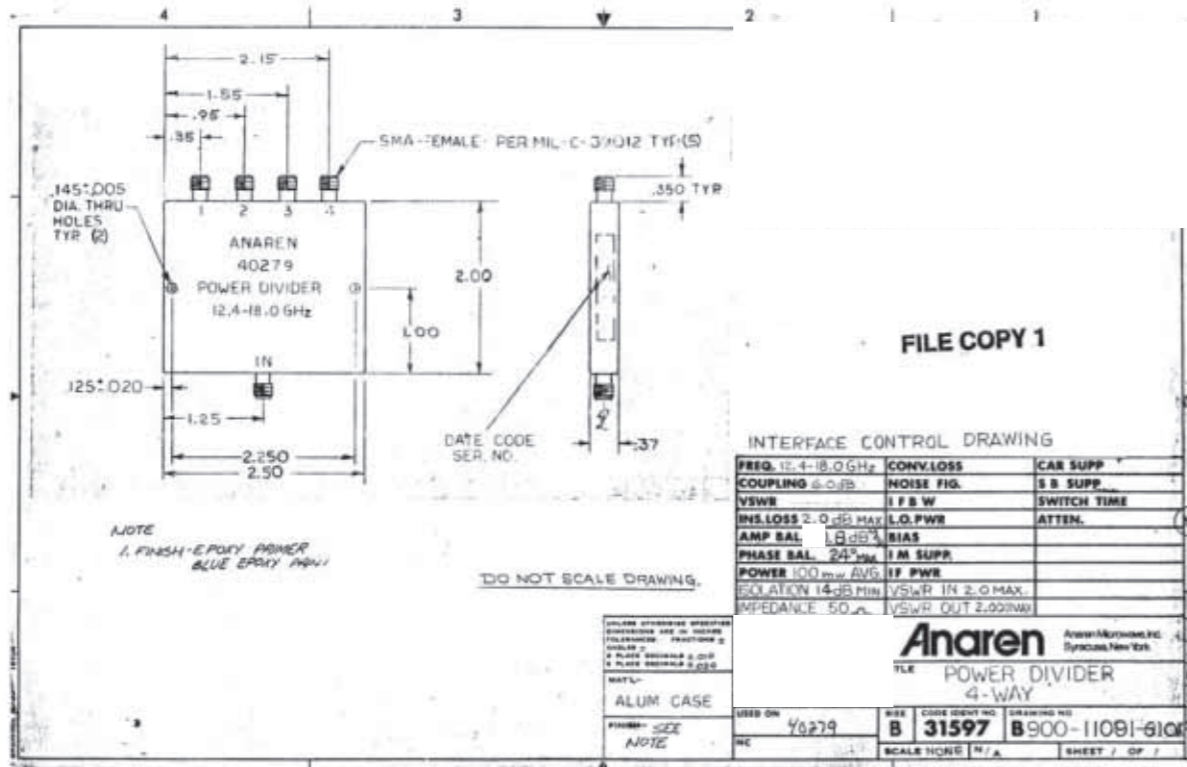
Features

- Military Grade
- 12.4 – 18.0 GHz
- 4-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 4A0286

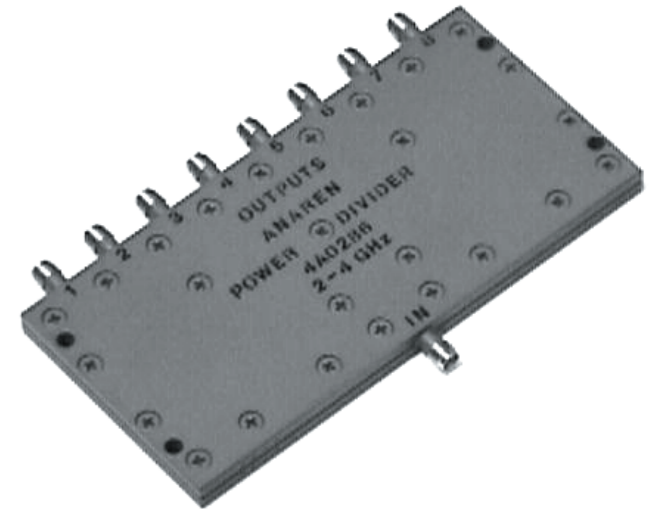
Power Dividers 8-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

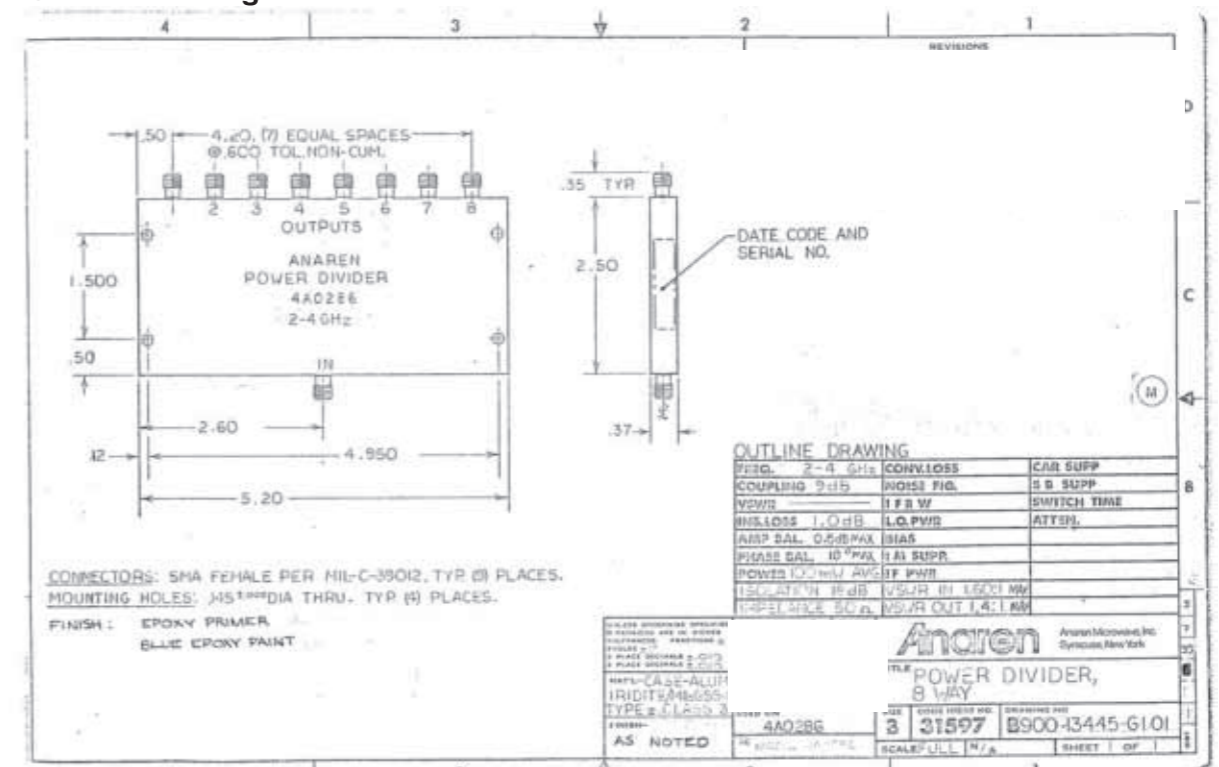
Features

- Military Grade
- 2.0 – 4.0 GHz
- 8-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Model 41730



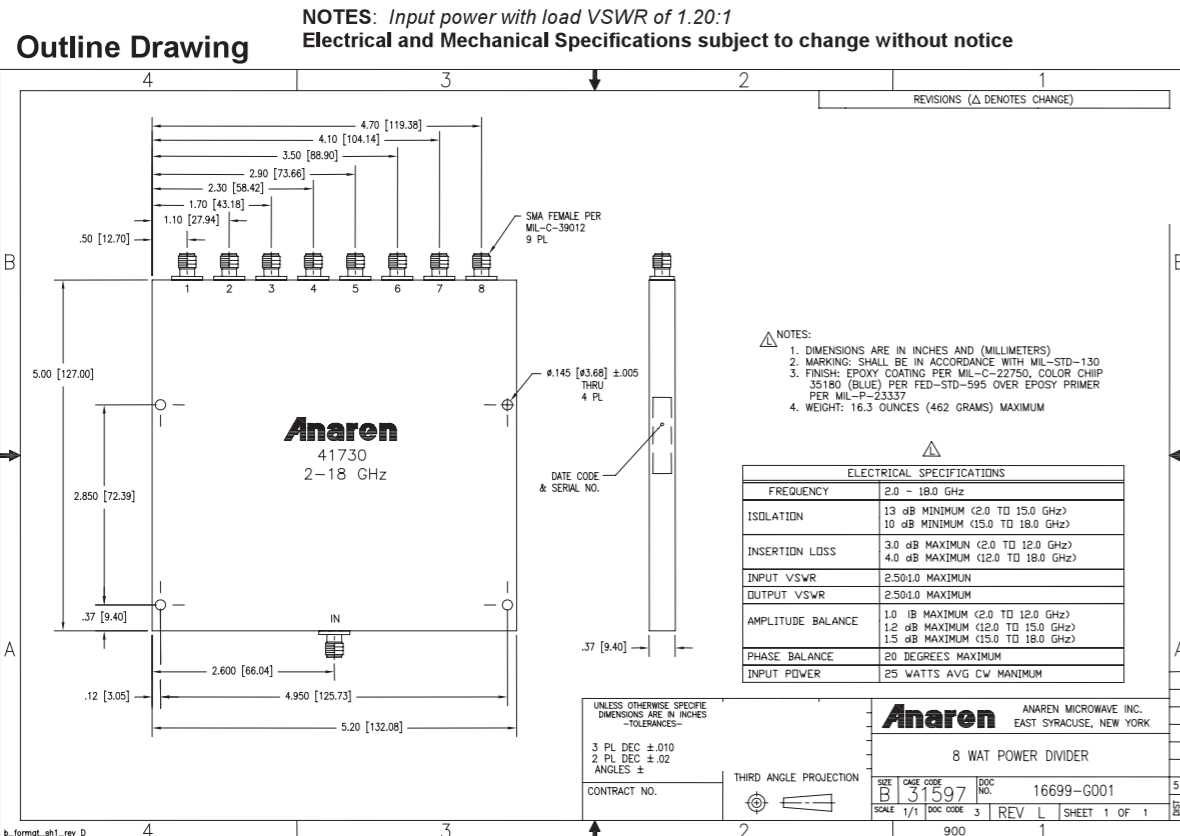
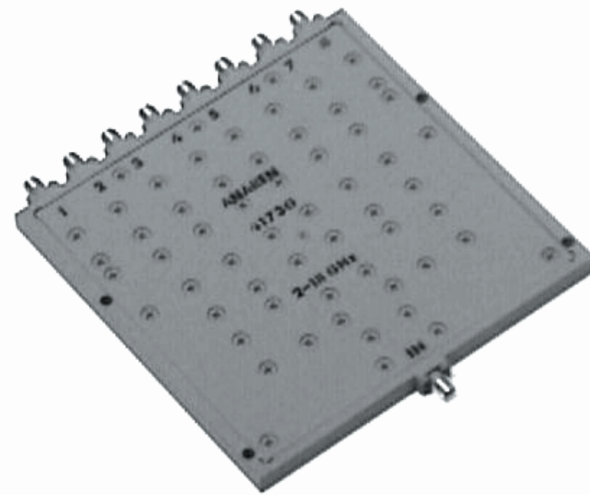
Power Dividers 8-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 2.0 – 18.0 GHz
- 8-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



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Model 40287

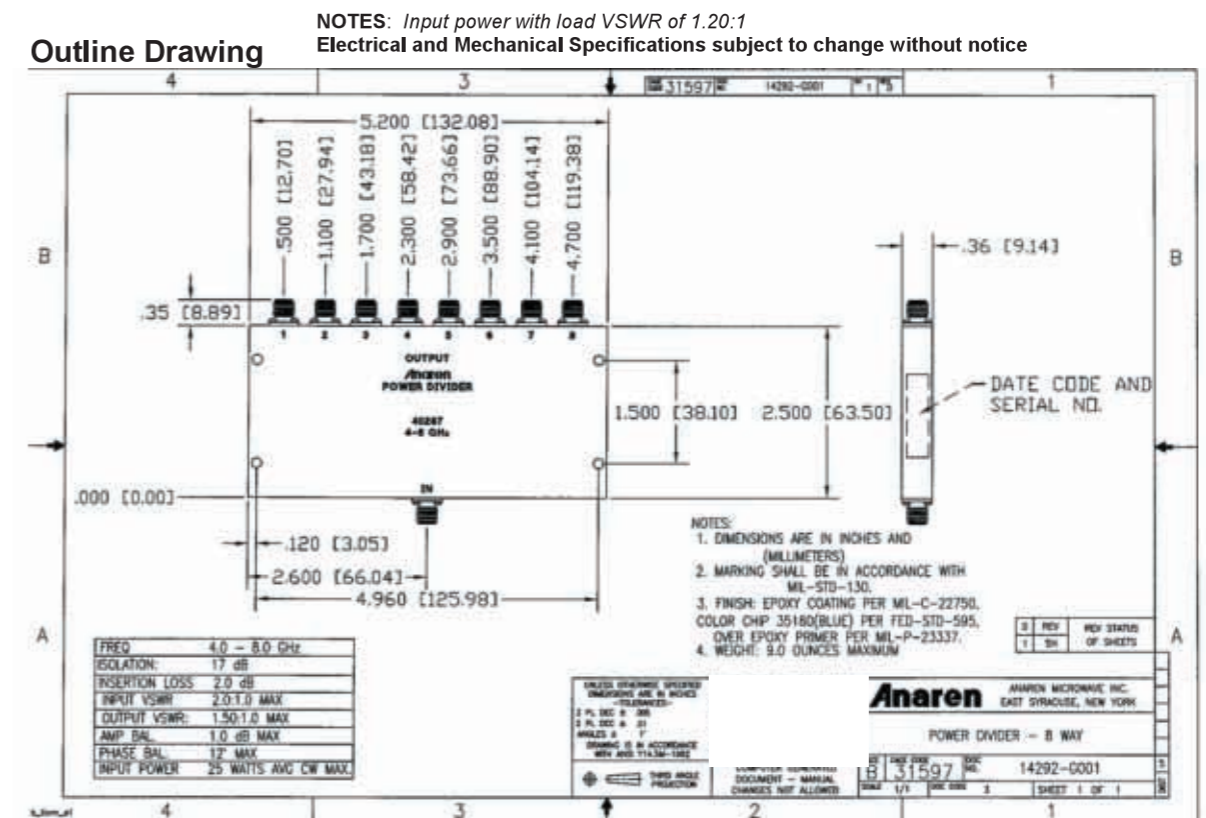
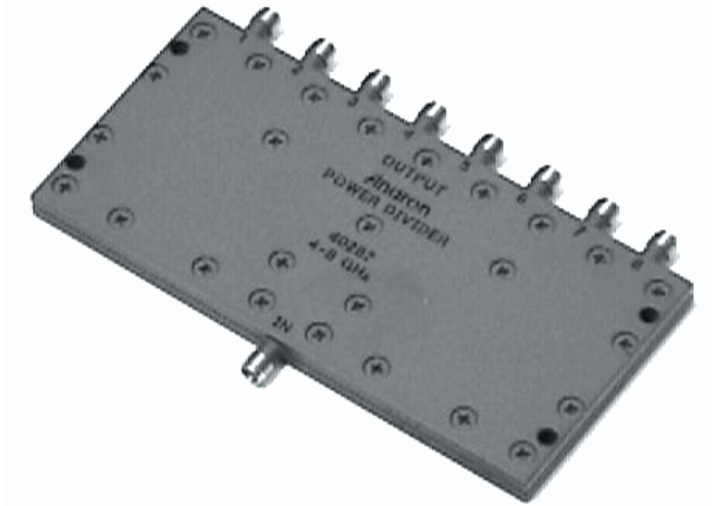
Power Dividers 8-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 4.0 – 8.0 GHz
- 8-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



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Model 4A0857



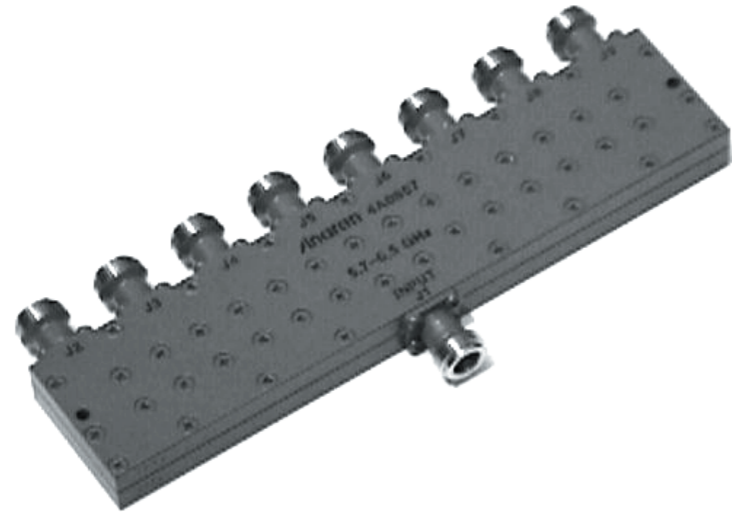
Power Dividers 8-Way

Applications

- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

- Military Grade
- 5.7 – 6.5 GHz
- 8-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Model 40288

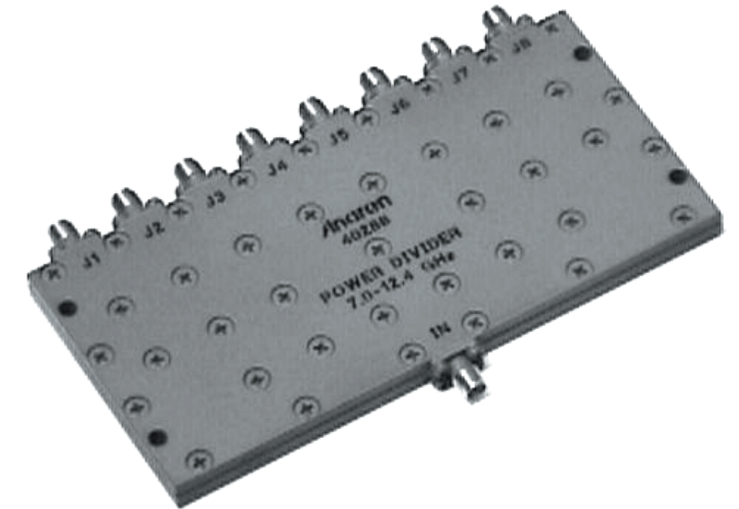
Power Dividers 8-Way

Applications

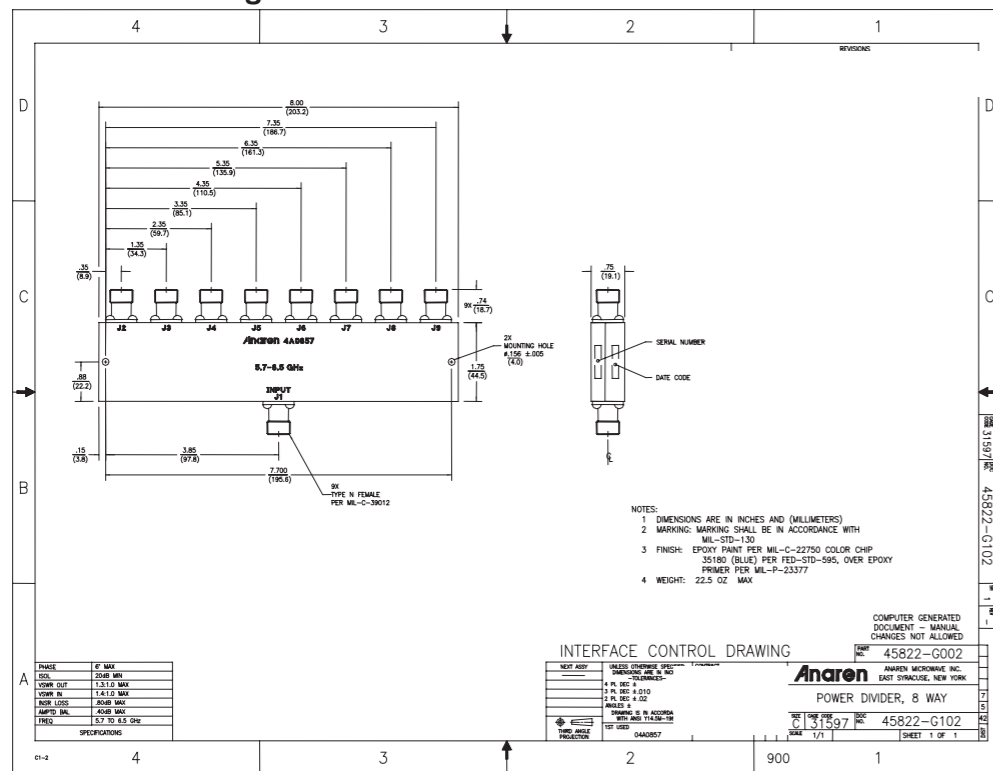
- Phased Arrays
- Antenna Feed Networks
- Image Reject Mixers
- Test Systems
- LO Power Dividers

