Nuts & Volts

Exploring Electronics And Technology For The Hobbyist And Professional

June 1999 Vol. 20 No. 6

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- Out of Sight High-Frequency Antennas
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No we don't mean from the shipping company, we mean Uninterruptible Power Supplies!

- ***TrippLite BCPERS500*** has 500VA rating, enough for one personal computer to be shut down properly when the power goes out.
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- Status LED's on front panel.
- Used, 30-day warranty

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- Status LED's on front panel.
- Used, 30-day warranty

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- Yamaha OPL MIDI/sound on board w/ drivers
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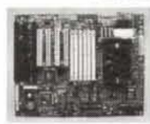
HSC#80469 **$99.00**



- ***M6MI*** "Pentium Pro" ATX motherboard has 4 PCI, 3 ISA slots, Intel 440FX PCIset
- Comes with tested "Pentium Pro" 150 MHz CPU installed w/ heatsink, fan & VRM module
- Supports up to 384Mb memory (6 x 72-pin SIMMs)
- Support for EDO, Fast Page Mode (FPM) memory, ECC
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Three types of rechargeable battery for a variety of uses!

Amazing power in a small package! Nickel-Metal Hydride (Ni-MH) batteries have the capacity of Nicads without the "memory" effect. These are factory-new, not pulls!

- **Toshiba 8TH-F5-F1-AIR**, 9.6VDC at 600 mAH, measures 4.5" x 1.875" x .25" thick (8 cells in series)
- Appears to have a thermal fuse for over-current protection

HSC#17871 **$17.50**

...Or you can choose a NiCad battery pack in a similar form-factor. These are a flat array of cells, like the battery above, with handy solder tabs for connection.

- Thin NiCad pack, 8.4VDC at 450 mAH, measures 4.5 x 1.875 x .25" thick (7 cells in series)

HSC#17872 **$12.50**

..Or you may need the power of a lead-acid battery. These are all new batteries with tab terminals. Perfect for hobbies, security systems, battery back-up, garden equipment, etc.

- **TR1.2-12**, 12VDC at 1.2 AH, measures 3.75 x 1.875 x 2"

HSC#17197 **$4.95**

- **TR4-6**, 6VDC at 4 AH, measures 2.75 x 1.75 x 4"

HSC#17588 **$4.95**

- **BAT-0063** (x2), 12VDC at 10AH, 4" x 6" x 4", this is two 6-volt batteries packaged in series by Best Power

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- New in box, 90-day warranty, includes AC adaptor, book

HSC#17862 **$27.50**

Home Alarm Stuff!

These items are dealer-returned inventory (shelf worn packaging but unused) of home security components that were made by Telko Inc. Mix and match to create your own bargain security system! All items have mounting screws or adhesive pads, instructions, and alarm units have window warning stickers. All parts have 30-day warranty.

- ST911 Automatic Phone dialer has screw terminals for sensor input, power adapter, and very long phone cord.
- Instantly contacts up to four pre-selected phone numbers with your own digitally recorded 16 second message.

HSC#17718 Phone Message Dialer **$27.50**

- S086N Glass Vibration Sensor Alarm -- self-contained unit detects attempted entry or breakage of fixed or sliding glass windows and doors. Only 2" across!
- High output 90 db alarm sounds instantly, providing a powerful deterrent to would-be intruders. Self-stick adhesive requires no tools. Alarm battery included.

HSC#17753 Glass Vibration Sensor Alarm **$2.95**

- S002M Digital Control Motion Alarm has wall-mount keypad, PIR infrared motion detector with 110° coverage to 60 feet, programmable security code, 10 - 15 second entry delay, extremely loud alarm.
- Uses 9V battery or AC Adapter (neither included)

HSC#17720 Digital Control Motion Alarm **$15.00**

- S008B Digital Control Motion Alarm with Safety Chime has wall-mount keypad, PIR infrared motion detector (same as S002M above) with very loud alarm OR safety chime alert.
- Uses 9V battery or AC Adapter (neither included)

HSC#17721 Digital Motion Alarm/Chime **$17.50**

- S082X Entry Guard Alarm has wall-mount keypad, magswitch activation (one switch included), programmable security code, 10 - 15 second entry delay, extremely loud alarm or pleasant door chime.
- Uses 3 AAA batteries (not included)

HSC#17722 Digital Entry Guard Alarm **$12.50**

PCI-Bus 56K Modem!

- Genica PCI-Bus 56K Modem at unheard-of price!
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- Voice from handset
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- Uses latest Lucent chipset, comes with Lucent drivers
- New retail box, with Trio application software on CD
- 90-Day Warranty

HSC#17532 **$39.95**

Video-hacker Dream!

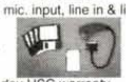
- Logitech Videoman Video-conference camera & interface
- These units were sold with Hewlett Packard S-700 workstations for videoconference capability
- We do not have technical data, software or manuals
- All we have is cameras with stand, and SCSI-II interface
- The camera is on a weighted stand that extends from 13" tall to over 20" tall, and has a stereo microphone
- Color camera is digital output only (not NTSC) as far as we can tell -- but who knows?
- Interface box has two SCSI-II ports on back, and a DC power input (we do not have the adapter), and on the front it has a mic. out jack, composite video input (BNC), and the connector for the camera cable.
- Note: HP and Logitech will provide no information on these

HSC#17503 **$39.95**

PCMCIA Sound Card!

Media Vision PCMCIA Sound Card

- Great for Portables, Laptops with PCMCIA Slot
- External pod has joystick port, mic. input, line in & line out jacks, volume control.
- Install software, inst. included.
- Win 3.x, W95 compatible
- New in OEM pkg (no box), 90-day HSC warranty
- We had these before at $39.95 and they went fast!



HSC#17036 **$29.95**

Compaq Docking Bay

- Compaq docking "Smartstation" for laptop computer (we don't know which!)
- Has two internal ISA slots
- SCSI port, network ports, serial, parallel, video, keyboard & mouse ports on back.
- Used, 90-day warranty

HSC#17713 **$39.00**

External SCSI Drive Cases

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- 50-pin SCSI connectors
- SCSI ID switch
- 65W Power supply (lots of power for hard drives, etc.)
- Fan-cooled, uses standard IEC Power cord (not included)

HSC# 17130 **$39.95**

- High quality low profile case for 5.25" drives, brand new!
- 7" x 2.25" x 11" overall size
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- SCSI ID switch, termination switch
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Write in 57 on Reader Service Card.

VOLUME 20
NO. 6
JUNE 1999

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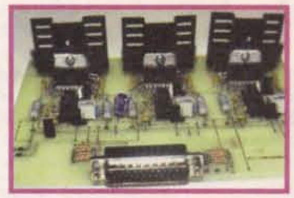

COLUMNS

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Departments

NUTS & VOLTS MAGAZINE IS PUBLISHED MONTHLY FOR $19.00 PER YEAR BY T&L PUBLICATIONS, INC., 430 PRINCELAND COURT, CORONA, CA. POSTMASTER: SEND ADDRESS CHANGES TO NUTS & VOLTS MAGAZINE, 430 PRINCELAND COURT, CORONA, CA 91719.

Published Monthly By
T & L Publications, Inc.
430 Princeland Court
Corona, CA 91719
(909) 371-8497
FAX (909) 371-3052

E-Mail
editor@nutsvolts.com
URL
http://www.nutsvolts.com

Subscription Order ONLY Line
1-800-783-4624

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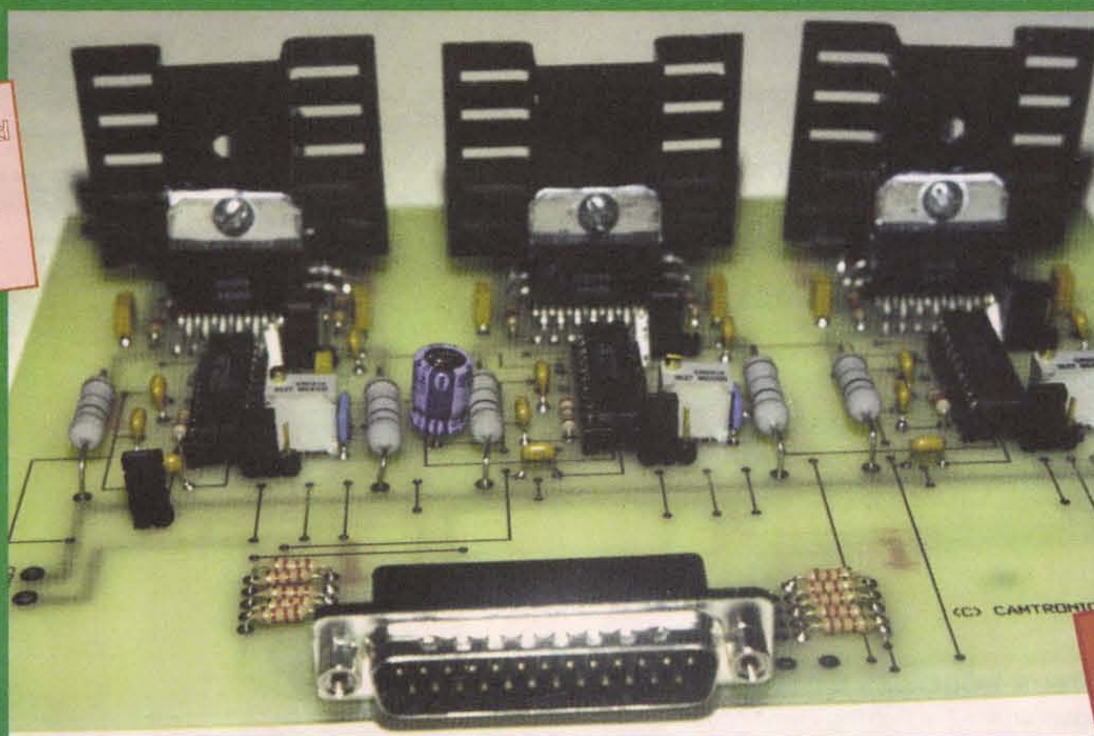
by Dan Mauch

Several years ago, I designed an L/R (Inductance/Resistance) step motor driver for various CNC machines that I had built. After a while, I found that I wanted more speed from the stepper motors. You can increase the speed of a stepper motor by increasing the motor supply voltage to several times the rated voltage. This allows the coils to charge faster so that more speed can be attained.

The problem with L/R type step motor drivers is that if you were, for example, to run a 5-volt, 1-amp motor from a 24V power supply and your L/R driver



The assembled three-axis chopper, step motor controller.

Part 2

Three-Axis Chopper, Step Motor Controller for Computer Numerical Control (CNC) Applications

was only rated at 1.25 amp per phase, you would burn out your driver. Thus, a current limiting resistor in series with the motor center taps would be required.