Features

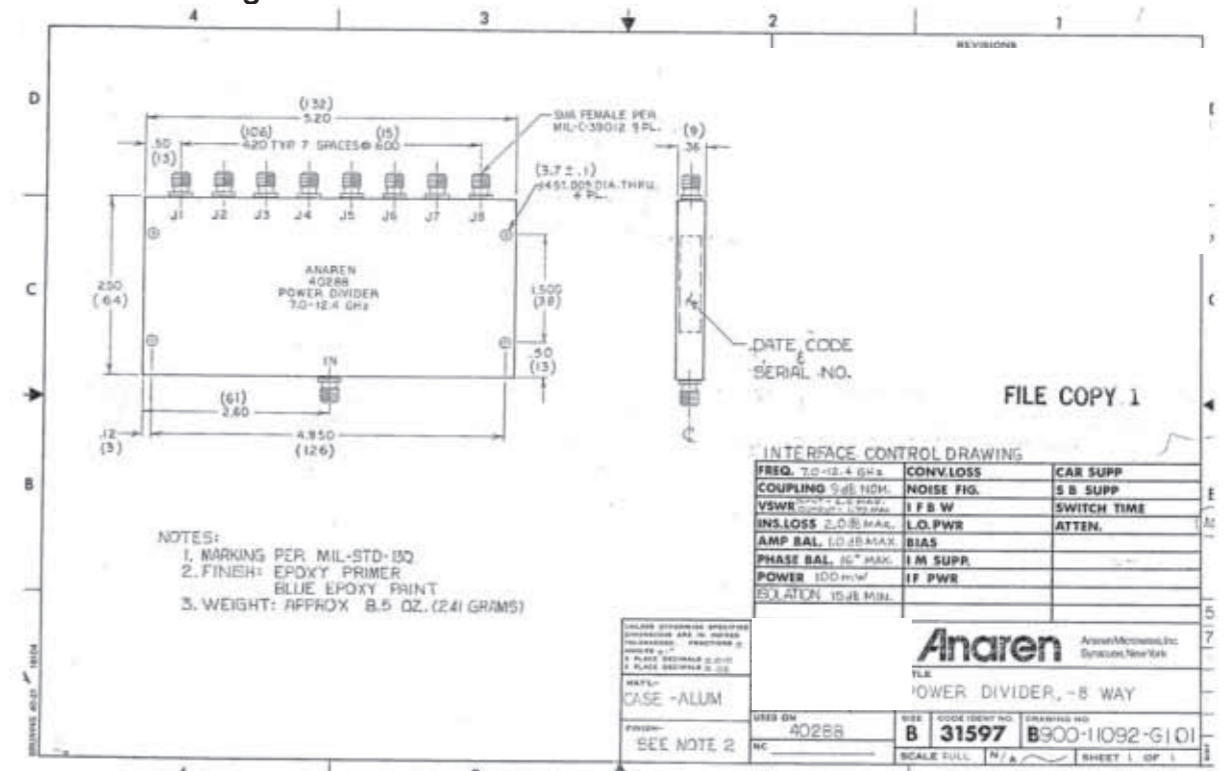
- Military Grade
- 7.0 – 12.4 GHz
- 8-Way Power Split
- In-Phase
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Low VSWR
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



Outline Drawing NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Cased Directional Couplers Selection Matrix

Directionals, H-style, cased									
Part Number	Frequency GHz	Power (W)	Size inches/ (mm)	Port Impedance (Ω)	Coupling Mean (dB)	Insertion Loss (dB)	Input VSWR (VSWR) Max :1	Frequency Sensitivity +/- (dB) Max	Directivity (dB) Min.
1F0626-10	2.0 - 4.0	50	1.61 x 0.58	50	10+/- .8	0.4	1.25	0.8	20
1F0626-20	2.0 - 4.0	100	1.61 x 0.58	50	20+/-1.5	0.4	1.25	1.25	18
1F0627-10	4.0 - 8.0	50	1.08 x 0.58	50	10+/- .8	0.4	1.25	0.8	15

Directionals, In-line, cased									
Part Number	Frequency GHz	Power (W)	Size inches/ (mm)	Port Impedance (Ω)	Coupling Mean (dB)	Insertion Loss (dB) Max	Input VSWR (VSWR) Max :1	Frequency Sensitivity +/- (dB) Max	Directivity (dB) Min
10010-10	0.225 - 0.4	50	4.9 x 1.4	50	10+/- .8	0.4	1.15	0.8	20
10013-10	0.25 - 0.5	50	6 x 1.2	50	10+/- .8	0.4	1.15	0.8	20
10013-20	0.25 - 0.5	100	6 x 1.2	50	20+/-1.	0.4	1.15	0.8	17
10014-30	0.5 - 1.0	100	3.7 x 1.2	50	30+/-1.5	0.4	1.2	0.9	15
10870-10	0.5 - 2.0	50	4 x 1.2	50	10+/-1.2	0.5	1.25	1	17
1C0870-20	0.5 - 4.0	100	4.9 x 1.4	50	20+/-1.5	0.5	1.3	1.5	17
10930-10	0.8 - 1.6	50	3.7 x 1.2	50	10+/- .8	0.35	1.2	0.8	20
10930-6	0.8 - 1.6	20	3.7 x 1.2	50	6+/- .8	0.35	1.2	0.8	20
10615-10	1.0 - 2.0	50	2.5 x 1	50	10+/- .8	0.35	1.2	0.8	20
10615-20	1.0 - 2.0	100	2.5 x 1	50	20+/-1.	0.35	1.2	0.8	20
10615-30	1.0 - 2.0	100	2.5 x 1	50	30+/-1.5	0.35	1.2	0.8	15
10616-10	2.0 - 4.0	50	2.44 x 1.25	50	10+/- .8	0.45	1.25	0.8	18
10616-20	2.0 - 4.0	100	2.44 x 1.25	50	20+/-1.	0.45	1.25	0.8	18
10616-30	2.0 - 4.0	100	2.44 x 1.25	50	30+/-2.	0.45	1.25	0.8	15
10616-6	2.0 - 4.0	20	2.44 x 1.25	50	6+/- .8	0.45	1.25	0.8	18
1G0617-10	4.0 - 8.0	50	1.3 x 0.9	50	10+/- .8	0.5	1.35	0.8	17
1G0617-20	4.0 - 8.0	100	1.3 x 0.9	50	20+/-1	0.5	1.35	1	16
1G0618-10	8.0 - 12.4	50	1.3 x 0.9	50	10+/- .8	0.6	1.45	0.6	15
1G0618-20	8.0 - 12.4	100	1.3 x 0.9	50	20+/-1	0.6	1.45	0.8	15
1G0618-6	8.0 - 12.4	20	1.3 x 0.9	50	6+/- .8	0.6	1.45	0.5	15

Model 1F0626-10



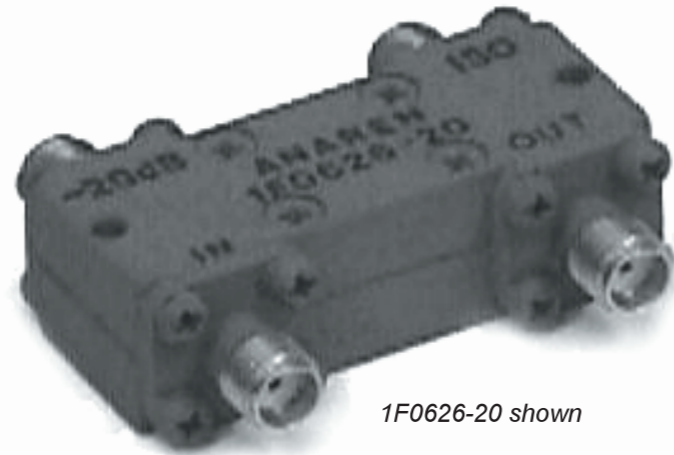
Directional Couplers "H" Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

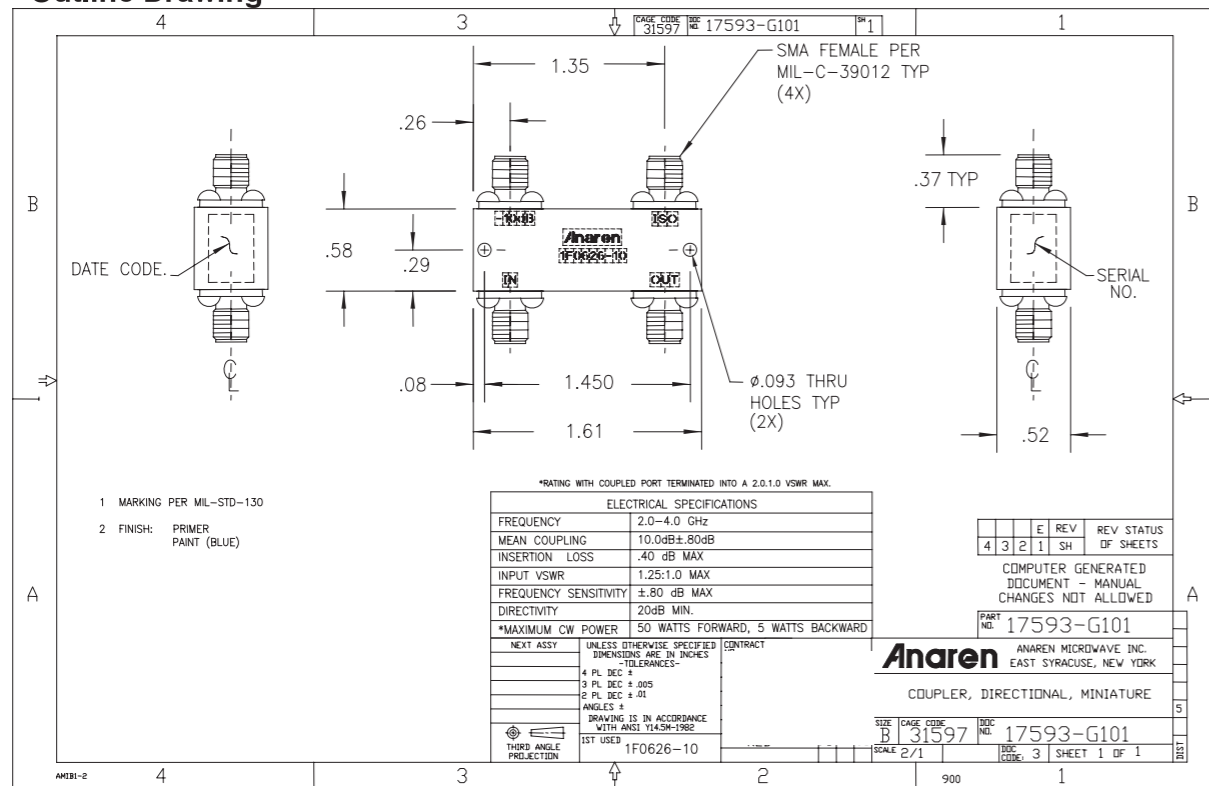
- Military Grade
- 2.0 – 4.0 GHz
- "H" Style Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- High Directivity
- Meets MIL-E-5400 Class 3 Requirements



1F0626-20 shown

NOTES: The power rating applies when optional termination is supplied by Anaren and coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 1F0626-20

Directional Couplers "H" Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

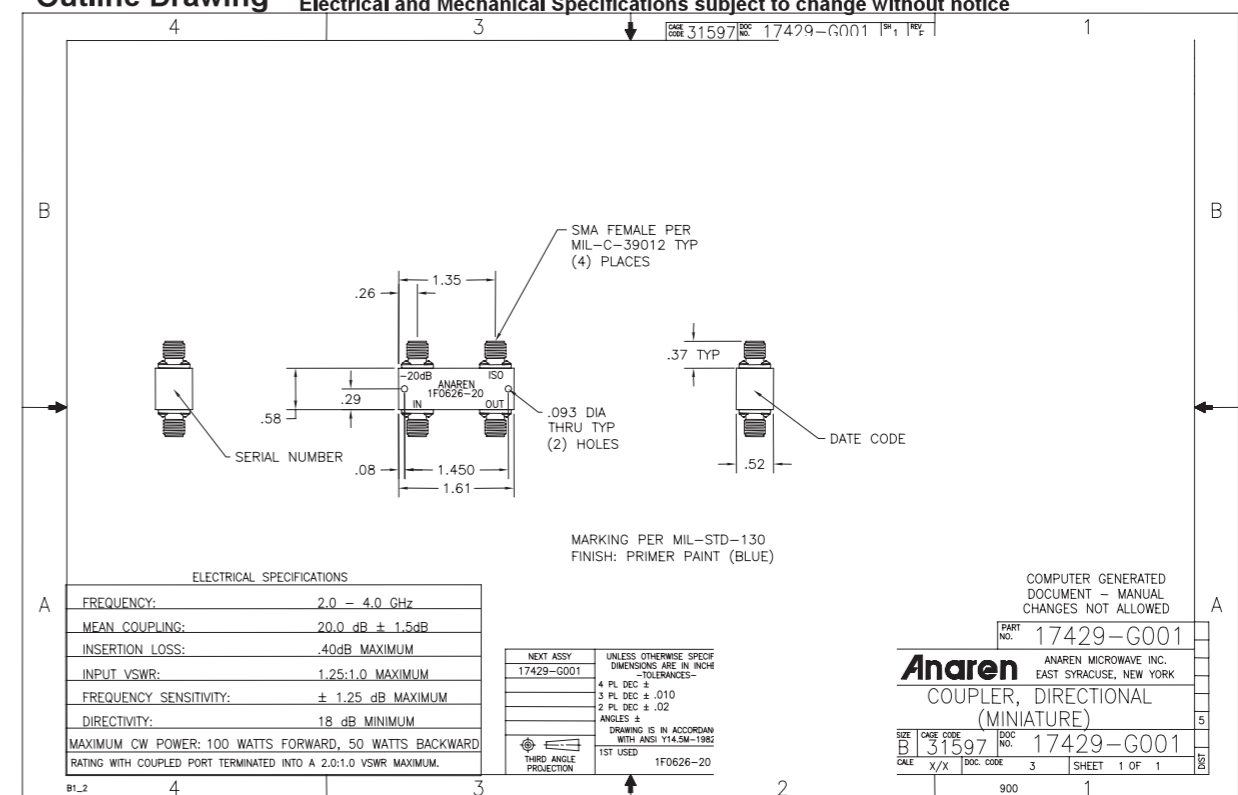
Features

- Military Grade
- 2.0 – 4.0 GHz
- "H" Style Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- High Directivity
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when optional termination is supplied by Anaren and coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Directional Couplers
H" Style



Applications

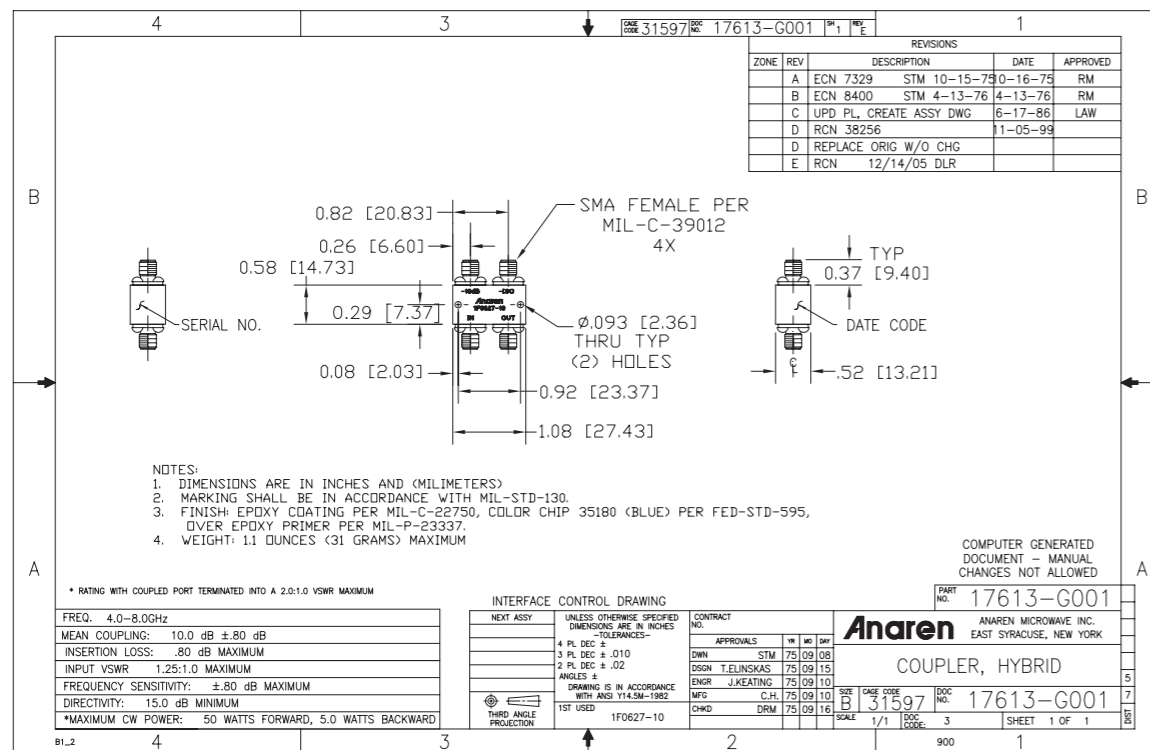
- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

- Military Grade
- 4.0 – 8.0 GHz
- "H" Style Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- High Directivity
- Meets MIL-E-5400 Class 3 Requirements

NOTES: The power rating applies when optional termination is supplied by Anaren and coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

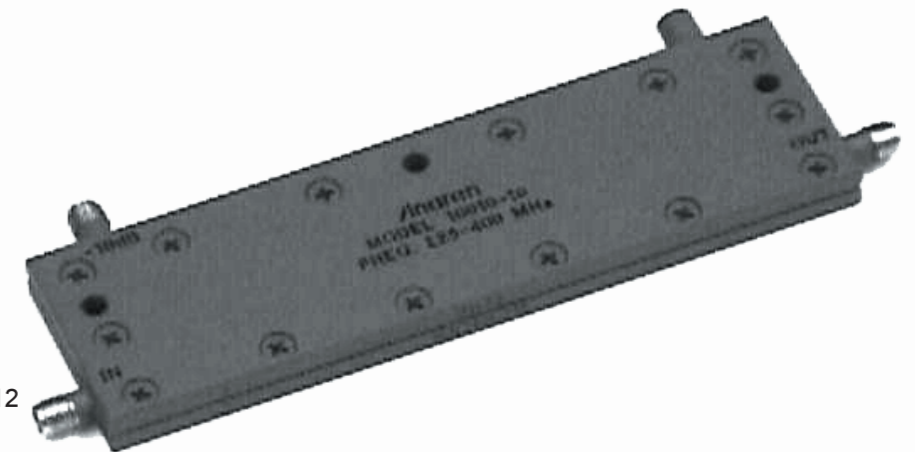
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Directional Couplers
In-Line Style