Rw = [(Vs-Vd)-Vm]* Im
R = is the wattage of the power resistor.
Vs is the voltage of the power supply.
Vd is the voltage drop across the output transistors.
Vm is the voltage rating of the stepper motor.
Im is the current rating of the stepper motor.

Thus, in the above example, an 18-watt resistor would be required for each center tap on the motor. If you have three motors, you would be dissipating quite a bit of power into the power resistors. On the other hand, a bipolar, Pulse Width Modulated (PWM) chopper driver would more efficiently operate a stepper motor at higher than rated voltages.

Some time ago, Karl Lunt of the Seattle Robotics Society and Clay Timmons on the Internet news group comp.robotics.misc discussed the SGS-Thompson L297 (Bipolar stepper motor controller) and the L298 (Dual 2 amp H-Bridge) combination as an efficient stepper motor controller and driver.

The data sheets for the above chips provide a good explanation of the operation of each chip. In short, the L297 takes step and direction signals and provides the correct phase sequences for the full-step, half-step, or wave-step modes and sends control signals to the L298 Dual H-Bridge. Additionally, the L297 has an onboard PWM chopper that provides switch-mode current control of the windings. The L298 can be used as a 2 amp stepper motor driver and has high-noise immunity. The L297, together with the L298 and a few other components, provides a complete bipolar step motor controller.

Since there are no chopper stepper motor controller kits on the market, I decided to design and build one. This circuit has proven to be a very low-cost solution to running stepper motors at higher than rated voltages.

The best part of the L297 and L298 combination is that they work well with many of the low-cost CNC software programs. I particularly like Desknc for Dos see www.deskam.com for a working demo copy. However, for our testing, we will use Dancam which is available for download at www.metalworking.com.

It is now time to build our three-axis, 2 amp driver, so we will have the controls ready for our machine that we will convert to CNC in a future article.

ASSEMBLY

Begin by reviewing the schematic and the circuit board layout illustrations. You may take the top overlay and place it directly over the top layer illustrations for finding any component that is not readily apparent. Note that all components are installed on the top of the board. To facilitate construction of this controller, a double-sided, plated-through PC board and a kit with all the parts is available from the source listed at the end of this article.

1. Insert snubber resistors R5, R7, R8, R9, R16, R17 (10 ohm 1/4 watt) into the board at the locations shown in the top overlay and solder. These pads are close to the adjacent diodes. Inspect after soldering to ensure there are no solder bridges.

2. Insert R3 (22K 1/4 watt). Bend for a .6" lead spacing. Solder in place.

3. Insert R1, R15, R13 (10K) into the locations shown. Solder in place.

4. Insert R21-R30 (2.2K) into PC board at the locations shown. Solder and clip excess leads.

5. Note the diode orientation on the top layer overlay. There are 24 diodes. Bend the leads of 12 diodes for a .5" lead spacing. Bend 12 diodes for a .55" lead spacing. Insert D1-D24 diodes ensuring that the cathode on the diode is properly oriented as shown in the top layer pictorial. These are a tight fit. Clip the leads about 3/16" long on the bottom of board. Start soldering from one side of the board working to the other ensuring the diodes stay in position.

6. Bend a scrap resistor lead into a U bend and insert it into the PC boards as a jumper for A2 and A3. Solder in place. Do not install a jumper in A1. There is an oscillator on the X-axis and it synchronizes the Y and the Z axis by connecting pins 1 of U1, U2, and U3 together. The oscillators on U3 and U4 must be grounded via this jumper in A2 and in A3 in order to function properly.

7. Insert U1-U3 20-pin DIP sockets with the notch facing U4-U6 and solder in place.

8. Insert R4, R6, R10, R11, R18, and R19 into the circuit board (.5 ohm 2-watt resistor). Solder and clip excess.

9. Insert C1, C15, and C22 (.22 uF ceramic capacitors).

10. Insert and solder C2 (.0033 uF) into the PC board. Solder and clip the excess leads. Ensure the lead does not short again the trace by pin 20.

11. Insert ceramic capacitors C7, C8, C9, C10, C16, C17 (.022 uF) into circuit board where shown. Solder and clip the leads.

12. Insert C3, C4, C5, C11, C13, C14, C18, C20, and C21 (.1 uF) into the PC board at the locations shown. Solder and clip the leads.

13. Insert C24, C25, C26, C27, C28, and C29 (681 pF) into the PC board and solder. Clip the excess lead.

14. Insert R2, R12, R14 (10K) RADIALLY into the PC board at the locations shown in the overlay drawing. The body should be next to pin 13 of the L298 and a piece of insulation placed over the exposed lead. Solder in place and clip excess lead.

15. Insert Vr1, Vr2, and Vr3 (1K trim pots) with the adjusting screw next to pin 14 of the 20-pin sockets. Solder and clip the excess lead.

16. Insert J1, J2, and J3 (three-pin SIP) into PC board and solder. Install a jumper on the two pins closest to the 10K resistor (half-step mode).

17. Install J4, J5, and J6 (three-pin SIP) into board and solder at locations shown. Install a jumper on the two pins next to the 20-pin DIP socket for J4, J5, and J6.

18. Insert P1 (DB25 connector) into the board and solder in place.

19. Install C6, C19, and C12 (470 uF electrolytic capacitor) as shown. Solder and clip the leads. Be sure the negative side of the caps line up with the GRD trace.

20. Insert C23 (100 uF electrolytic capacitor) into the circuit board. Ensure that the negative on the capacitor is oriented to connect with the ground trace.

21. Insert J7 (two-pin) header into the circuit board and solder. Do not install a jumper over the pins.

22. Insert U4-U6 into the circuit board using the overlay drawing for a guide. Solder the 15 pins. Install heatsinks on U4-U6 using a light coat of heatsink compound between U4-U6 and the heatsinks.

23. Insert the 18-gauge motor wires into the top or from the bottom (user's preference) on the board for each motor connection, i.e., phase a, A, b, B. Use a 12" length of red wire for phase "a." Use a 12" yellow wire for phase "A." Use a 12" orange wire for phase "b." Use a 12" green wire for phase "B." Ensure no loose strands are shorting against the diode leads. Solder the connections. Secure with a tie wrap as close to the 470 uF caps as possible. The connector pins for the motor end should not be installed until the controller is placed in a case and the leads should be trimmed to length for a neat installation. Then crimp and solder the 12 (18-gauge) female pins to the motor leads. Insert the leads into the Molex 6 conductor male connector. 1=red=phase a, 2=no connection, 3=yellow=phase A, 4=orange=b, 5=no connection, 6=green=phase B. Make sure to connect the correct wire with the correct pin hole location. The pin hole numbers are on the back end of the connector. A standard configuration is phase a=1, phase A=3, phase b=4, and phase B=6 holes 2 and 4 are not used.

24. Insert 22 gauge, two white wires, two yellow, an orange, and a blue wire into the circuit board at the locations shown in the pictorial next to the DB25 connector. Solder and secure with a tie wrap as close to the board as possible. Do not put the female pins on the other end until the unit is installed in a case. Then trim the leads to suit, crimp and solder the female pins, and insert into the 3 and 4 pin receptacles. One white wire (common) goes to pin 1 of the pin circuit female connector. The blue wire goes to pin 2 of the four-circuit connector. The yellow wire by the blue wire on the circuit board goes to pin 3 and the orange wire to pin 4. The other white wire connects to pin 3 of the three-circuit Molex connector. The last yellow wire connects to pin 1 (>) of the three circuit connector. Pin 2 is not used (1=yellow, 2=no connection, 3=white).

The logic power leads are 18", 18-gauge red and black wires, respectively. Solder one end of the red wire to the +5 pad on the circuit board as shown in the pictorial and the black lead at the GRD connection as shown on the top layer of the circuit board. Trim the wires to suit your installation. Then crimp and solder male 18-gauge pins onto the red and black wires. Insert the red wire into the two-circuit Molex connector (1=red, 2=black) at the hole by the orientation (>) notch of the connector. The black wire is inserted into

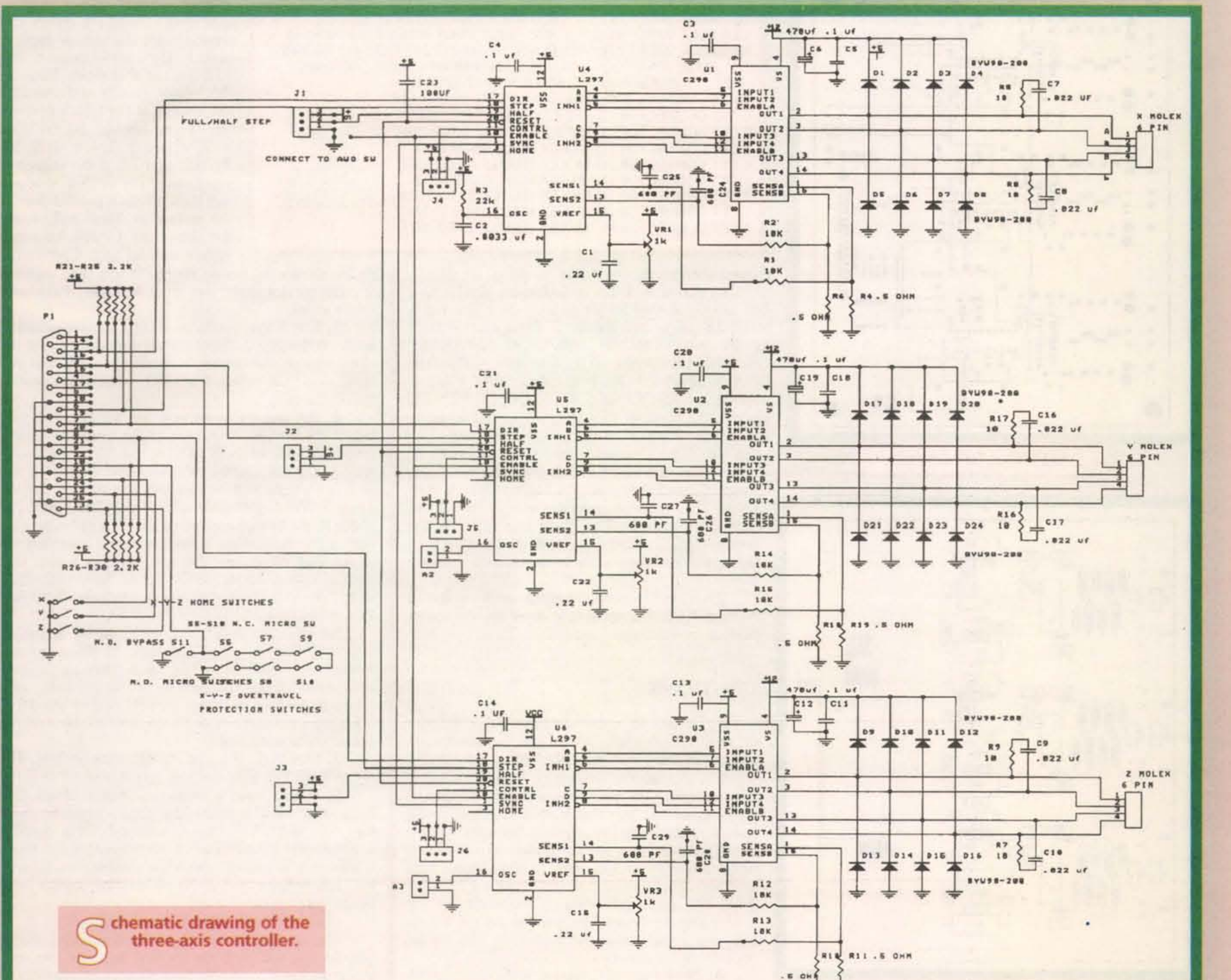
A double sided printed circuit board is available for $25.00 +$4.00 S/H from the source below listed.