Applications

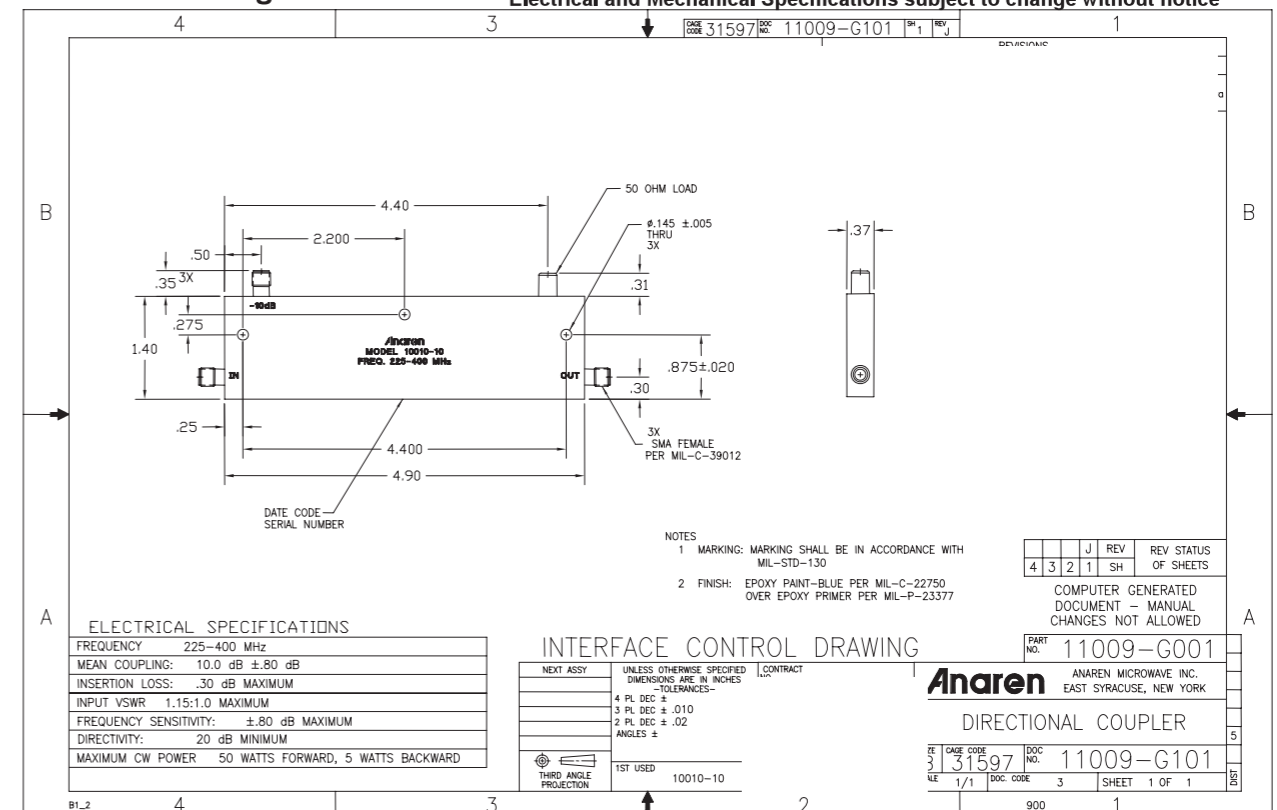
- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

- Military Grade
- 0.225 – 0.4 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

- Military Grade
- 0.25 – 0.5 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



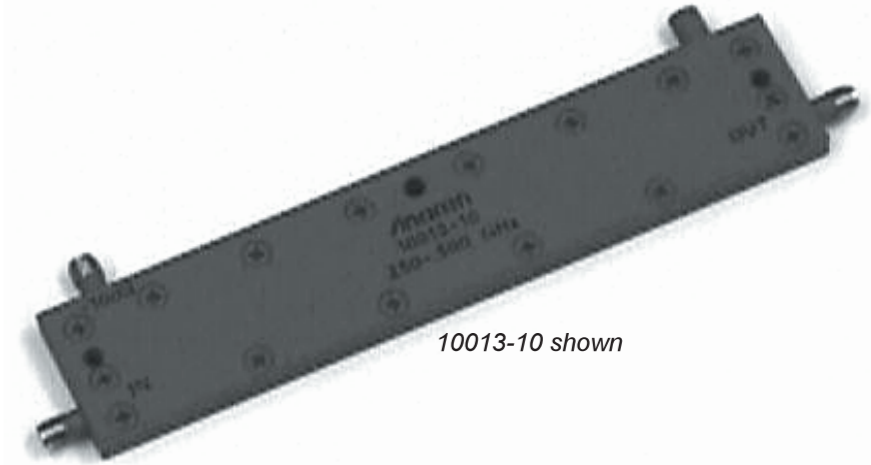
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

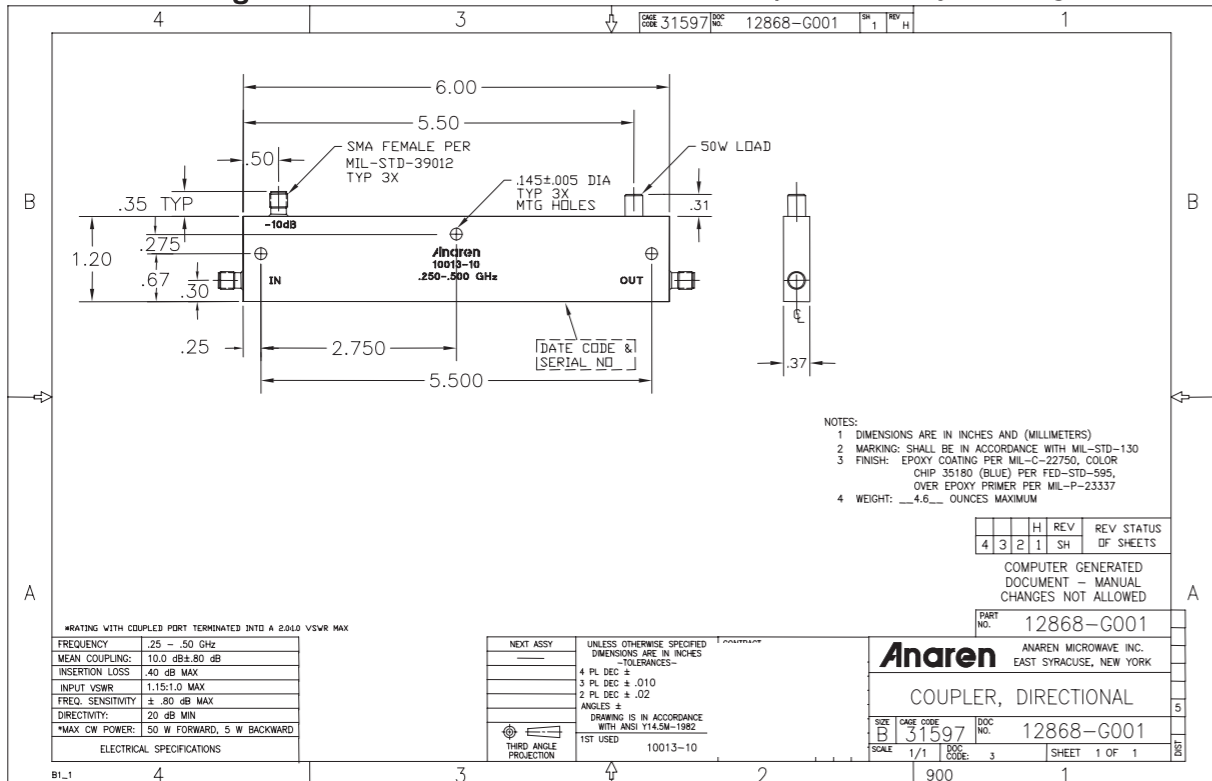
Features

- Military Grade
- 0.25 – 0.5 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



10013-10 shown

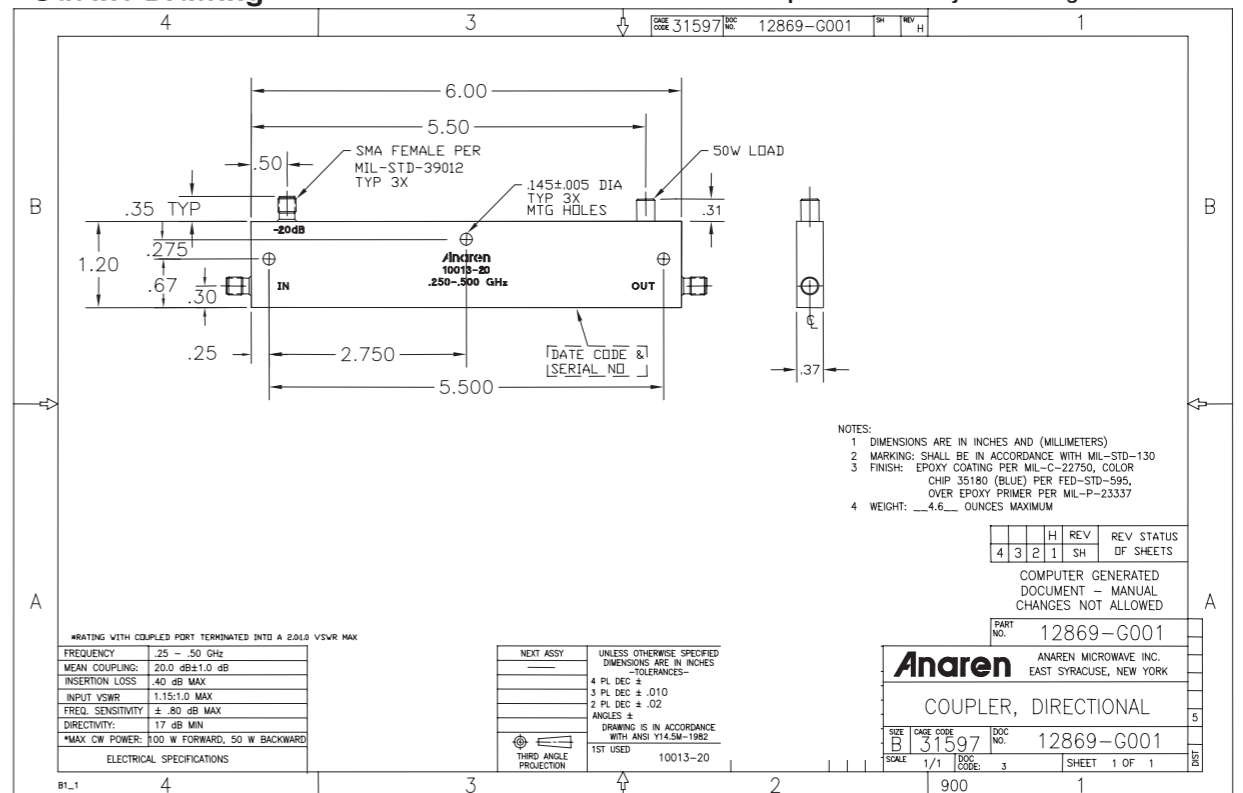
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Model 10014-30



Directional Couplers In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

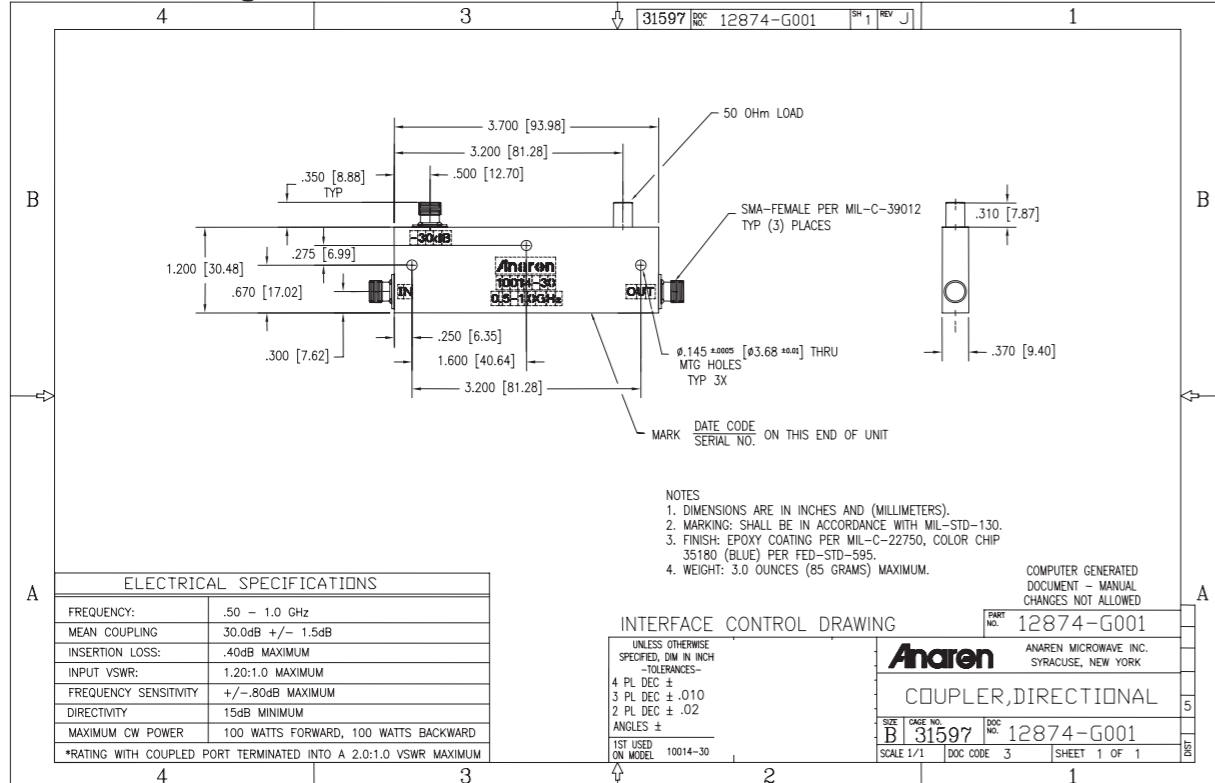
Features

- Military Grade
- 0.5 – 1.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Model 10870-10

Directional Couplers In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration



Features

- Military Grade
- 0.5 - 2.0 GHz
- "In-Line" Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination

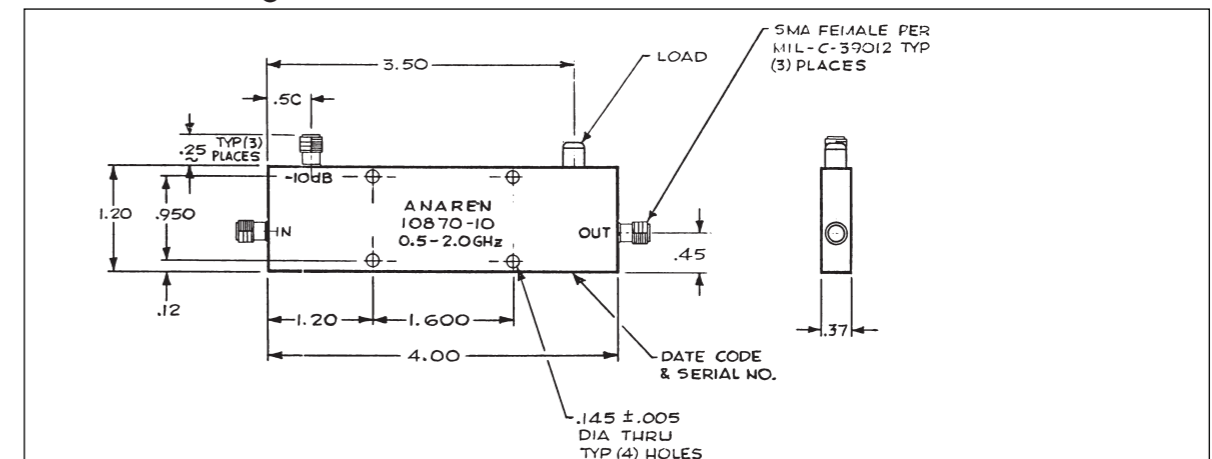
Electrical Specifications

Model#	Frequency GHz	Coupling dB Mean	Insert. Loss dB Max	Input VSWR Max:1
10870-10	0.5 - 2.0	10.0 ± 0.8	0.50	1.25

Model #	Freq. Sems. dB Max	Directivity dB Min/Typ	Max CW Power* Forward Backward
10870-10	±0.90	17/22	50 5

Notes: Electrical and Mechanical Specifications subject to change without notice. Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. *These power ratings apply when coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination. In general the Max CW Power is identical to 3 dB couplers when there is no internal termination or one supplied by Anaren. All models have SMA connectors.

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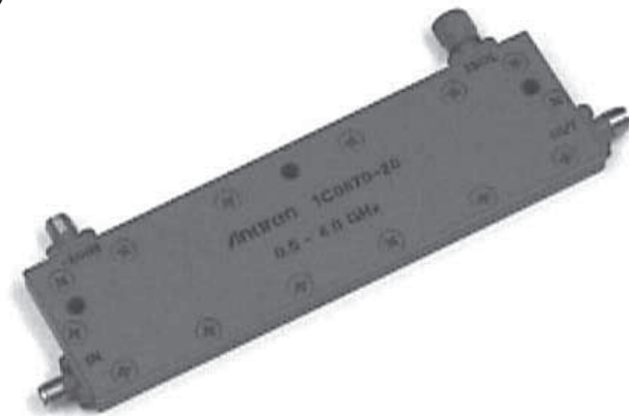
Directional Couplers "In-Line" Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

- Military Grade
- 0.5 - 4.0 GHz
- "In-Line" Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination



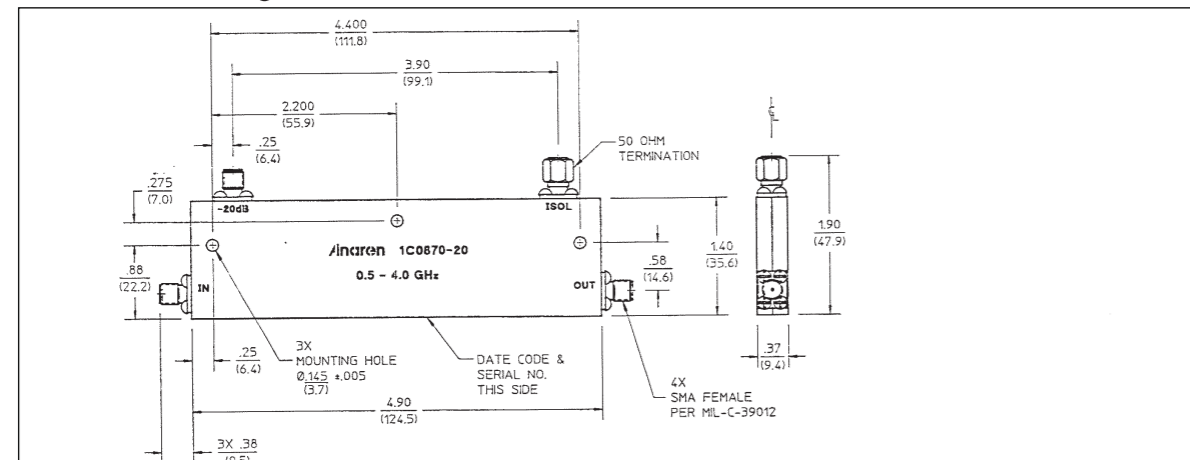
Electrical Specifications

Model#	Frequency GHz	Coupling dB Mean	Insert. Loss dB Max	Input VSWR Max:1
1C0870-20	0.5 - 4.0	20.0 ± 1.5	0.50	1.30

Model #	Freq. Sems. dB Max	Directivity dB Min/Typ	Max CW Power* Forward Backward
1C0870-20	±1.5	17/20	100 50

Notes: Electrical and Mechanical Specifications subject to change without notice. Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. *These power ratings apply when coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination. In general the Max CW Power is identical to 3 dB couplers when there is no internal termination or one supplied by Anaren. All models have SMA connectors.

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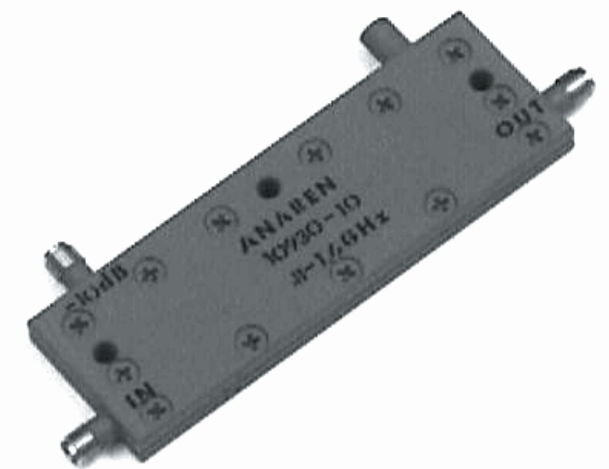
Directional Couplers In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

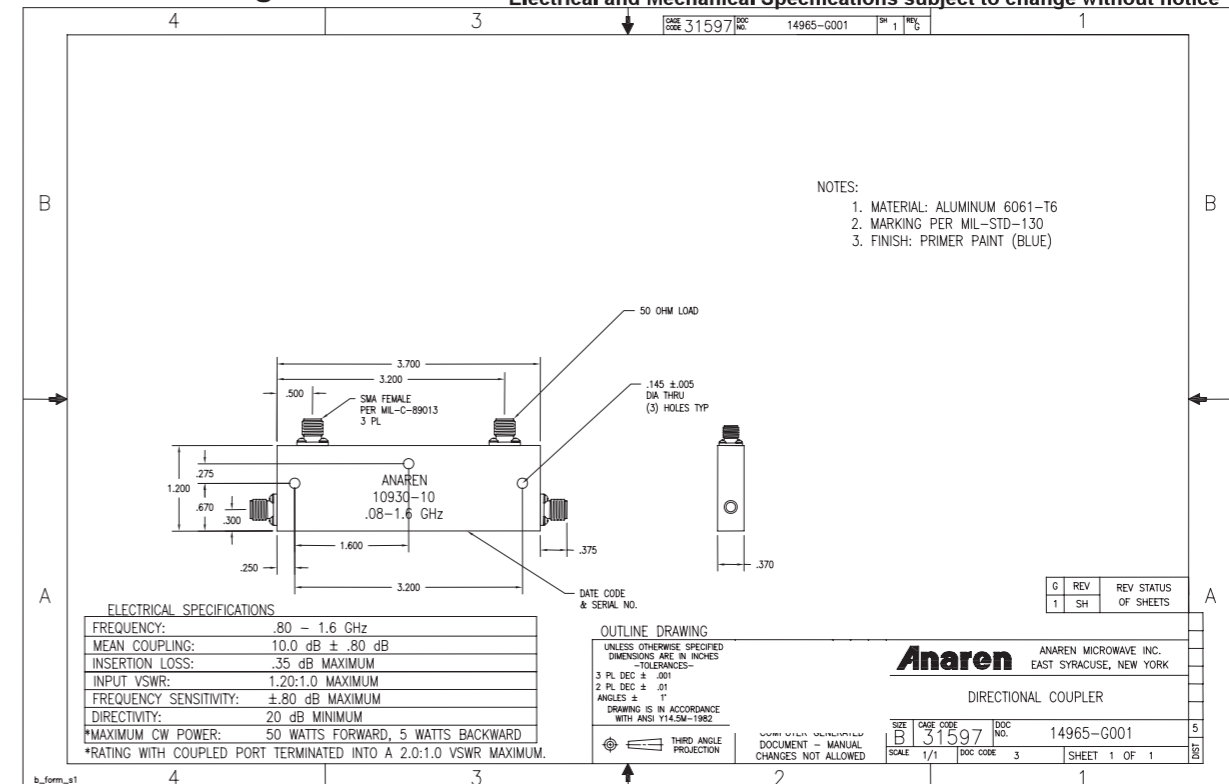
Features

- Military Grade
- 0.8 - 1.6 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less. Higher power can be handled with a lower VSWR termination. Electrical and Mechanical Specifications subject to change without notice.