A complete controller kit with PC board, software, all wires and components is available for $145.00 +$9.00 S/H from Camtronics, Inc.

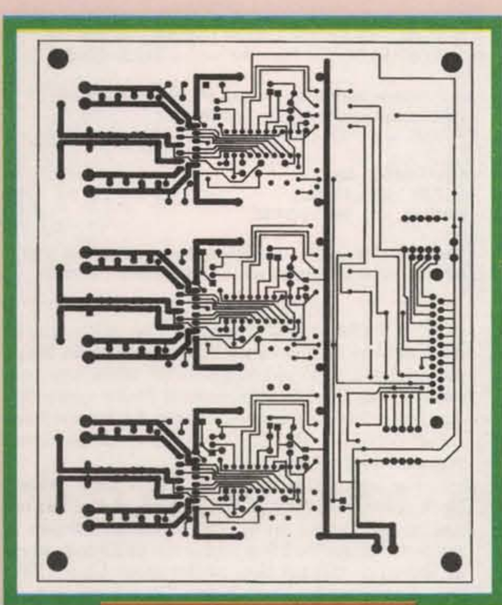
SOURCE

Camtronics, Inc
18230 130th Pl. N.E.
Bothell, WA 98011-3118

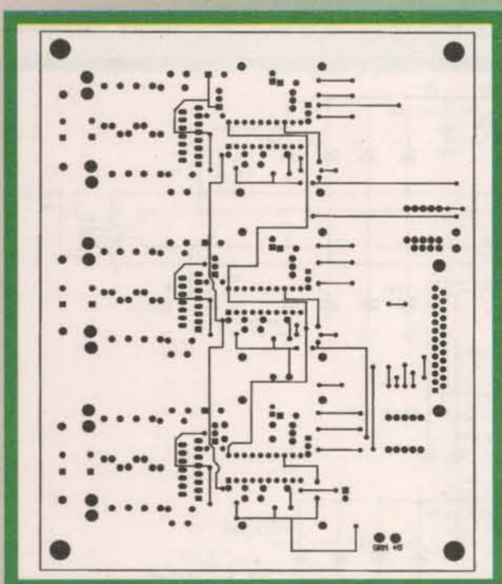
You may contact Dan Mauch at dmauch@seanet.com or visit his web page at www.seanet.com/~dmauch



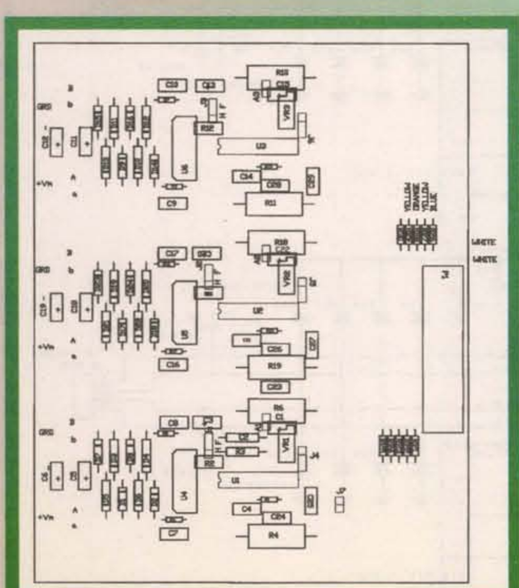
Schematic drawing of the three-axis controller.



L298N&V BOTTOM LAYER



L298N&V TOP LAYER



L298N&V TOP OVERLAY

BILL OF MATERIAL

Note all resistors are 1/4 watt unless otherwise noted.

DESIGNATOR	COMMENT	PATTERN
A1	WIRE JUMPER	SIP2
A2, A3	WIRE JUMPER	SIP2
C1,C15,C22	.22 uF 50V CERAMIC	RADO.2
C2	.0033 uF 50V	RADO.2
C3,C4,C5,C11,C13,	.1 uF CERAMIC 50V	RADO.2
C14,C18,C20,C21	.1 uF CERAMIC 50V	RADO.2
C6,C12,C19	470 uF 50V	RADO.2
C7,C8,C9,C10,C16,C17	.022 uF CERAMIC	RADO.2
C23	100 uF 35 V	RADO.2
C24,C25,C26,C27,C28	680 pF	RADO.2
C29,	680 pF	RADO.2
D1-D24,	BYW98-200 OR EQUAL	AXIAL.5
JI-J6,	3 PIN HEADER	SIP3
J7,	2 PIN HEADER	SIP2
P1,	DB25 RIGHT ANGLE MALE CON.	DB25RA/M
R1,R2,R12,R13,R14,R15	10K	AXIAL.3
R3,	22K	AXIAL.3
R4,R6,R10,R11,R18,R19	.5 OHM 2 WATT	AXIAL.6
R5,R7,R8,R9,R16,R17,	10 OHM	AXIAL.3
R21-R30	2.2K	AXIAL.3
U1-U3	L297	20 PIN DIP
U4-U6	L298N	MULTIWATT 15
VRI-VR3	1K TRIM POT	SIP3
SOCKETS (3)	IC SOCKETS	20 PIN DIP
PC BOARD	PCB	
HEATSINKS (3)	THM 6072	
JUMPERS (7)	J1-J7 SHORTING JUMPERS	
18 GAUGE WIRE (12)	MOTOR WIRES (12 INCHES)	
18 GAUGE WIRE (3)	BLACK Vm GROUND (18 INCHES)	
18 GAUGE WIRE (3)	RED VM + 2VDC (18 INCHES)	
18 GAUGE WIRE (1)	RED +5VDC LOGIC POWER (12 INCHES)	
18 GAUGE WIRE (1)	BLACK GROUND FOR LOGIC (12 INCHES)	
22 GAUGE WIRE (6)	HOME/OVERTRAVEL PROT. SWITCHES	
18-22 GAUGE PINS (26)	MALE PINS 02-09-2118	
18-22 GAUGE PINS (26)	FEMALE PINS 02-09-1119	
6 CKT CONNECTORS (3)	MOLEX MALE 03-09-1061	
6 CKT CONNECTORS (3)	MOLEX FEMALE 03-06-2061	
4 CKT CONNECTOR (1)	MOLEX MALE 03-09-1041	
4 CKT CONNECTOR (1)	MOLEX FEMALE 03-09-2041	
3 CKT CONNECTOR (1)	MOLEX MALE 03-09-1032	
3 CKT CONNECTOR (1)	MOLEX FEMALE 03-09-2031	
2 CKT CONNECTOR (4)	MOLEX MALE 03-09-1027	
2 CKT CONNECTOR (4)	MOLEX FEMALE 03-09-2021	

the remaining hole.

The power leads for each axis are similar. Use 18" length of red, 18-gauge wire for +Vm and a black, 18-gauge wire for the GND. leads. Caution: EACH AXIS MUST HAVE A SEPARATE GROUND LEAD ALL THE WAY BACK TO THE POWER SUPPLY OR THE UNIT MAY CAUSE THE MOTORS TO MISS-STEP. DON'T TRY TO ELIMINATE THESE LEADS. Solder the wires to the circuit board as shown in the pictorial. The wires should be trimmed to length to suit the installation. Crimp and solder a male pin onto each wire. Insert the red wire into the two-pin Molex connector. The red lead goes in the hole by the orientation (>) notch. The black lead goes to the remaining hole. Mark these motor power leads so you never mix them with the 5-volt logic connectors.

25. Clean the board and inspect it using a 5-X magnifying lens to ensure there are no solder bridges or unsoldered terminals. Correct as necessary.

CAUTIONS

1. Be sure to mount the three-axis controller on insulated standoff. One of the mounting pads is close to the Vm connection and could cause a short to ground if a conducting standoff is used. Alternatively, you may scrape off the mounting pad copper foil (top and bottom and inside the hole) and eliminate the problem that way.

2. Never boot the computer with the controller powered up and ready to run. Always turn on your computer first and move to the CNC program first before powering up the controller. As your computer boots, the parallel port is initialized and could cause the motors to step in an uncontrolled manner.

3. Never use a computer with the parallel that is built into the motherboard. If you fry the parallel port on this type of computer, it could be very expensive to repair. Always use an old AT 286-12 to a 486-66 computer with separate parallel ports on an I/O board. They only cost about $20.00 to replace. This warning is only given because we can not be sure of the user's circumstances. We have never burnt out a parallel port, but if you have a computer that has business records or is an expensive computer, then use it at your own risk while testing.

TESTING

Do not connect to your parallel port at this time. Do not install U1-U3 at this time.

1. Using an ohmmeter, verify there is no short circuit between +12VDC and ground on each axis. Similarly, check between +5VDC and ground for a short.

2. Switch the meter to read voltage. Connect a 5VDC power supply to the +5VDC connection and ground. (The controller was designed to use a standard AT style PC power supply rated at 200 watt. These are cheap and work well for low voltage applications.) Do not connect the +12VDC at this time. Turn on the power supply and measure the voltage at the DB25 connector. There should be 5 VDC ± .3V at pins 2, 3, 4, 6, 7, 8, 10, 11, 12, and 13. If the voltage is significantly higher than this you can burn out your parallel port. If the voltage is significantly lower (i.e., less than 4 volts), improper signals may be sent. Correct the problem with the power supply. If you read voltages at some but not all the pins identified, then check your solder joints.

3. Check that you have +5 at the corresponding leads on the X-Y-Z home switch connector using the white wire as the common. Similarly, verify that you have +5 on the yellow lead of the over travel protection connector.

4. Set the reference voltages for U1, U2, and U3. With +5 volts connected to the controller board, adjust VR1 to obtain .5 VDC on pin 15 of the socket for U1. Do not exceed +1V. The Vref divided by the Rs (.5 ohm resistor determines the current output. Thus, a .5VDC reference voltage will yield 1 amp per phase in the two phases on mode. The H bridge cannot handle more than 1 ampere unless a cooling fan is provided. Maximum Vref is 1 VDC for a two amp current rating. REMEMBER TO RESET THE REFERENCE VOLTAGE USING Vrl-Vr3 WHENEVER YOU CHANGE POWER SUPPLIES.