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Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

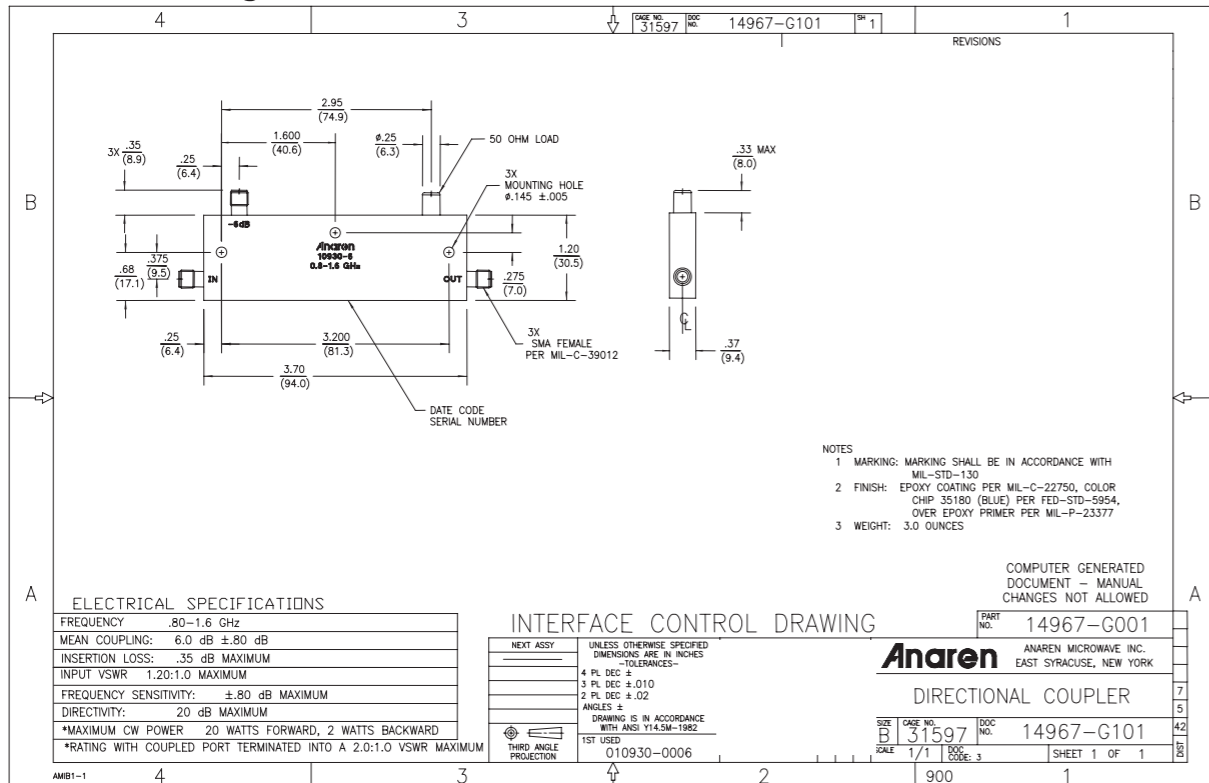
Features

- Military Grade
- 0.8 – 1.6 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
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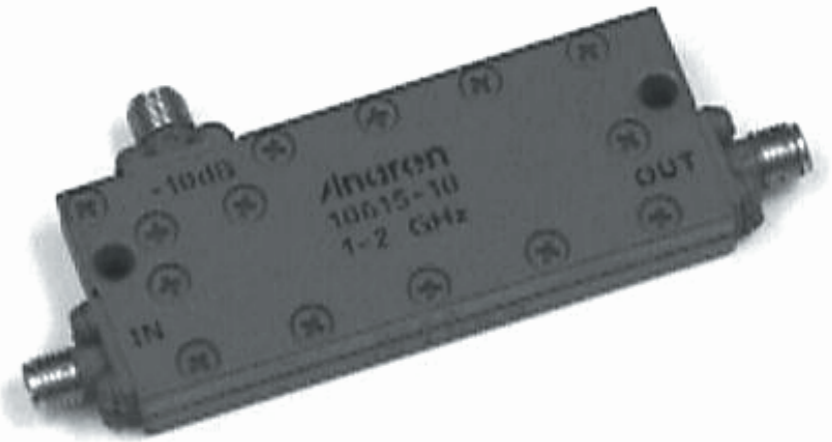
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

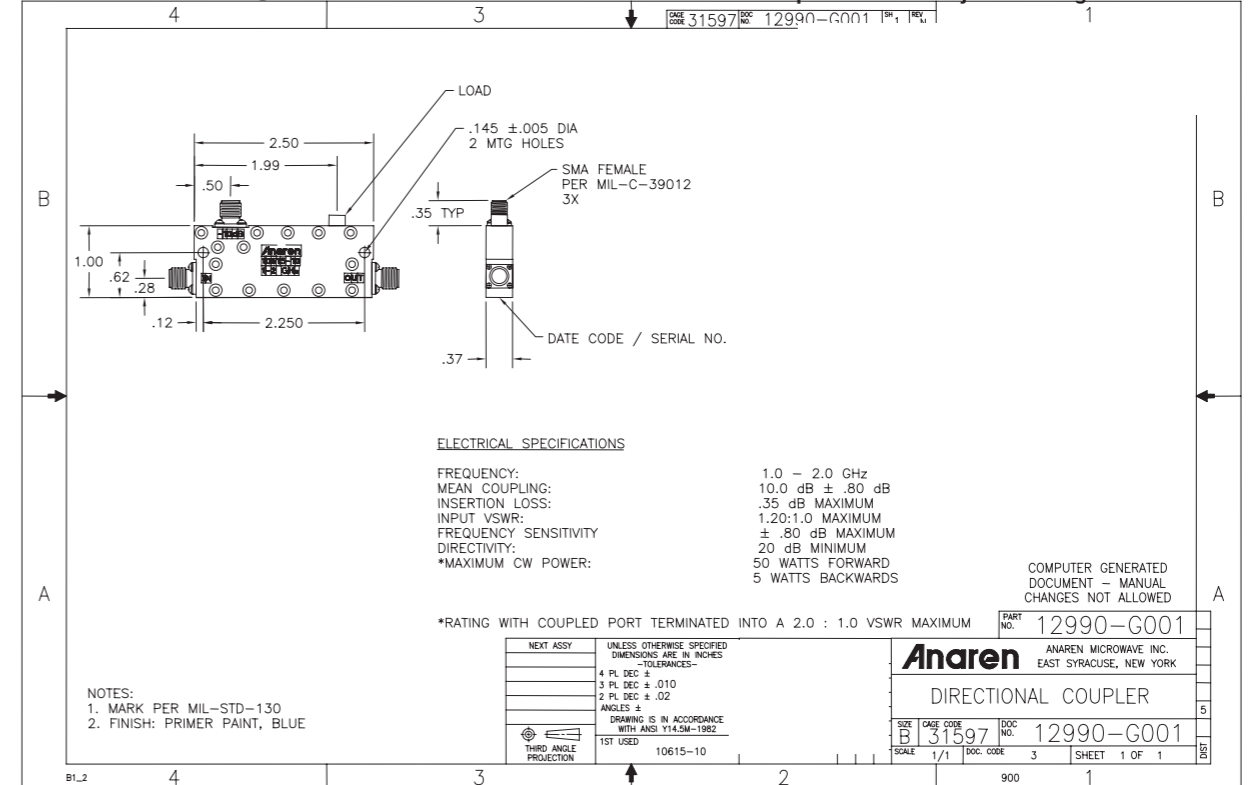
Features

- Military Grade
- 1.0 – 2.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



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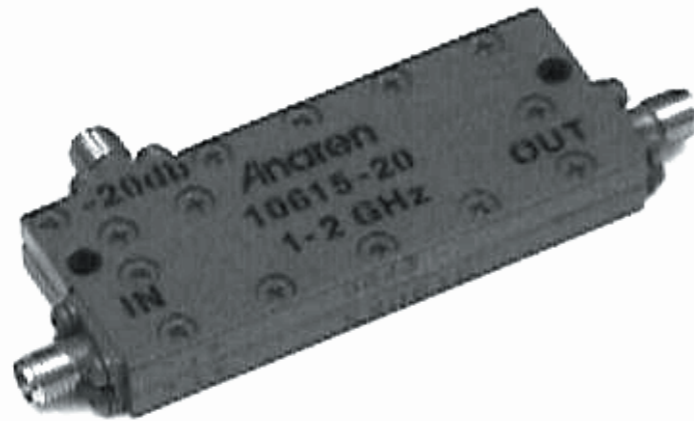
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

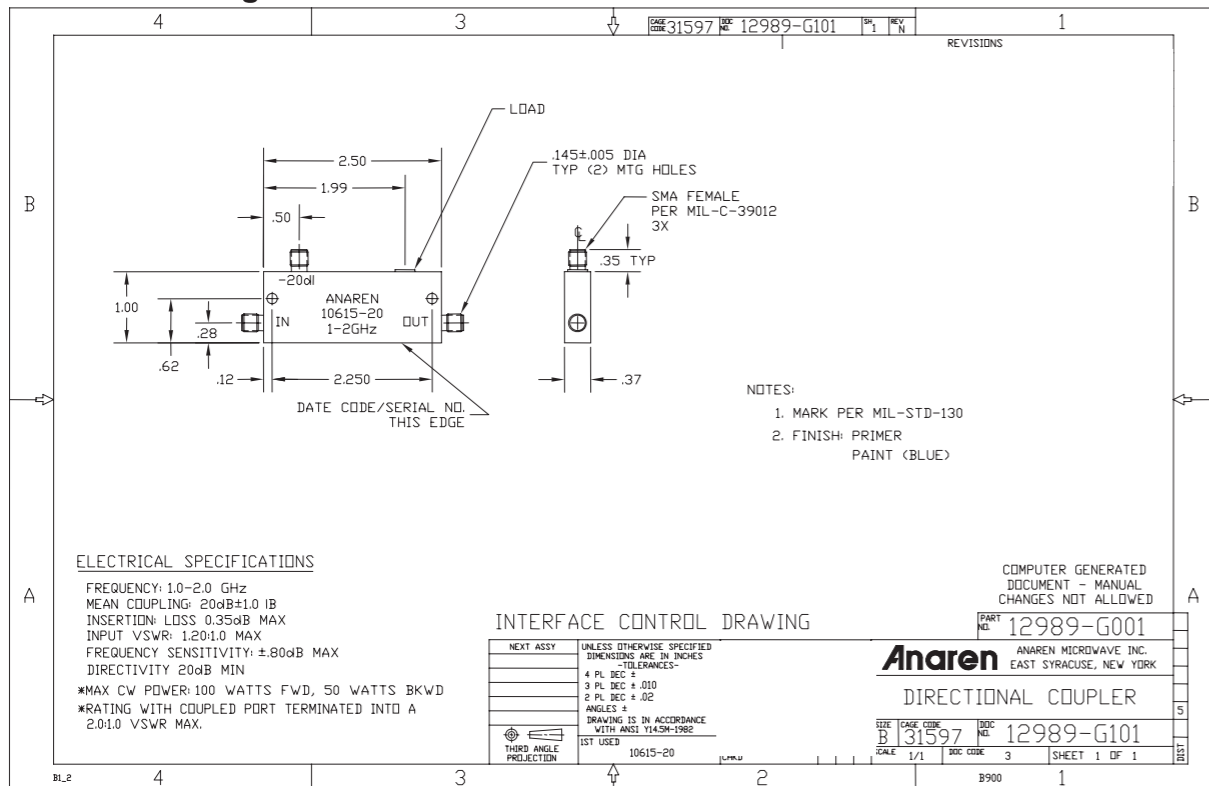
Features

- Military Grade
- 1.0 – 2.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
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NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
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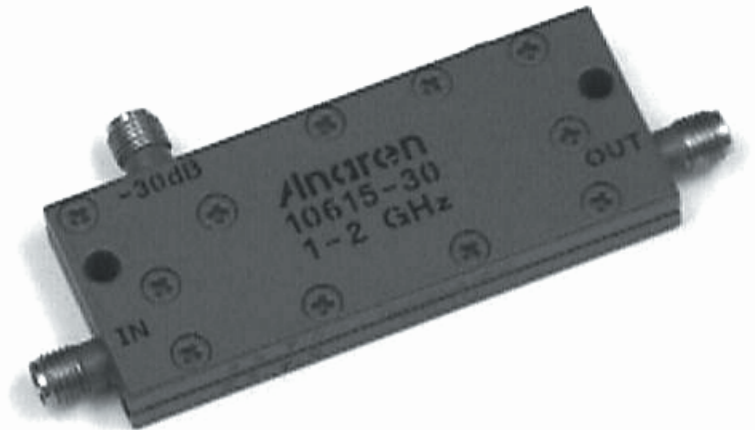
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

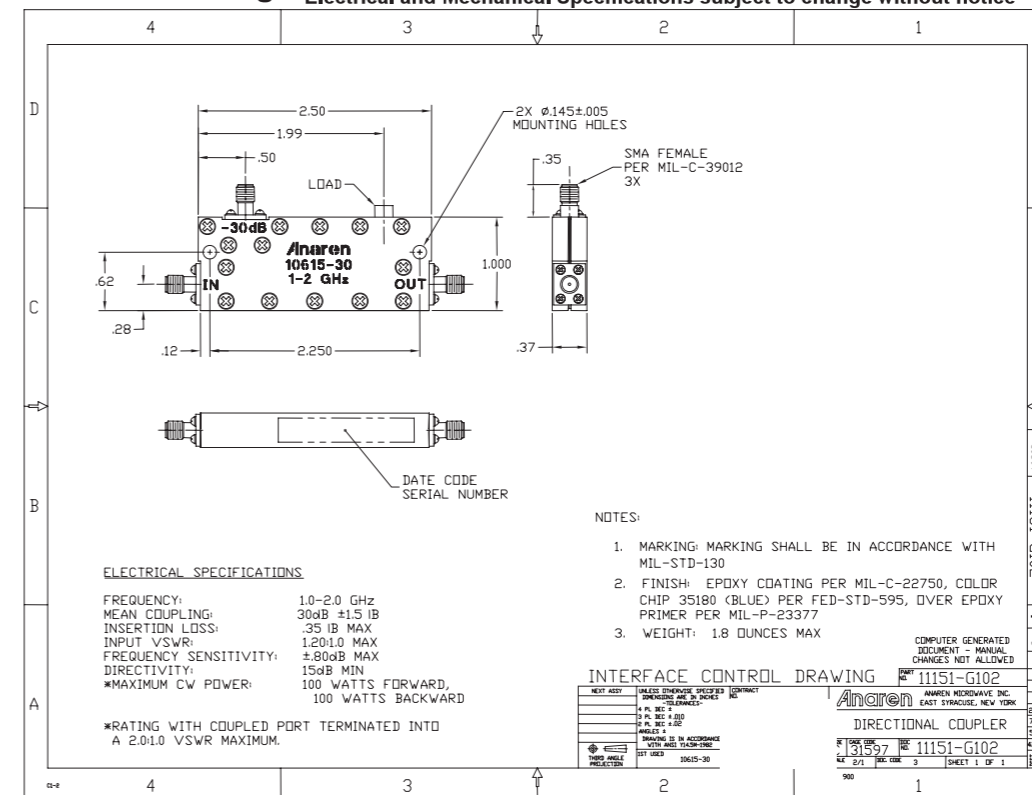
Features

- Military Grade
- 1.0 – 2.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
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Directional Couplers
In-Line Style

Applications

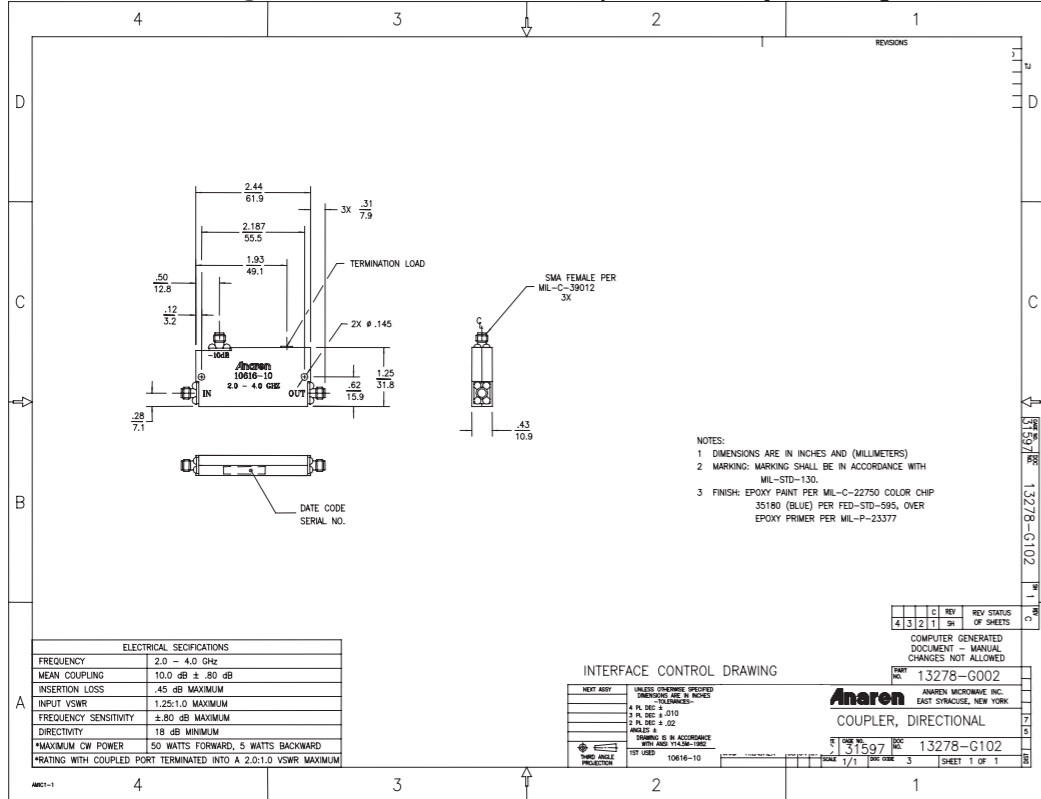
- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

- Military Grade
- 2.0 – 4.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



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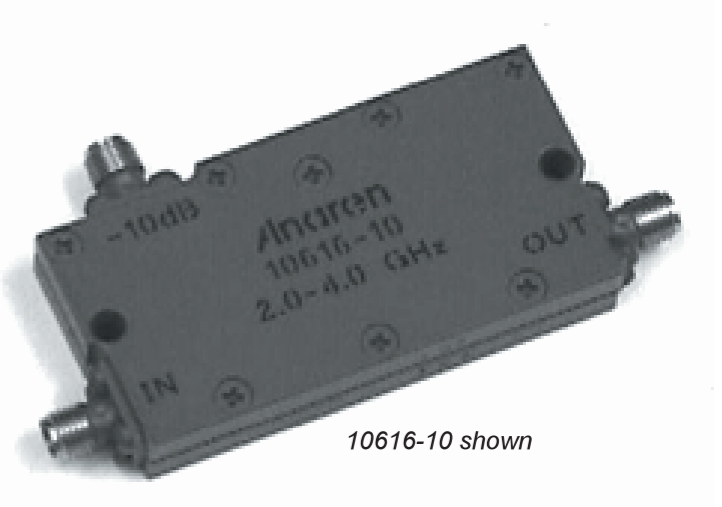
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