Set reference voltage on pin 15 on U2 and using Vr2, and U3 using Vr3, similarly. If different rated motors are used, then set each variable resistor accordingly. If the voltage will not set correctly, look for solder bridges or opens on VR1 and on pin 15 of U1. Check for opens near J4, J5, and J6. Shut off the power when completed.

5. Insert U1, U2, and U3 into their sockets. The notch faces U4, U5, and U6, respectively.

6. If you have a frequency meter, check that there is an 18 kHz to 20 kHz synchronization signal on pin 1 of U1-U3. Do not proceed if this signal is less than the stated value or not present. If the signal is absent or incorrect, check the oscillator circuit with the 22K resistor and 3300 pF cap for correct positioning or shorts.

This concludes the assembly and initial checkout. In the next article, we will connect the controller to the PC, the stepper motors, configure the software, and test the controller and stepper motors. **NV**

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reader FeedBack

***Dear Nuts & Volts*:**

I would like to comment on the Tech Forum answer published for question #3996 Mar. '99. When a polarized electrolytic is reverse-biased, its leakage resistance drops rapidly. So, when two of them are connected back-to-back to make a non-polarized capacitor and, a voltage is applied to the series pair, nearly all of the voltage will appear across the forward-biased capacitor. This means the voltage rating of each capacitor must be as great as the maximum applied voltage. To create a 5uF 300V non-polarized capacitor, you should connect two regular 10uF 300V electrolytics back-to-back.

Bob E. Baker, Carmichael, CA

Dear Nuts & Volts:

I was just browsing a complimentary copy of *Nuts & Volts* and I was bothered enough by the answer to #3996, Mar. '99 in the Apr. '99 issue that I had to notify you immediately of a dangerous answer that was given.

The answer highlights an example of connecting two polar electrolytics back-to-back. The answer says the two 150 volt, 10uF caps in series will be equivalent to a 5uF at 300 volts. This is absolutely wrong. The reason a polarized capacitor is polarized is that it must not be operated with any significant reverse voltage. This hook-up just described requires the capacitor to accept the full 150 volts in reverse!

If you try this, the forward capacitor will be forced to take most of the voltage because the reversed capacitor is very leaky. The voltage across capacitors does not divide according to capacitor value just because they are there.

Other important factors always contribute to the voltage division. In this case, the capacitor reverse leakage is far greater than any other factor. The result is that the 300 volts will at first divide such that the capacitor in normal polarity will be forced to excessive voltage drop. This will lead to excess forward leakage to match the reverse leakage of the other series capacitor. Then both caps will heat up due to this excess current flow and they will ultimately fail in what might be a dangerous explosion much like a firecracker.

Using two caps to create a non-polar cap has always been questionable at best. The devices made for this application at least have the manufacturer thinking about how they are applied and used. One is always better off to use the proper component within its ratings.

Mouser carries non-polar and bi-polar caps in addition to the other suppliers mentioned. With one style of non-polar caps, Mouser's catalog cautions that it is for circuits that are "sometimes reversed or to which short duration AC is impressed." By the way, the acronym NPO normally refers to zero temperature coefficient ceramic capacitor, not to Non-Polar Electrolytic (maybe NPE).

I hope this answer will correct an unsafe application of electrolytic capacitors. There is a lot more to capacitors than just the volts and capacitance. Many caps are misapplied leading to short life or sometimes disaster. They can blow up like a small bomb in the wrong circumstances.

Bob Hillman, Big Bend, WI

Dear Nuts & Volts:

The answer provided by Ken Simmons to the question of NP capacitors (#3996), ignores a very important factor. Although ordinary capacitors connected in series are equivalent to a single cap, as stated, polarized electrolytics are different in that they behave something like a short circuit when a reverse polarity voltage is applied.

In an audio speaker application, they will be reversed-biased during portions of the signal. To approximate a 5uF NP value, connect two 5uF polarized units in series-bucking, as shown in the letter.

By the way, I understand that NP caps even for motor start applications are fabricated from two polarized units.

Phillip Milks, via Internet

Dear Nuts & Volts:

Your Jan. '99 issue had an excellent article about the PIC-ICE II, In Circuit Emulator for PIC16 microcontrollers. I would like to make your readers aware of another reasonably priced unit they may wish to consider. Zilog makes a line of microcontrollers similar to the PIC16, although not quite as extensive, and only available as OTPs.

The Z86E04 will fit in a board designed for a PIC with minimal changes. They sell the Z86CCP01ZEM, an in-circuit emulator and programmer for the OTP chips, for under $100.00. To use the 28 and 40 pin versions requires an accessory kit for another $90.00 that adds 28 and 40 pin ZIF sockets for programming, and 28 and 40 pin target cables for emulation. The included developer studio integrates the editor, assembler, and debugger under one interface as does the PIC-ICE. The most notable difference is the speed, the Zilog emulator runs at full system speed.

The crystal and capacitors on the emulator PCB are pluggable, so the crystal from the final circuit can be used on the emulator if timing is really critical.

Tom Wyckoff, via Internet

Dear Nuts & Volts:

In the Jan. '99 issue, Mr. Henry Van Zee asked for a circuit to light LEDs for input frequencies of 60 and 62 Hz. One reader suggested using two 567 tone decoder ICs. While this approach is sound and will work as requested, it seems that what Mr. Zee is trying to do is to simulate the old vibrating reed frequency meters used to monitor the output of motor-driven portable generators. These meters used 8-10 steel reeds of varying resonant frequency which were driven by a coil coupled to the output of the generator. In operation, all of the reeds wiggled slightly, however, the reed whose resonant frequency was closest to the driving frequency of the coil vibrated the most.