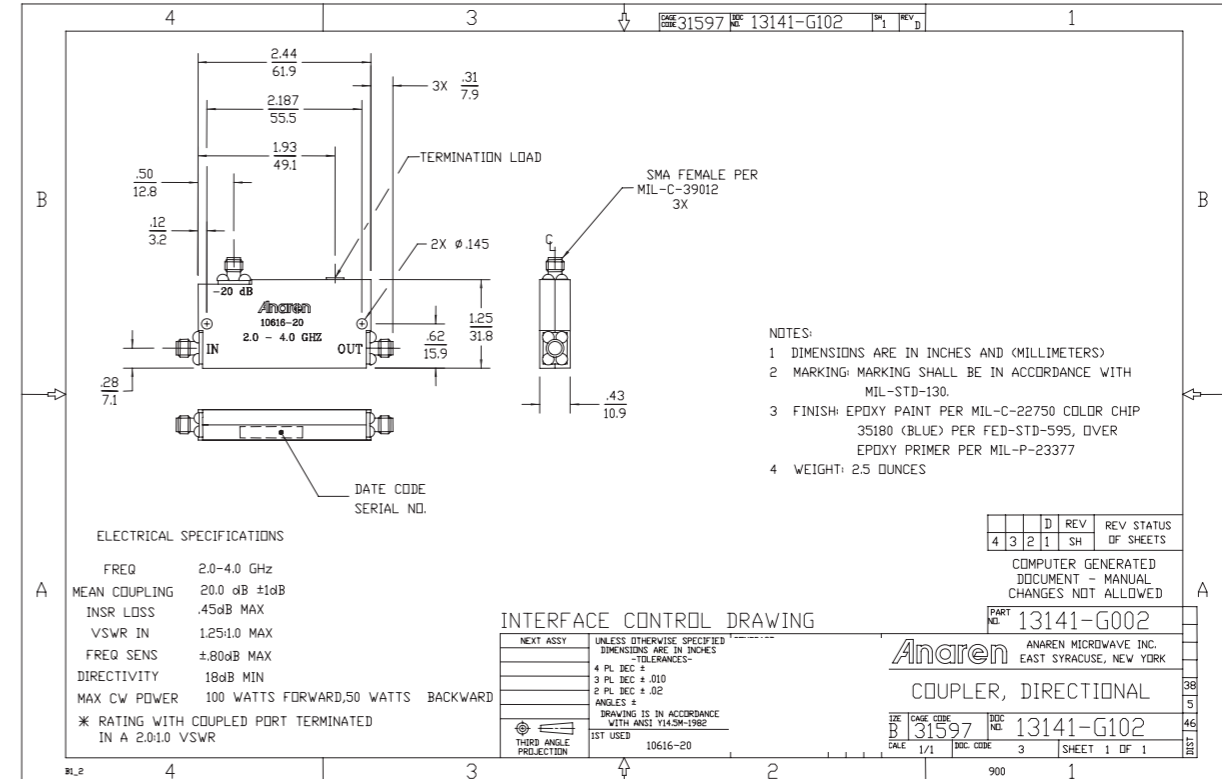
Features

- Military Grade
- 2.0 – 4.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



10616-10 shown

Outline Drawing



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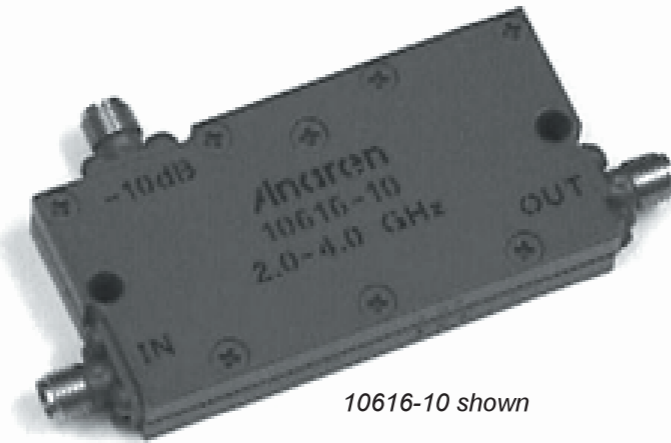
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

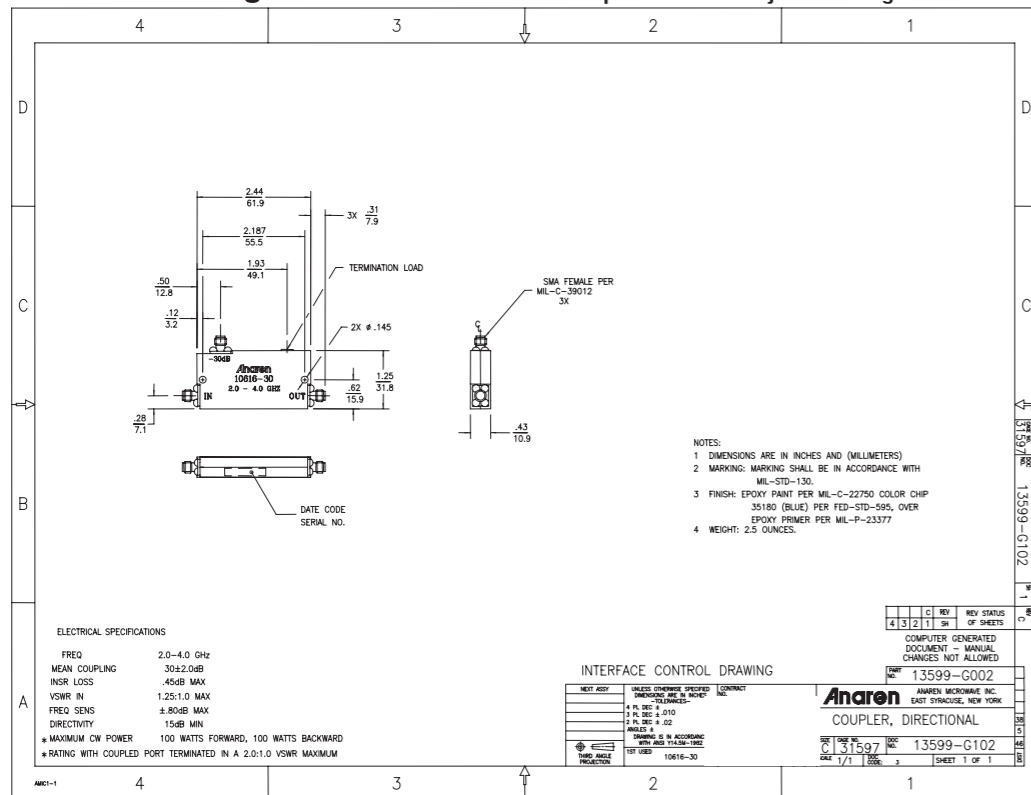
- Military Grade
- 2.0 – 4.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



10616-10 shown

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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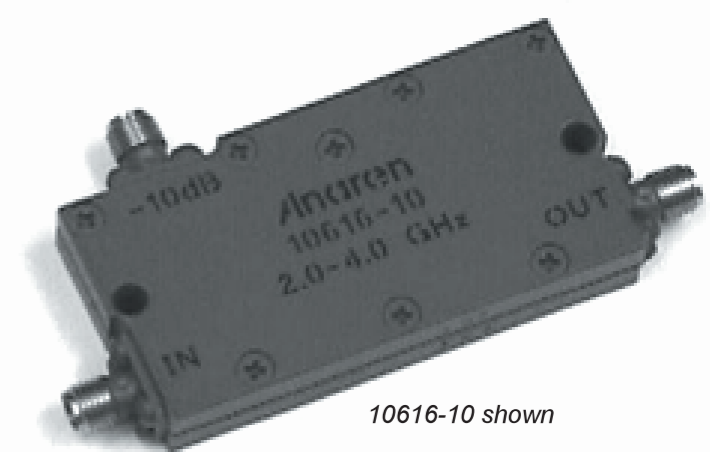
Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

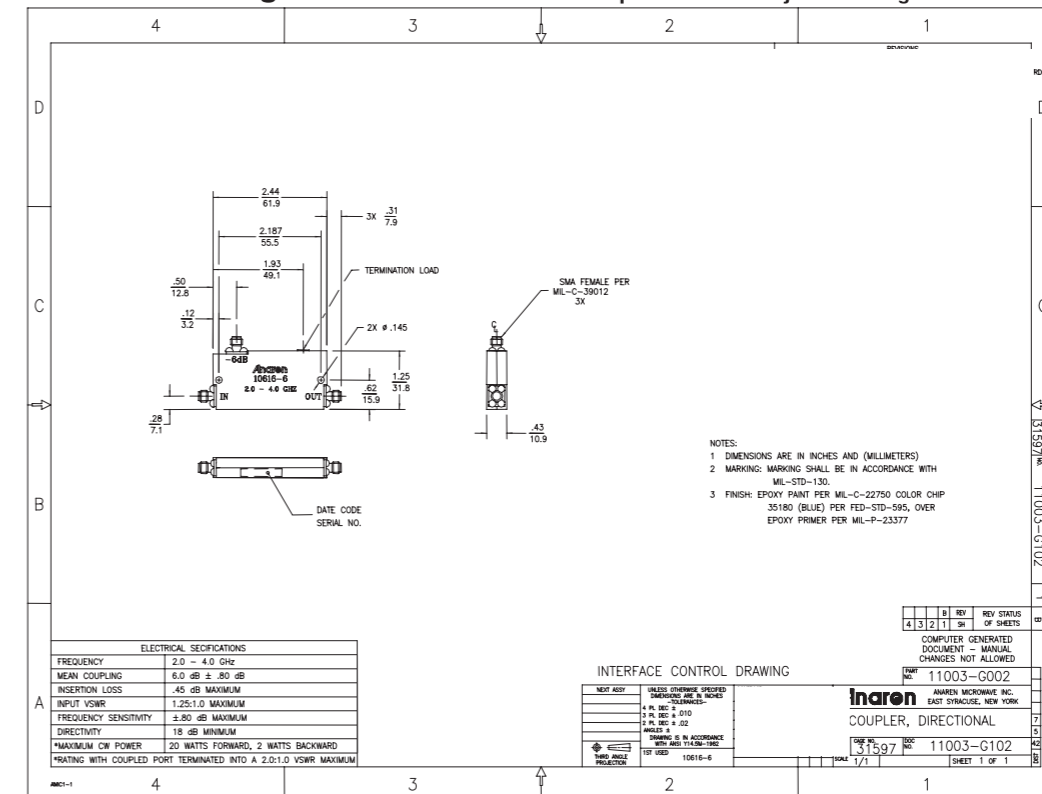
- Military Grade
- 2.0 – 4.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



10616-10 shown

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



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Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

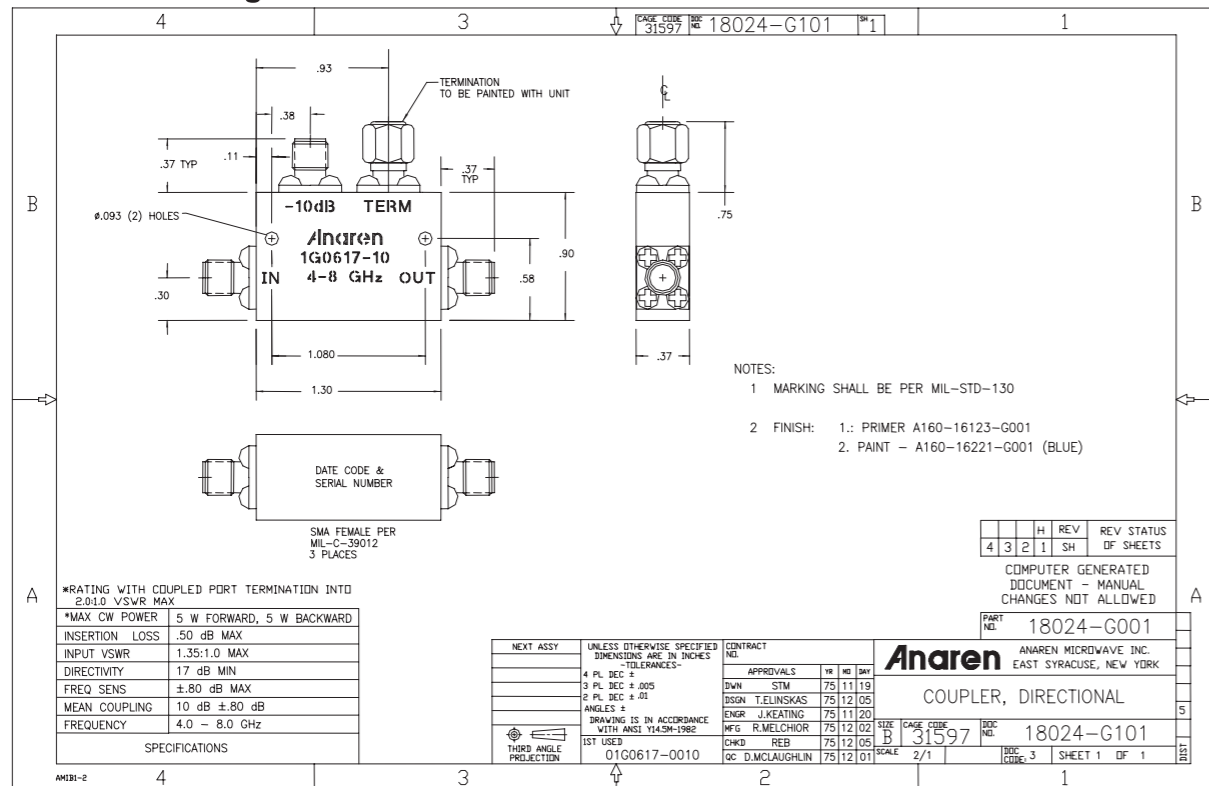
- Military Grade
- 4.0 – 8.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



1G0617-20 shown

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

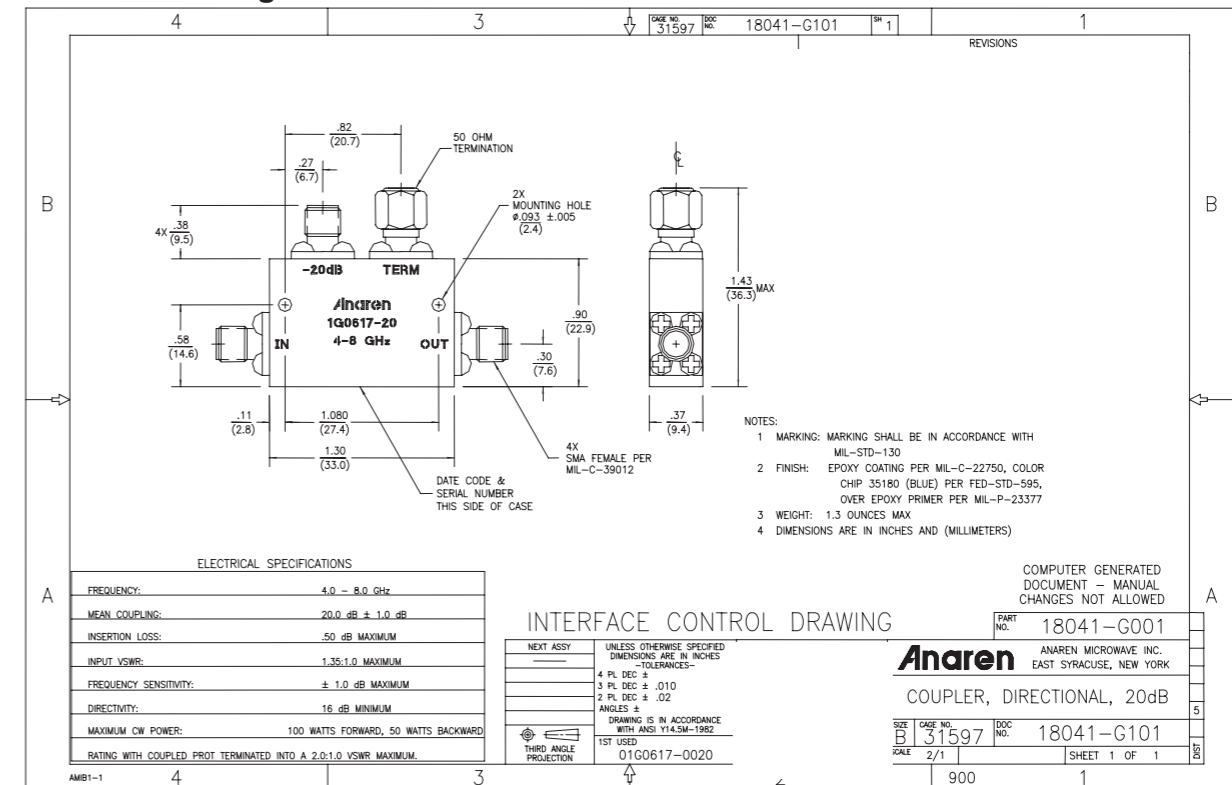
Features

- Military Grade
- 4.0 – 8.0 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

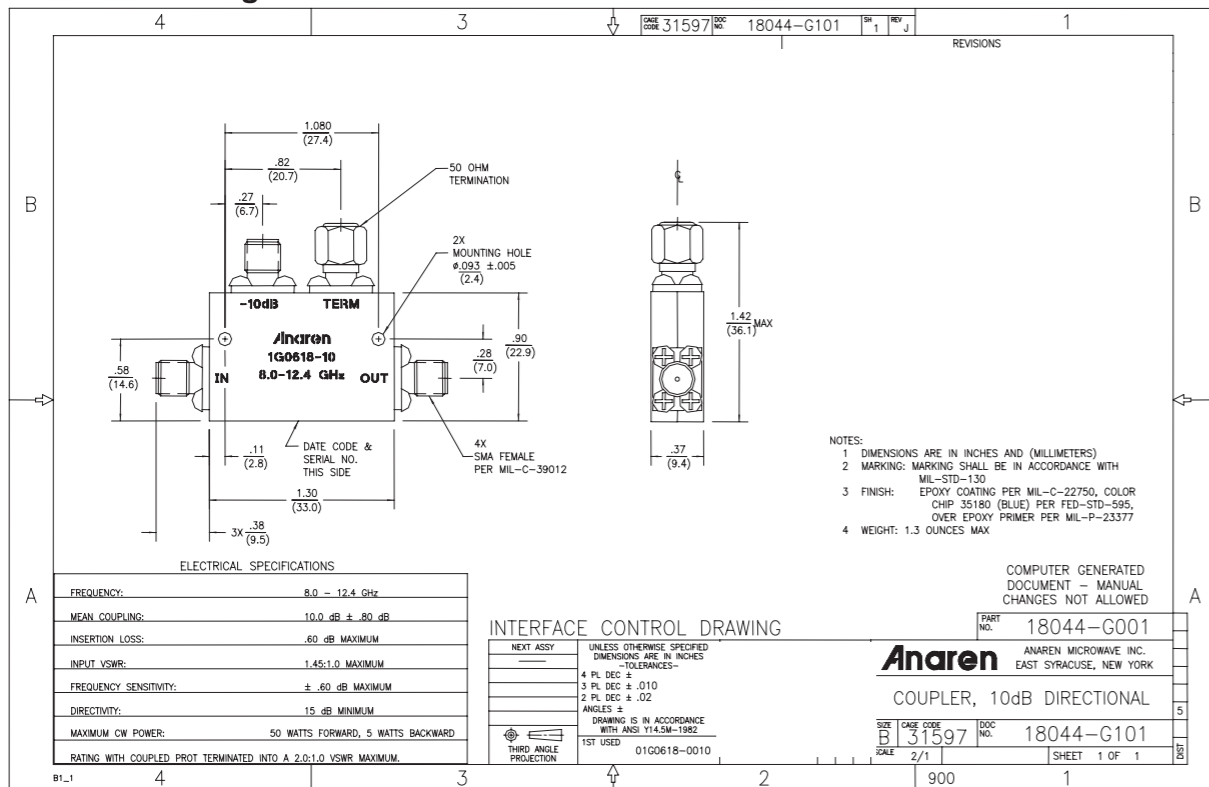
- Military Grade
- 8.0 – 12.4 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



1G0618-20 shown

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Directional Couplers
In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

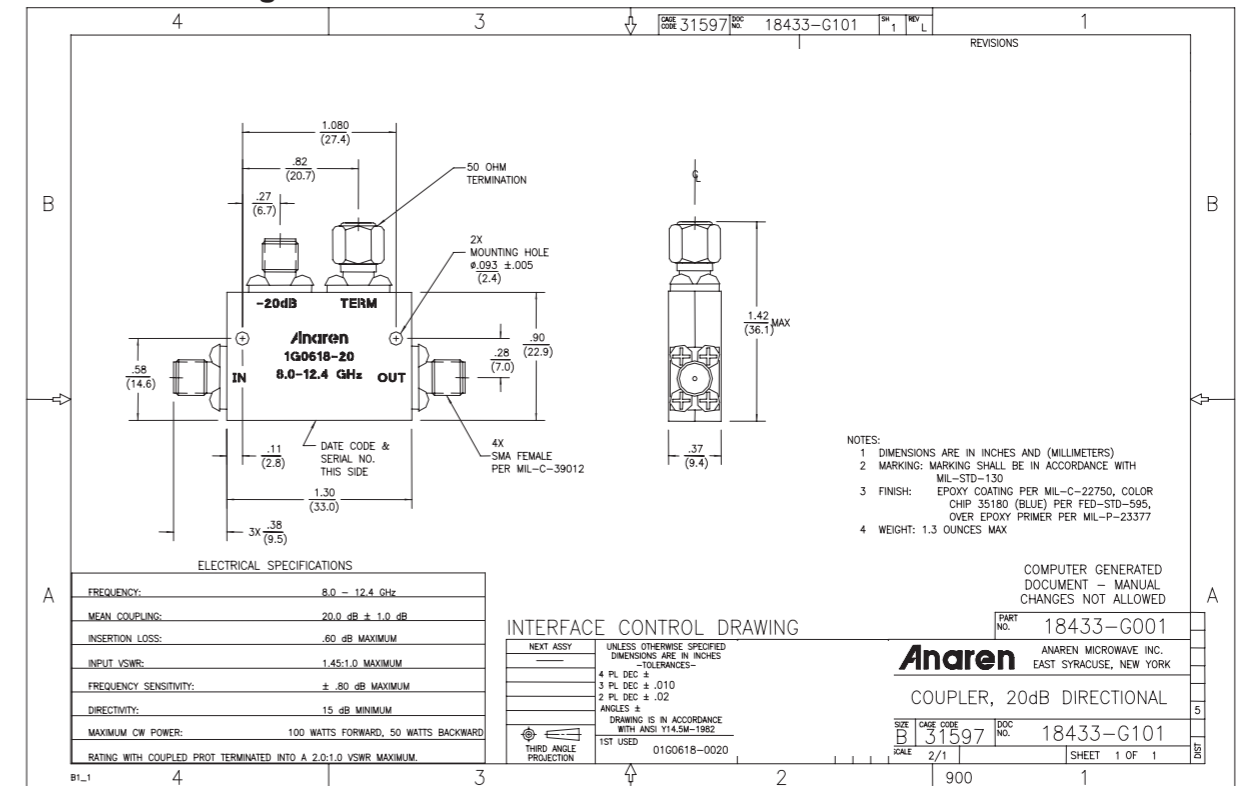
Features

- Military Grade
- 8.0 – 12.4 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Model 1G0618-6



Directional Couplers In-Line Style

Applications

- Subassemblies
- Lab Systems
- Leveling Loops
- Power Monitoring
- Test and Calibration

Features

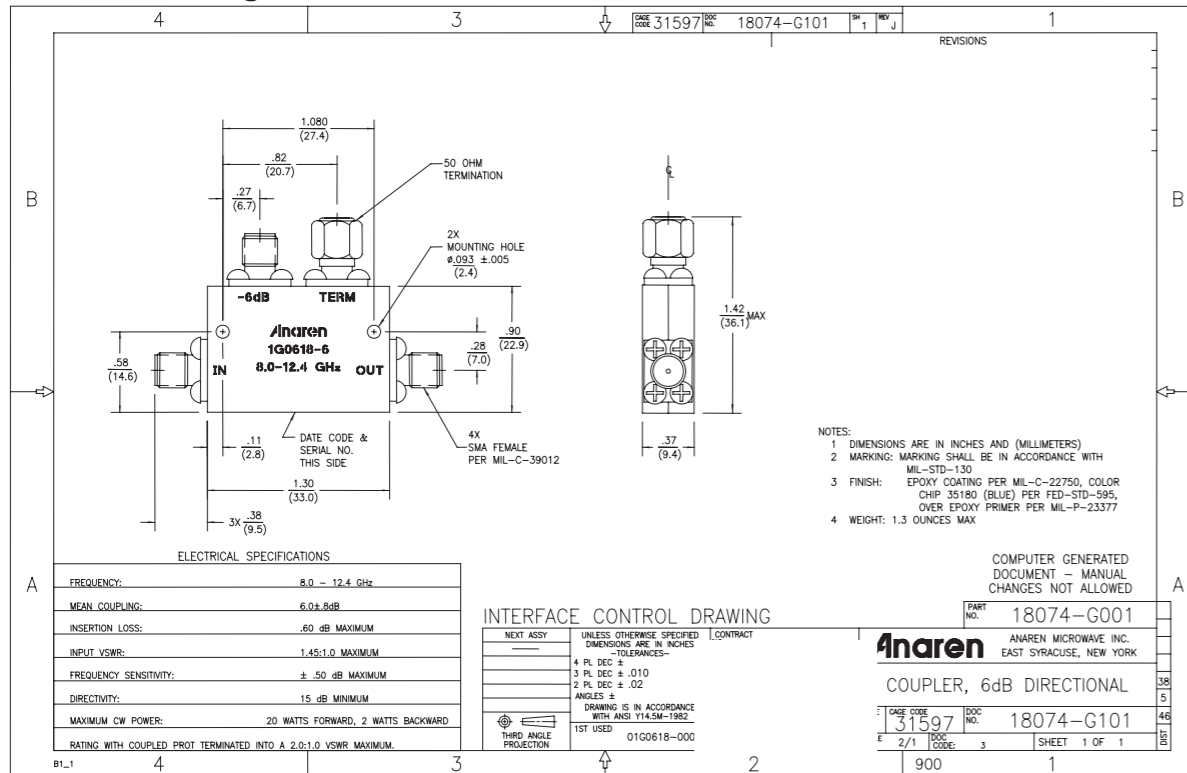
- Military Grade
- 8.0 – 12.4 GHz
- In-Line Configuration
- Connectors Per MIL-C-39012
- Rugged Aluminum Housing
- Built in Termination
- Meets MIL-E-5400 Class 3 Requirements



1G0618-20 shown

NOTES: The power rating applies when coupled port VSWR is 2.0:1 or less.
Higher power can be handled with a lower VSWR termination
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Mixers Selection Matrix

Mixers, Double Balanced									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation LO-RF (dB) Min	Conversion Loss (dB) Max	VSWR RF (Max:1)	IF Frequency (MHz)	RF Power Input (dBm)	LO Power (dBm Nom)
74125	1.0 - 4.0		1.65 x 1.2	35	9	3.5	DC-1000	4	10
73126	1.5 - 5.0		1 x 1	18	9	3	DC-1000	4	12
74127	2.5 - 10.0		1.18 x 1.05	28	8.5	4	DC-1500	4	12
76127	2.5 - 10.0		1.18 x 1.05	25	9.5	4	DC-1500	10	18
73128	4.5 - 12.0		0.82 x 0.82	15	9	4.5	DC-4000	4	12
74129	5.0 - 18.0		1.2 x 0.74	26	11	4.5	DC-2500	4	12

Mixers Quadrature IF									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation LO-RF (dB) Min	Conversion Loss (dB) Max	VSWR RF (Max:1)	IF Frequency (MHz)	IF Amp Bal +/- (dB)	IF Phase Bal +/- (degrees)
250126	2.0 - 4.0		3 x 2.9	20	12	2	DC - 400	1	10

Mixers Balanced OrthoQuad									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation LO-RF (dB) Min	Conversion Loss (dB) Max	VSWR (Max:1)	Noise Figure (dB) Max	IF Frequency (MHz)	Bias (Yes/No) "S"
7A0124	0.5 - 1.0		3 x 3	20	7.5	1.6	8.5	DC - 150	No

Mixers Image Rejection									
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Isolation LO-RF (dB) Min	Conversion Loss (dB) Max	IF Output (MHz)	RF VSWR Max:1	LO VSWR Max:1	Image Rejection (dB) Min
150017-240	4.0 - 8.0		3 x 2.5	14	9	160 - 320	2	2.5	15

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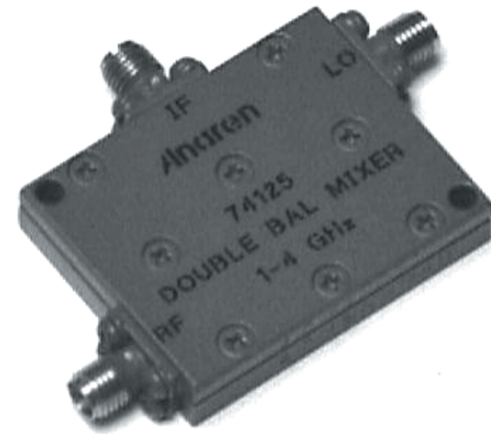
Mixers
Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors

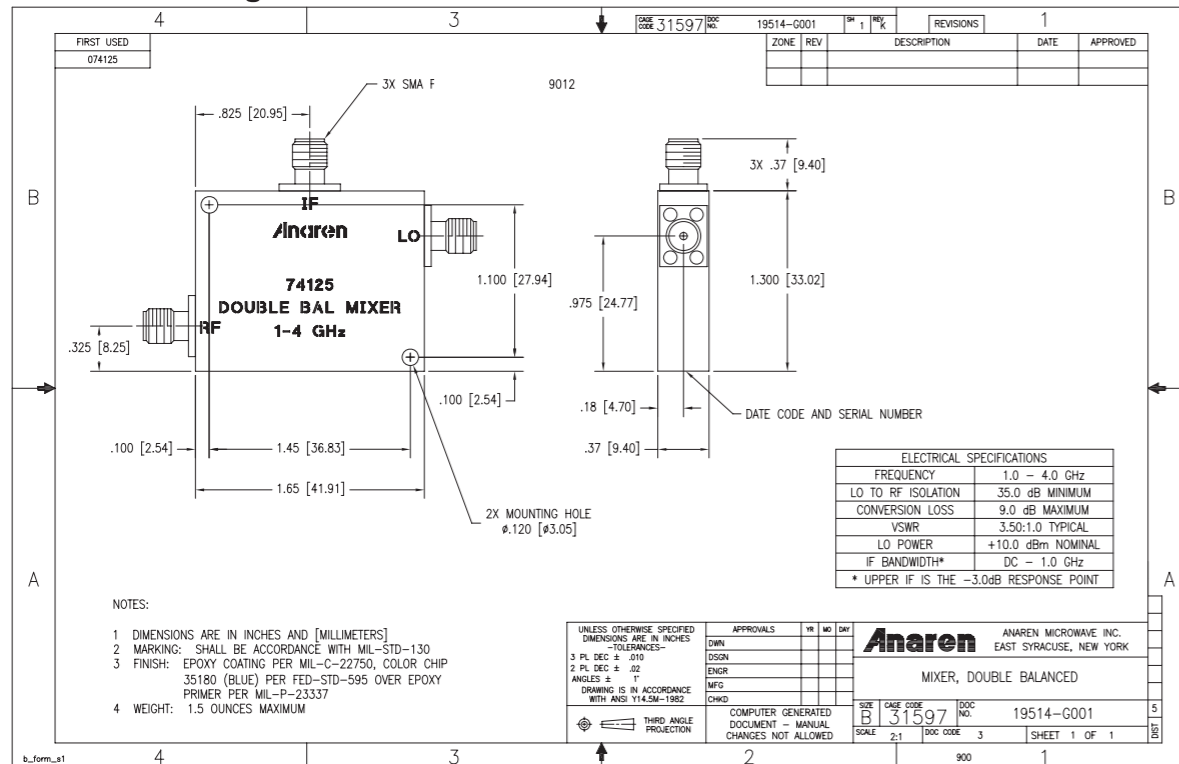
Features

- Extremely Wide IF Bandwidth
- 1.0 – 4.0 GHz
- Excellent LO/Rf Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice



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Mixers
Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors



Features

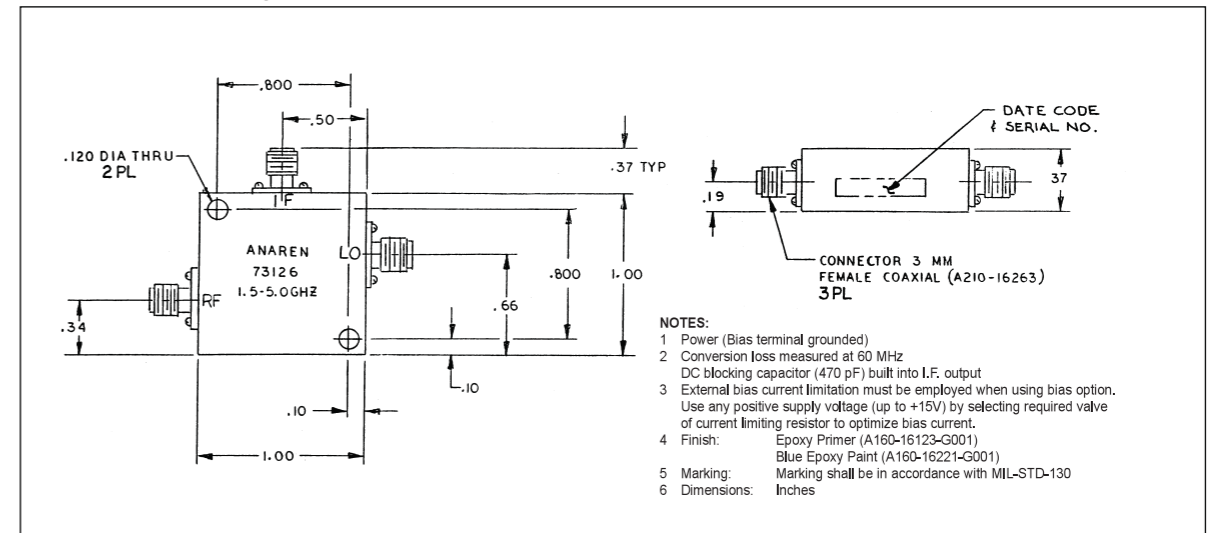
- Extremely Wide IF Bandwidth
- Good LO/Rf Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012

Electrical Specifications

Frequency GHz	Isolation _{LO-RF} dB Min/Typ	Convers. Loss dB Max/Typ	VSWR _{RF} Typ : 1
1.5 - 5.0	18/28	8.5/7.0	3.5
IF Freq. ¹ MHz	RF Power ² Input dBm	LO Power dBm Nominal	
DC-1500	+4	+12	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. 1) Upper IF frequency is the -3 dB response point. 2) At 1dB Compression point. Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



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Model 74127



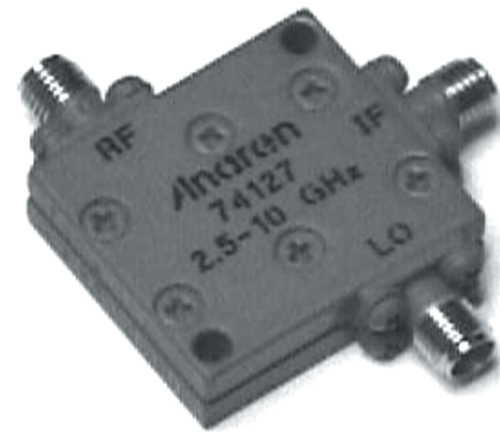
Mixers Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors

Features

- Extremely Wide IF Bandwidth
- 2.5 – 10.0 GHz
- Excellent LO/RF Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements



Model 76127

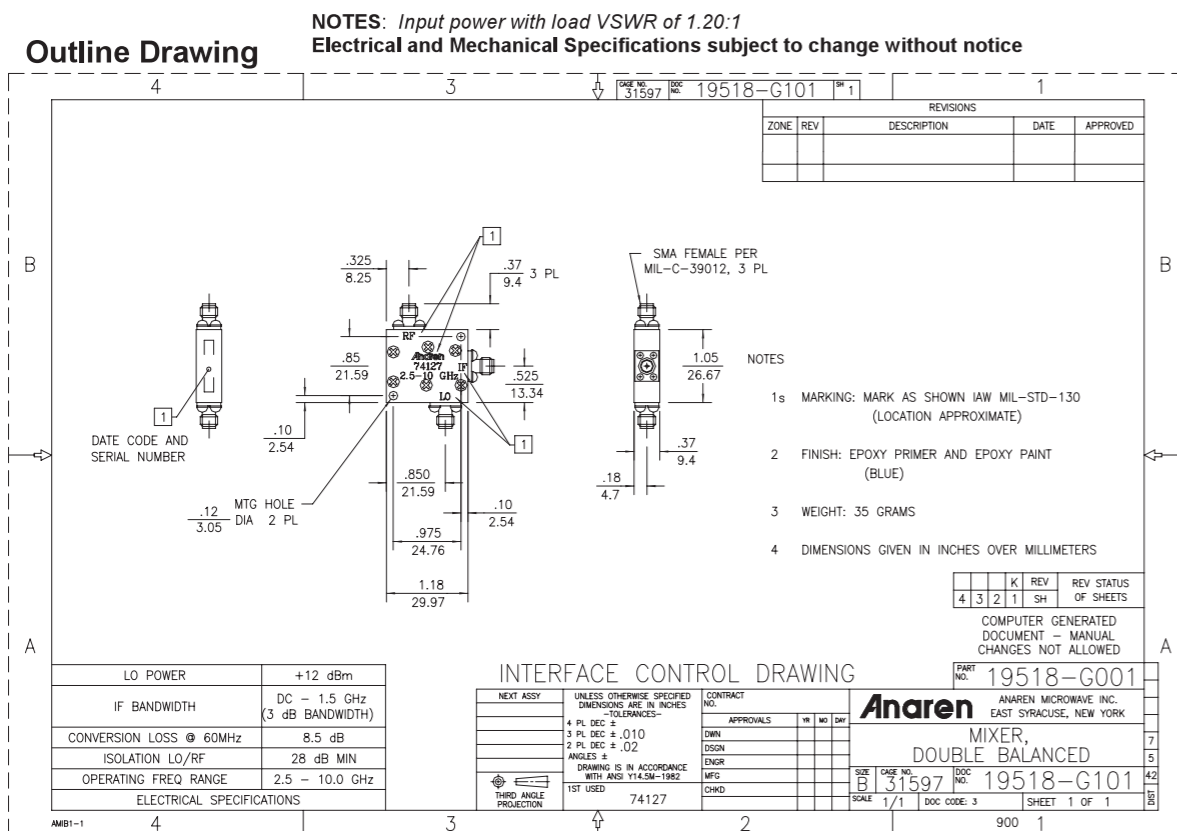
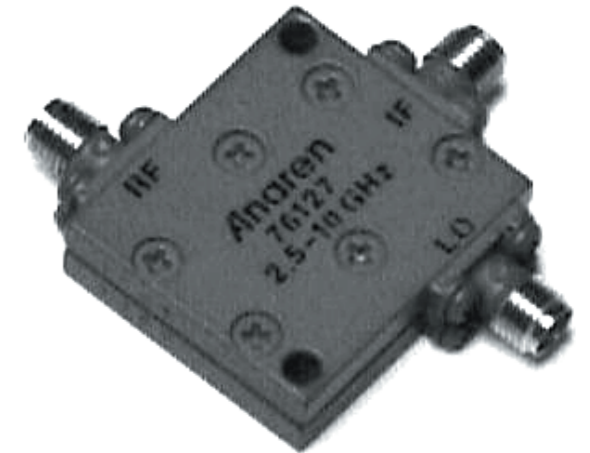
Mixers Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors

Features

- Extremely Wide IF Bandwidth
- 5.0 – 18.0 GHz
- Excellent LO/RF Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements



Mixers
Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors



Features

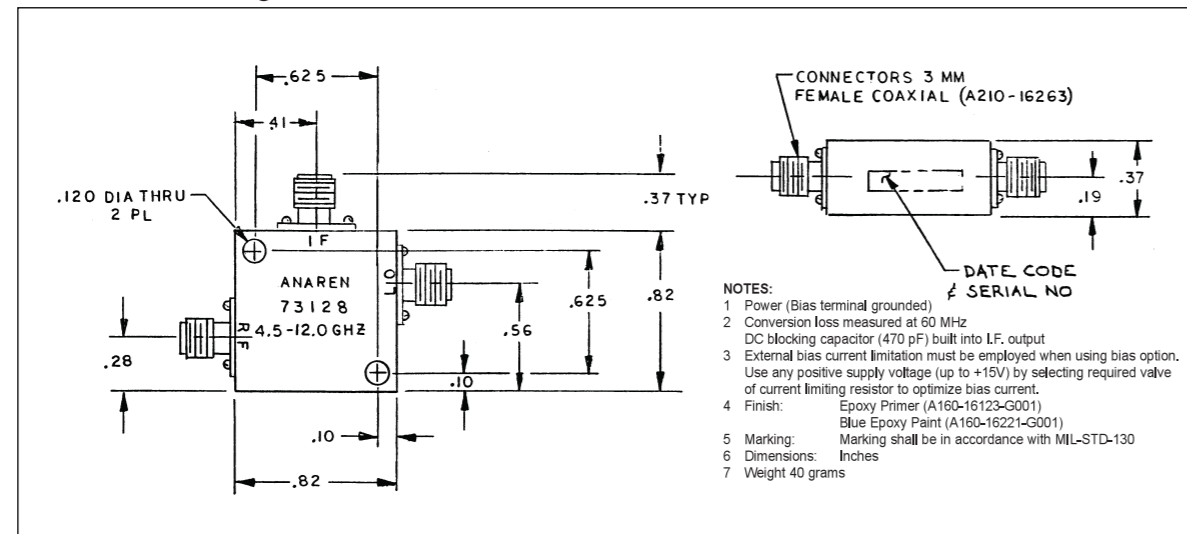
- Extremely Wide IF Bandwidth
- Good LO/RF Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012

Electrical Specifications

Frequency GHz	Isolation _{LO-RF} dB Min/Typ	Convers. Loss dB Max/Typ	VSWR, RF Typ : 1
4.5 - 12.0	15/23	9.0/8.0	4.5
IF Freq. ¹ MHz	RF Power ² Input dBm	LO Power dBm Nominal	
DC-4000	+4	+12	

Notes: Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. 1) Upper IF frequency is the -3 dB response point. 2) At 1dB Compression point
Electrical and Mechanical Specifications subject to change without notice.

Outline Drawing



Mixers
Double Balanced

Applications

- Wideband Down Converters
- Wideband Up Converters
- Balanced Modulators
- Bi-Phase Modulators
- Phase Detectors

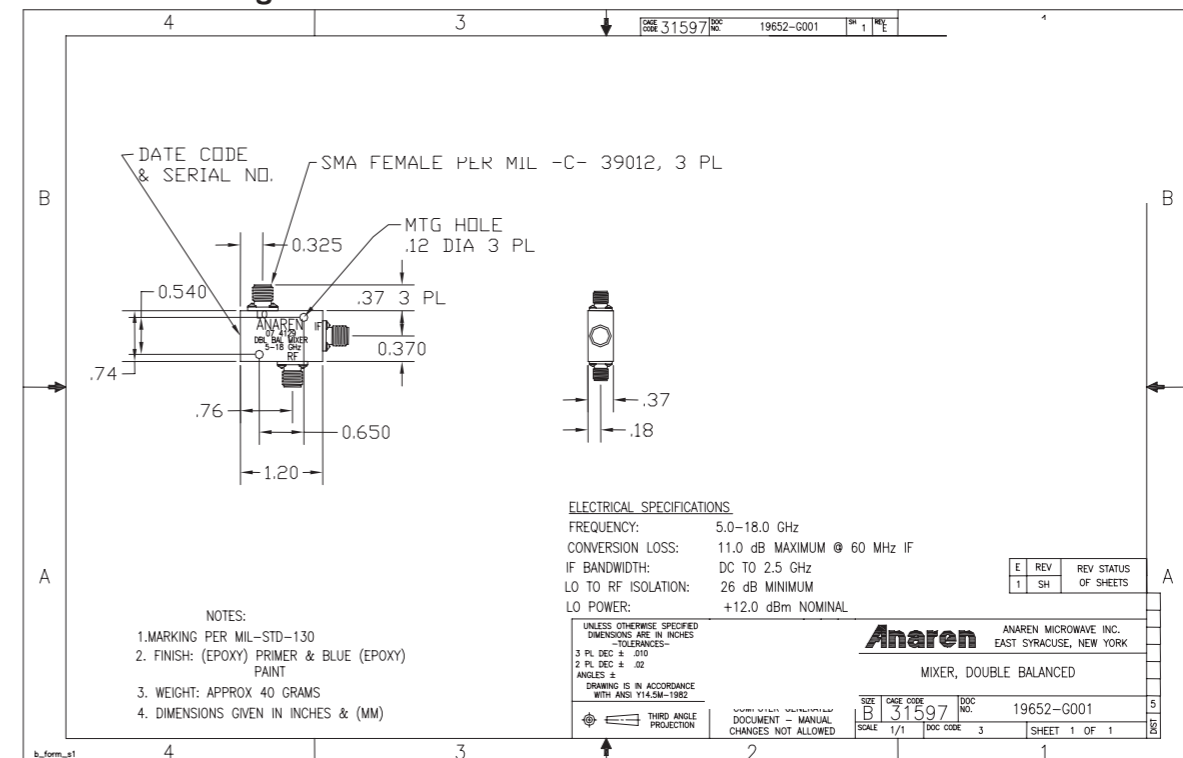


Features

- Extremely Wide IF Bandwidth
- 5.0 – 18.0 GHz
- Excellent LO/RF Isolation
- Multi-Octave Performance
- Good Intercept Point
- Miniature Size
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements

NOTES: Input power with load VSWR of 1.20:1
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



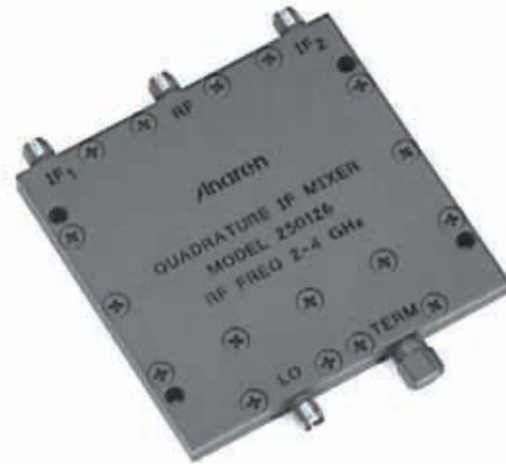
Mixers
Quadrature IF

Applications

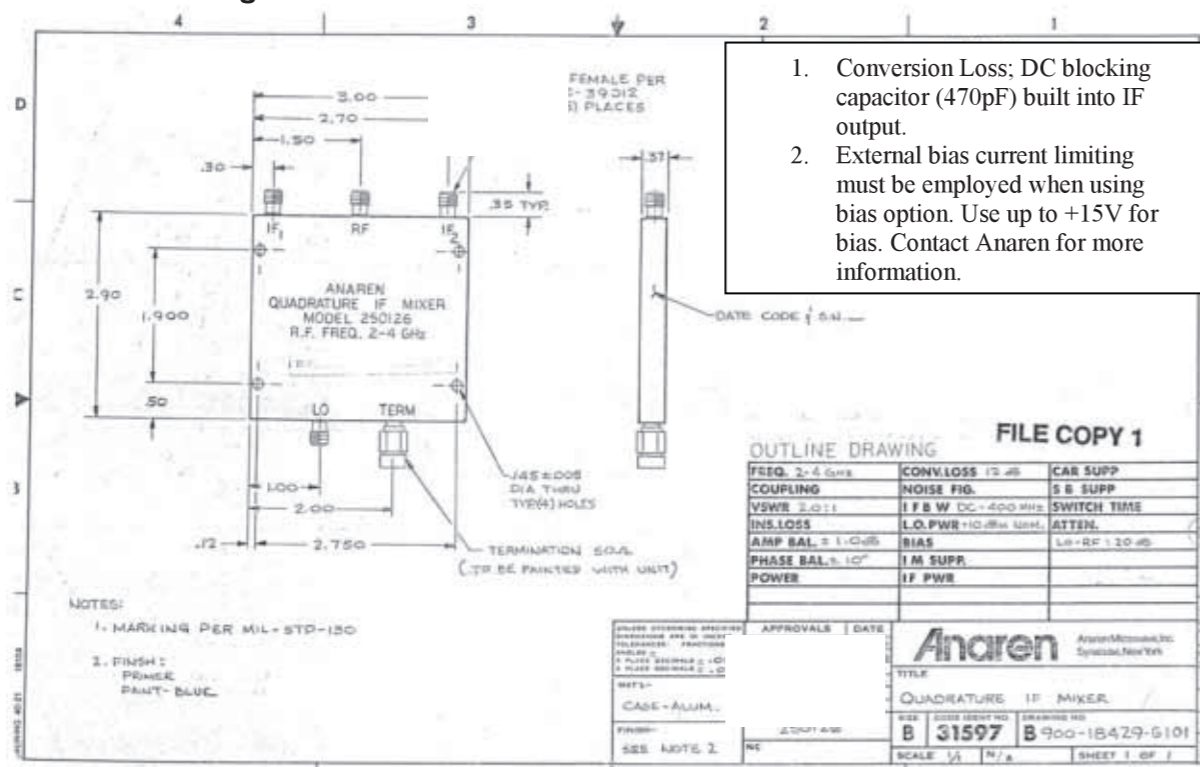
- PSK Demodulators
- Quadrature Phase Detectors
- Doppler Systems/Radar Altimeters
- Image Rejection Mixers
- Error Sensors in Adaptive Systems

Features

- Military Grade
- 2.0 – 4.0 GHz
- IF Center Frequencies from 30 to 240 MHz Available (Specs are for IF Center of 60MHz)
- Good Phase/Amp Balance
- Good LO/RF Isolation
- Good LO/RF VSWR
- Connectors per Mil-C-39012
- Biased Versions Available
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing NOTES: Electrical and Mechanical Specifications subject to change without notice



1. Conversion Loss; DC blocking capacitor (470pF) built into IF output.
2. External bias current limiting must be employed when using bias option. Use up to +15V for bias. Contact Anaren for more information.

Mixers
Balanced, OrthoQuad®

Applications

- Down Converters
- Demodulators
- Pulse Modulators
- Current Controlled Attenuators
- Phase, Frequency Discriminators



Features

- Military Grade
- Good LO/RF Isolation
- Connectors Per MIL-C-39012
- Low Conversion Loss
- Good Intermodulation Performance
- Good LO/RF VSWR

Electrical Specifications

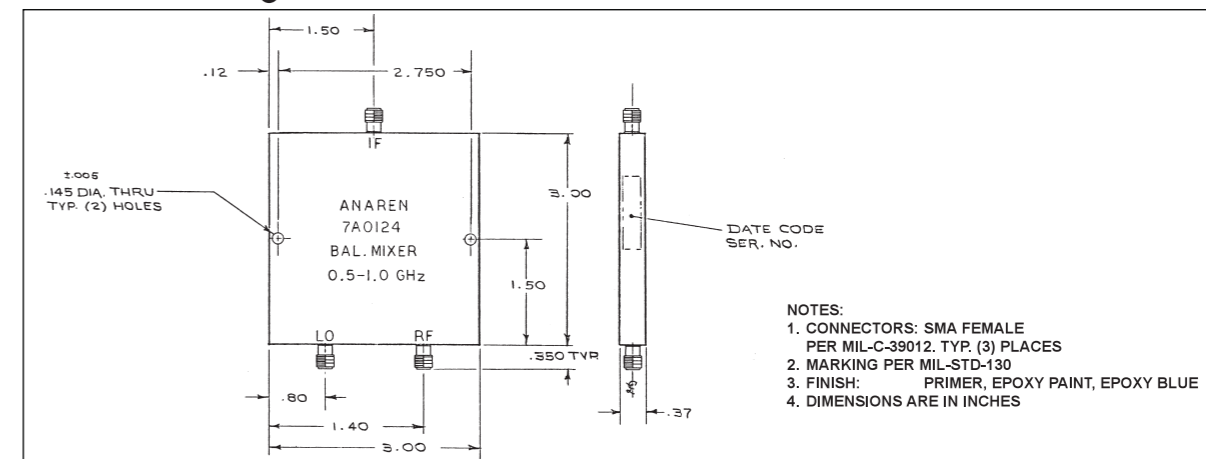
Frequency GHz	Isolation _{LO-RF} dB Min/Typ	Convers. Loss dB Max/Typ	VSWR _{RF, LO} Max/Typ :1
0.5 - 1.0	20/25	7.5/6.5	1.6/1.2
Noise Fig. ¹ dB Max	IF Freq. ² MHz		
8.5/7.5	DC-150		

Note: Impedance: 50 ohms nominal. Operating temperature -54 to +95°C. LO drive of +8 dBm. All measurements are made in 50 ohm system. For biased models, conversion loss and noise figures specify @ 0 dBm LO power. Mixers have internal bias networks that allow operation over LO dynamic range ≥ 20 db while maintaining optimum conversion loss.

Electrical and Mechanical Specifications subject to change without notice.

¹Noise figure is single sideband using a 30 MHz amplifier having a noise of 1.5 dB. ²Upper IF frequency is the -3dB response point.

Outline Drawing



- NOTES:
1. CONNECTORS: SMA FEMALE PER MIL-C-39012. TYP. (3) PLACES
 2. MARKING PER MIL-STD-130
 3. FINISH: PRIMER, EPOXY PAINT, EPOXY BLUE
 4. DIMENSIONS ARE IN INCHES

Model 150017-240



Mixers Image Rejection



Model 150017-300 shown above

Applications

- Wideband Sweeping Receivers
- Spectrum Analyzers
- Surveillance Receivers
- Wideband Test Instrumentation
- Starved LO Systems

Features

- 30 to 240 MHz IF Available
- Military Grade
- 4.0 – 8.0 GHz
- Excellent Image Suppression
- Low Conversion Loss
- Stainless Steel Connectors
- Biased Versions Available
- Meets MIL-E-5400 Class 3 Requirements

Modulators, PIN Attenuators, Phase Discriminators election Matrix

Modulators, Balanced							
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	IF Input (MHz)	Conversion Loss (dB) Max	Carrier Suppression (dB) Min	RF VSWR Max:1
70666	2.0 - 4.0		2.35 x 2.35	DC - 250	8	16	1.6
70668	8.0 - 12.4		2.35 x 2.35	DC - 400	9.5	15	1.8

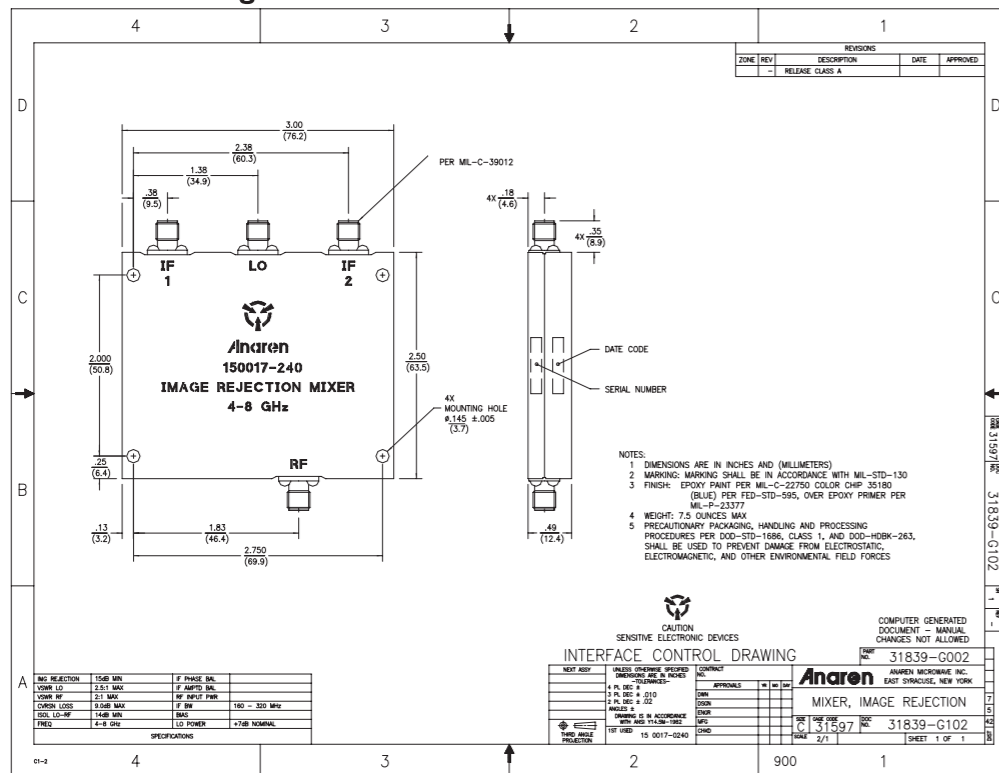
Modulators, Single Sideband							
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	IF Input (MHz)	Conversion Loss (dB) Max	Carrier Suppression (dB) Min	Sideband Suppression (dB) Min
90337-DC	4.0 - 8.0		3 x 2.9	DC - 400	9.5	15	16

PIN Attenuators, cased										
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Dynamic Range (dB) Min	Insertion Loss (dB) Max	Flatness +/- (dB) Max	Linearity +/- (dB) Max	VSWR Ins. Loss State (Max:1)	VSWR Atten. State (Max:1)	
61525	1.0 - 2.0		1.88 x 1.56	60	1.5	2.5	3	1.4	1.65	
61526	2.0 - 4.0		1.88 x 1.56	60	1.9	2.5	3	1.71	1.65	
61527	4.0 - 8.0		1.88 x 1.56	60	2.2	2.5	3	1.8	1.9	
61528	8.0 - 12.4		1.88 x 1.56	60	2.8	2.5	3	1.9	2.1	

Phase Discriminators, cased							
Part Number	Frequency GHz	Power (W)	Size inches/(mm)	Phase Accuracy +/- (degrees) Max	Tangential Sensitivity (dBm)	VSWR Max:1	Dynamic Range (dB)
20756	2.0 - 4.0		5.3 x 2.75	7	-43	1.8	30

Outline Drawing

NOTES:
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Model 70666



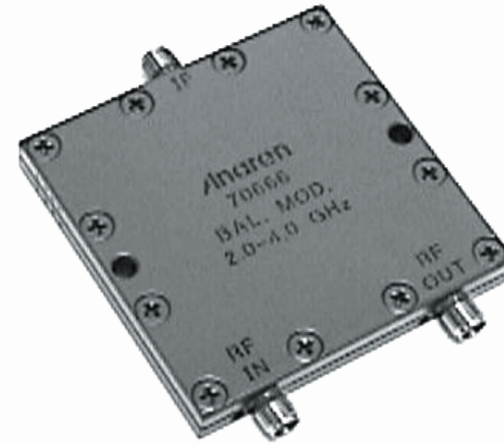
Modulators Balanced

Applications

- Up Converters
- Double Sideband Modulators
- Amplitude Modulators
- Pulse Modulators
- Current Controlled Attenuators
- Suppressed Carrier Systems
- Bi Phase Modulators
- Digital PSK Systems

Features

- Military Grade
- 2.0 – 4.0 GHz
- Excellent Carrier Suppression
- Low VSWR
- Good Bi Phase Tracking
- Low Conversion Loss
- Connectors Per MIL-C-39012



Model 70668

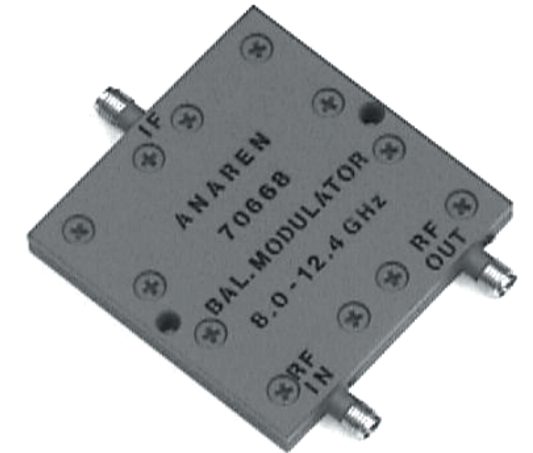
Modulators Balanced

Applications

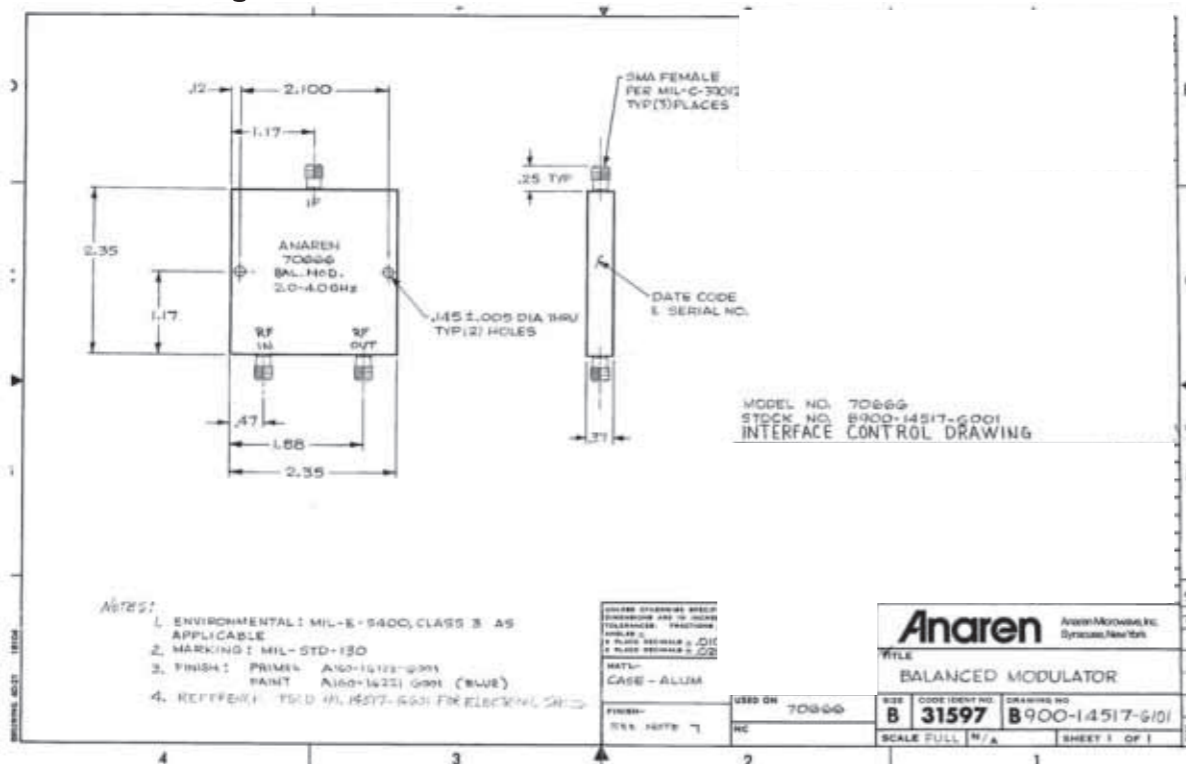
- Up Converters
- Double Sideband Modulators
- Amplitude Modulators
- Pulse Modulators
- Current Controlled Attenuators
- Suppressed Carrier Systems
- Bi Phase Modulators
- Digital PSK Systems

Features

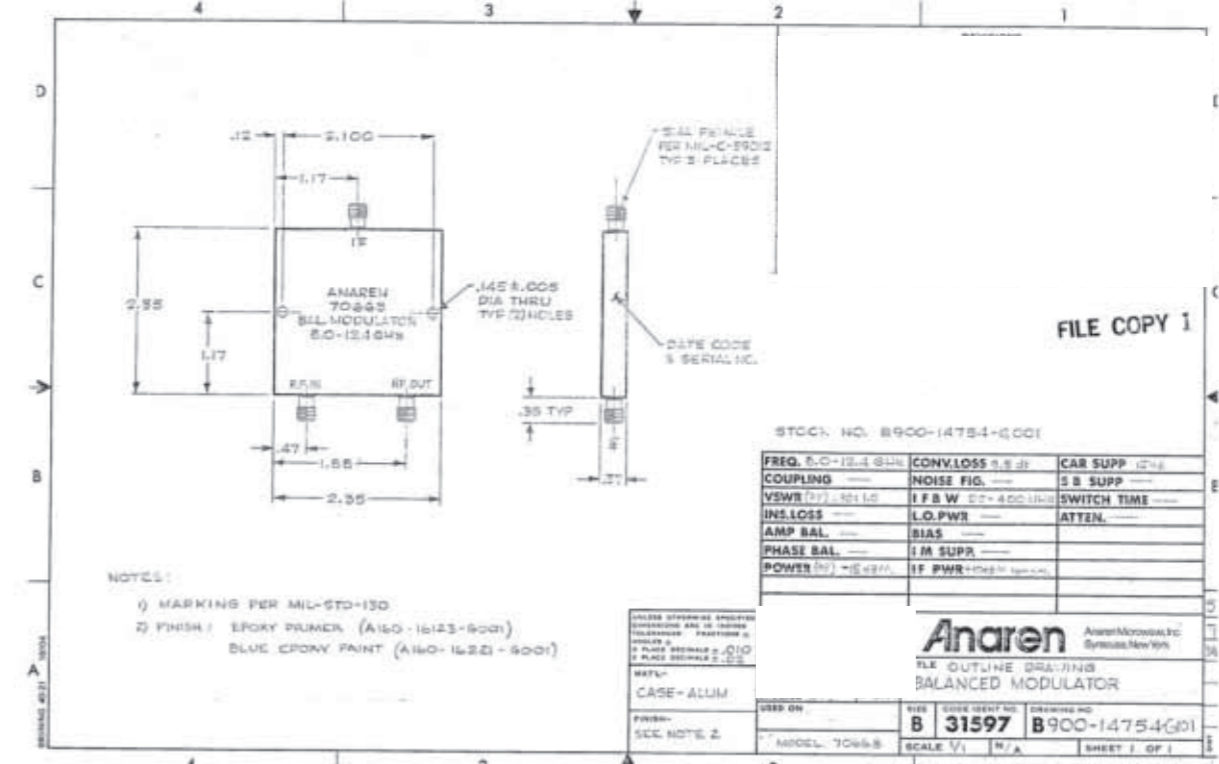
- Military Grade
- 8.0 – 12.4 GHz
- Excellent Carrier Suppression
- Low VSWR
- Good Bi Phase Tracking
- Low Conversion Loss
- Connectors Per MIL-C-39012



Outline Drawing NOTES: Electrical and Mechanical Specifications subject to change without notice



Outline Drawing NOTES: Electrical and Mechanical Specifications subject to change without notice



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Model 90337-DC



Modulators Single Sideband

Applications

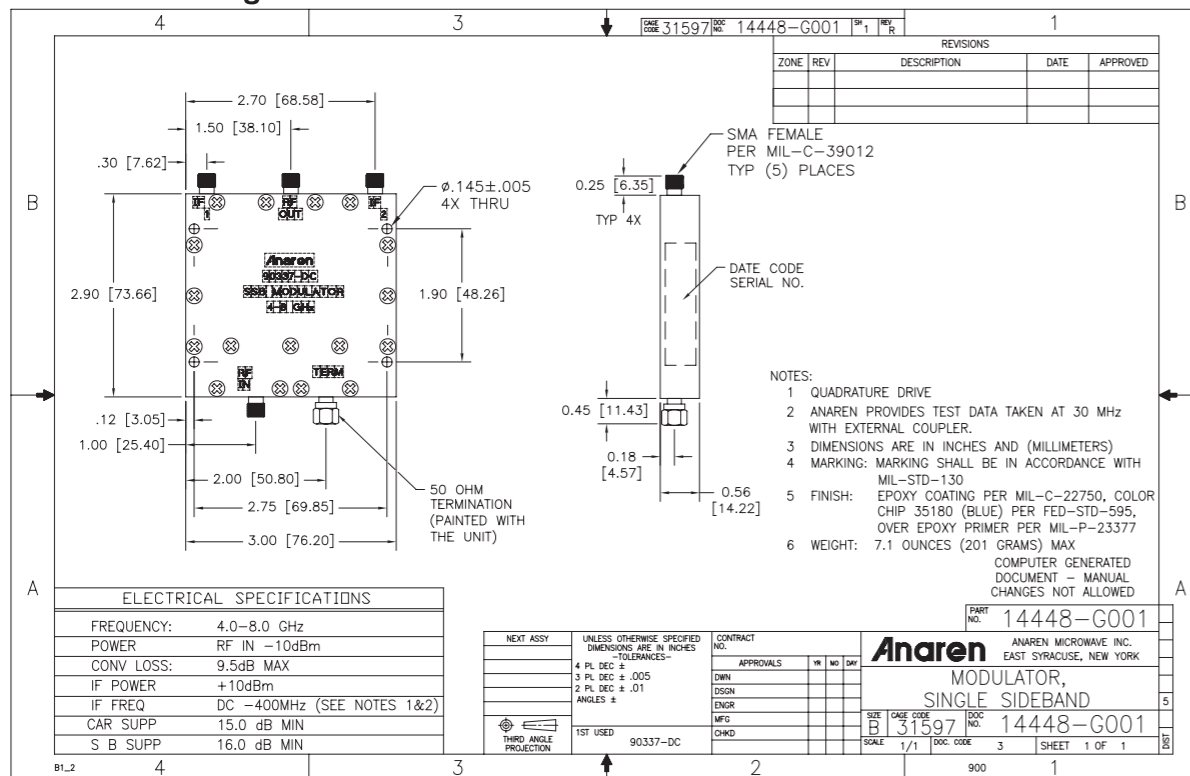
- SSB Communication Systems
- Down/Up Converter Systems
- Precision Frequency Offset
- Doppler Simulators

Features

- Military Grade
- 4.0 – 8.0 GHz
- High Unwanted Sideband Suppression
- Wideband Operation
- Excellent Carrier Suppression
- Connectors Per MIL-C-39012
- 30 to 240 MHz IF Frequencies Available



Outline Drawing NOTES: Electrical and Mechanical Specifications subject to change without notice



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Model 61525

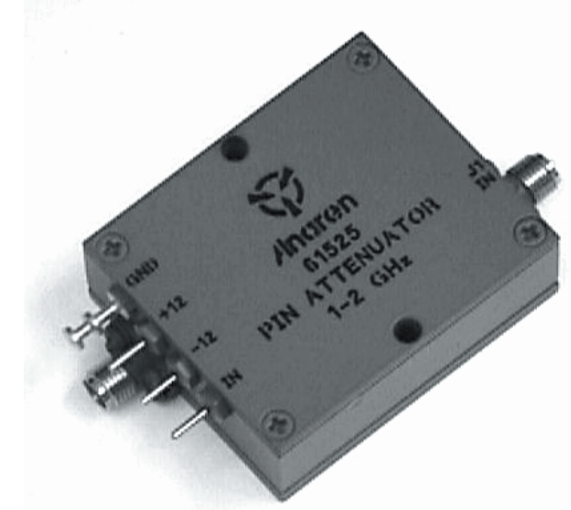
Attenuators PIN Diode

Applications

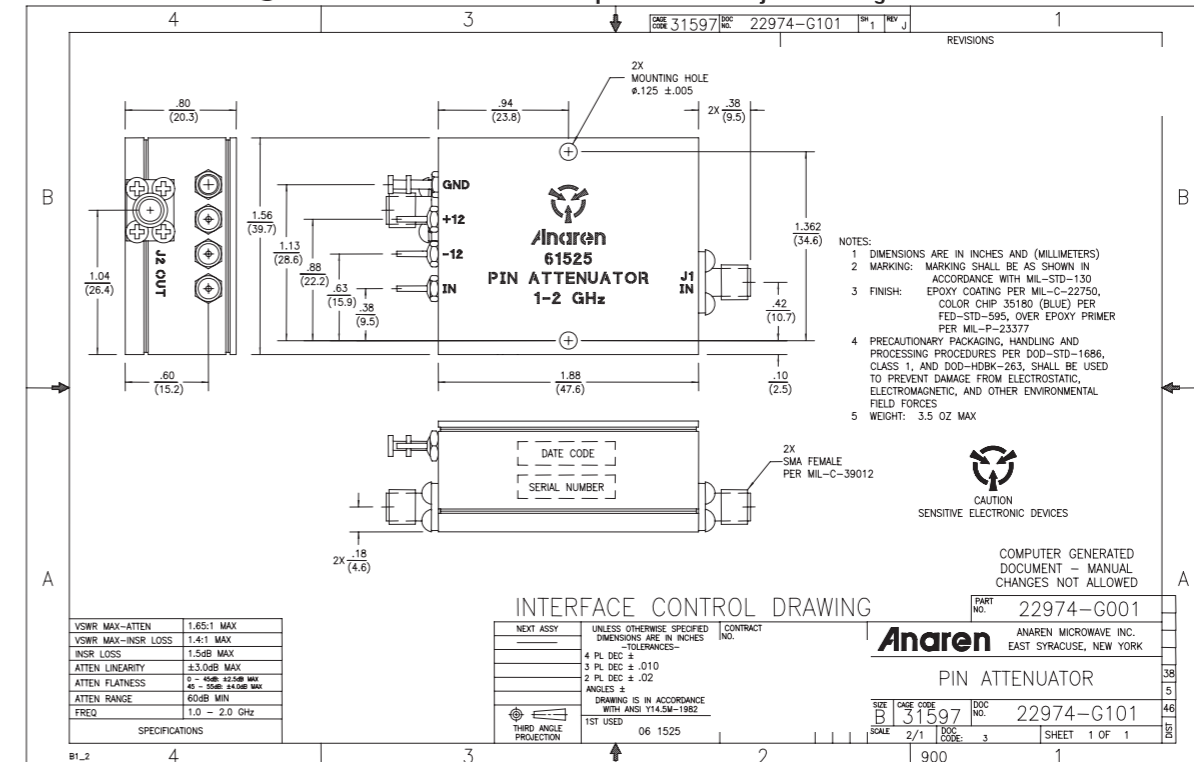
- Load Sensing Devices
- Precision Attenuation Controllers
- Instrumentation

Features

- Military Grade
- 1.0 – 2.0 GHz
- Low VSWR
- Flat Response
- Supply Voltages: +12V @120mA, -12V @40mA
- Control Voltage 0 to 10 volts (6dB/Volt) Typical
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements



Outline Drawing NOTES: Model has 10,000 ohm drive impedance and 100 kHz drive bandwidth. Flatness Specified to 45 dB, add +/- 1.5dB to 60 dB. Electrical and Mechanical Specifications subject to change without notice



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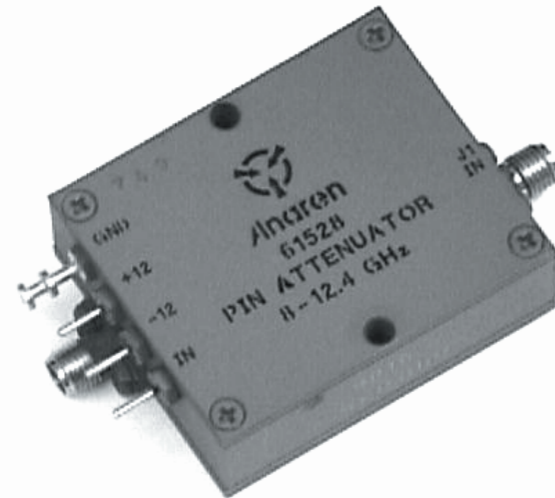
Attenuators
PIN Diode

Applications

- Load Sensing Devices
- Precision Attenuation Controllers
- Instrumentation

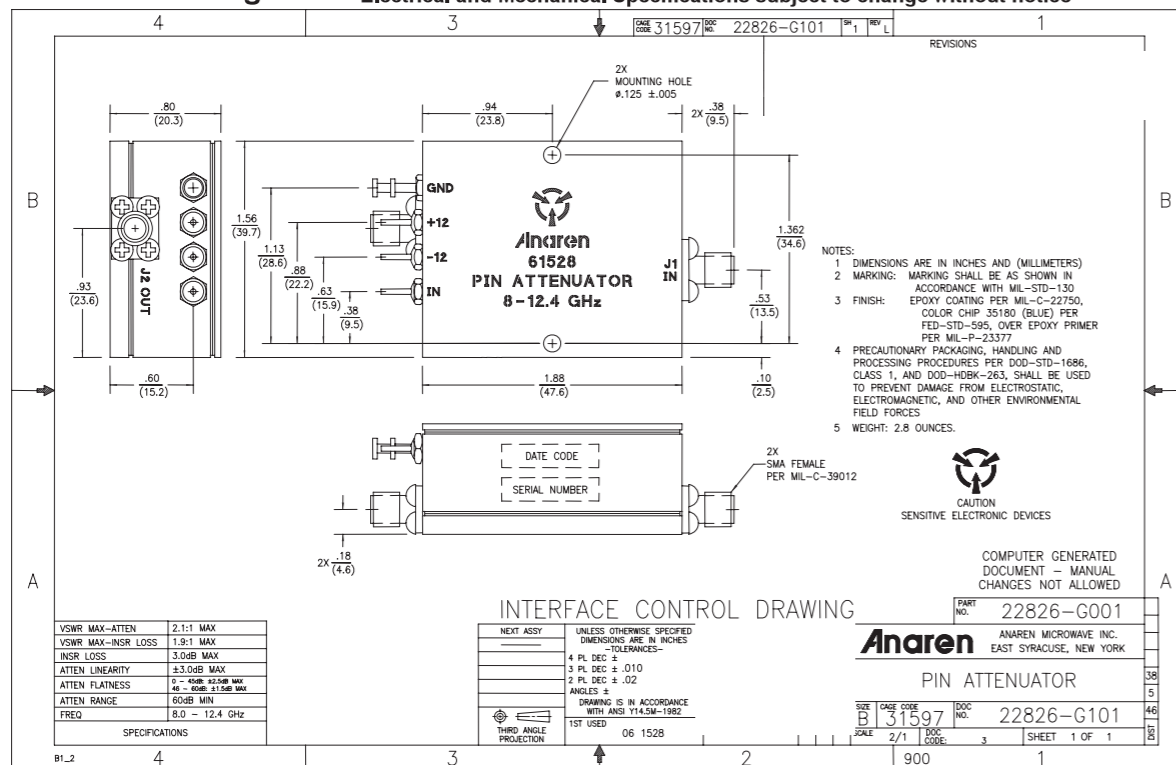
Features

- Military Grade
- 8.0 – 12.4.0 GHz
- Low VSWR
- Flat Response
- Supply Voltages: +12V @120mA, -12V @40mA
- Control Voltage 0 to 10 volts (6dB/Volt) Typical
- Connectors Per MIL-C-39012
- Meets MIL-E-5400 Class 3 Requirements



NOTES: Model has 10,000 ohm drive impedance and 100 kHz drive bandwidth. Flatness Specified to 45 dB, add +/- 1.5dB to 60 dB.
Electrical and Mechanical Specifications subject to change without notice

Outline Drawing



Phase Discriminators
Without Video Amplifier

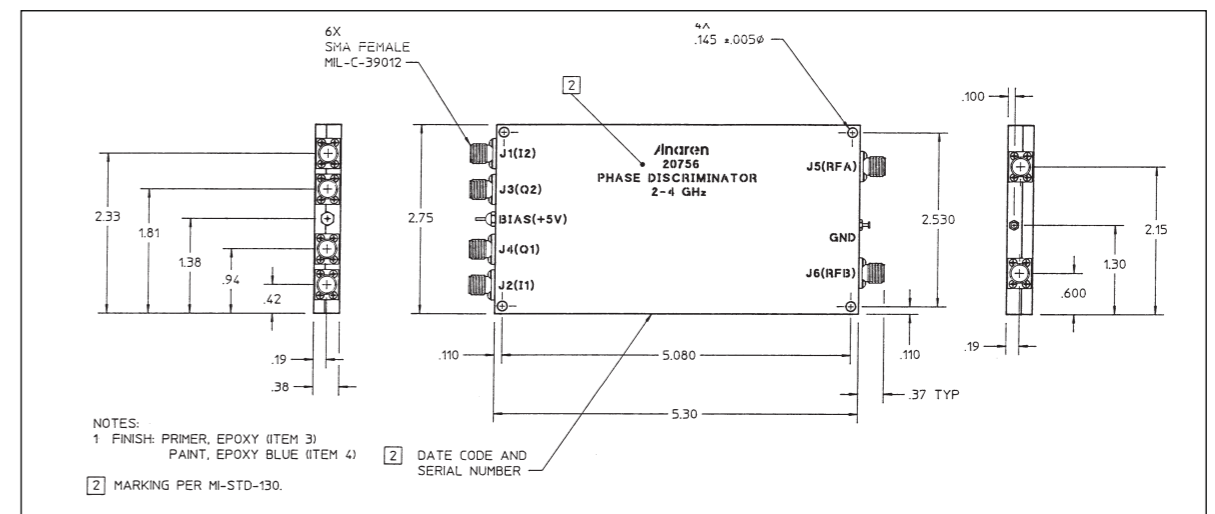


Electrical Specifications

Without Video Amplifier		Frequency
		GHz
2 0756		2.0-4.0
Phase Accuracy	Tang. Sensitivity	VSWR
Degrees Max	dBm	Max:1
+7	-43	1.8

Notes: Electrical and Mechanical Specifications subject to change without notice. Impedance: 50 ohms nominal. Meets MIL-E-5400 Class 3 requirements. Additional screening available for military and space applications. Dynamic Range: 30 dB Voltage/Power Sensitivity: 100 mV/mW typ (Models 2075X: +5V @ 3 mA, Models 2A075X: ± 15v @ 125 mA max)

Outline Drawing



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