By observing which reed was vibrating most strongly, the generator's governor could be set to keep the output frequency at a nominal 60 or 400 Hz. This device can be easily and cheaply simulated with a simple two-IC circuit.

Design a phase locked loop based on an LM566 with a center frequency of 60 Hz and a bandwidth of about ±4 Hz. Connect the generator or other AC source (isolated and attenuated as required) to the input of the PLL. Connect the error signal of the PLL to the input of a bargraph display IC which drives an array of 8-10 LEDs.

The PLL compares the external signal to its own internal reference frequency which is generated by a voltage controlled oscillator (VCO).

As the input frequency deviates from the design or center frequency of 60 Hz, the feedback system within the PLL will generate an error signal which causes the VCO frequency to shift. This causes the VCO to track the input frequency exactly. Since the error signal is proportional to the deviation from the PLL center frequency, a bargraph display connected to the VCO control signal indicates deviations from the center frequency.

Through proper design of the PLL and selection of the correct calibration resistors, the bargraph display can be made to change in response to 1 Hz changes in the input frequency.

Dave Sarraf, via Internet

Dear Nuts & Volts:

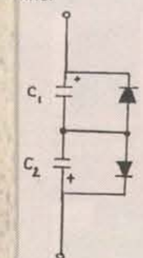
Mr. Simmon's solution to Tech Form question #3996 about non-polarized capacitors raises some safety concerns. The two capacitors are "in series" in appearance only. If the combination sees an AC signal with no DC component (or a small one), then each capacitor experiences a reverse-bias on one-half cycle. Reverse-bias and sufficient ripple current can cause either capacitor to overheat and possibly explode. (I speak from experience.)

Mr. Simmon's solution works fine for a quick test or breadboard (exercise caution, check the waveform with a scope, and wear safety goggles), but Mr. Broussard's original application in #3996 is to replace a capacitor in an ARC-5 receiver. Back-to-back capacitors is not a safe way to go in that application. Also, if the back-to-back combo was connected to a capacitance bridge, it would measure 7-10uF. Again, the capacitors are not electrically in series and the value depends on when each capacitor reverse biases and conducts (it can vary widely).

Finally, the part Mr. Broussard needs is not available from MCM Electronics or Digi-Key.

CORRECTED ANSWER TO #3996

A non-polarized capacitor (also called a "bipolar" cap) has no positive or negative terminal. A non-polarized capacitor yields the benefits of an electrolytic: high capacity per given volume, moderate voltage, low ESR, and high surge current capability in non-DC applications. It's fairly common in TV and radio circuits and if you can't find an exact replacement, the circuit below will do the job just fine.



C1 and C2 are 5uF	450WVDC:
Sprague	#TVA1703
Mallory	#TC70
Cornell-Dubilier	#WBR5-450

All are available from Newark Electronics, 1-800-4-NEWARK or www.newark.com. There are a few important design considerations. **A.** These capacitors are not in series for calculation purposes. The total capacitance in the diagram is not

$$\frac{1}{C_{total}} = \frac{1}{5.0uF} + \frac{1}{5.0uF} = 2.50uF$$

It's just 5.0uF. Also, the total voltage capacity is not 900 volts. It's just 450 volts. These capacitors are not in series. The diodes simply put one capacitor into the circuit and then the other.

B. The diodes and the capacitors might have to carry some surprisingly high currents. Good examples are the power stage of an amplifier or the vertical deflection circuit of a television. Be sure to check the "ripple current rating" and "core temperature" for the capacitors and the "forward current rating" for the diodes. Also the diodes must be 400V PIV minimum. If the old capacitor burned out, consider designing 20%-50% more current carrying capacity into the replacement.

C. Pay attention to safe design practices. If a diode "opens" due to high current or a bad solder joint, the associated capacitor can explode (just like any other reversed-biased electrolytic).

Bob Miller, Trenton, NJ

Newsbytes

ObjectARX multimedia CD-ROM Course teaches how to program AutoCAD in C++

Ransen Software announces Ransen's ObjectARX Course, a unique multimedia CD-ROM that teaches you how to program AutoCAD 2000 and AutoCAD 14 in C++. This self-paced course consists of 20 chapters, a help file, and many complete source code examples. The course takes you step-by-step though creating applications for AutoCAD using Autodesk's ObjectARX programming libraries.

Ransen's ObjectARX Course was devised by Owen Ransen, a registered AutoCAD applications developer who is also the author of "Programming AutoCAD in C/C++" (Wiley and Sons 1997). Having faced the same problems that other real-world developers face, he saw a need for a general and useful way of introducing AutoCAD C++ programming since the official Autodesk documentation is very detailed but sometimes too much so. Ransen's ObjectARX Course offers tutorials, practical examples, and help files written in a programmer-friendly language.

Each chapter consists of a concept overview followed by a detailed explanation, with a self-test summary quiz to check that the student has absorbed the concept. A laboratory exercise for practical experience of the ideas introduced concludes each chapter.

Subjects covered in Ransen's ObjectARX Course include "Getting Started," "An ARX View of AutoCAD Drawings," "How to Create 2D and 3D Objects," "Handling Layers and Blocks," and many others. A valuable feature that programmers will appreciate is the Help File, which covers in a practical way many important problems that AutoCAD programmers face.

To make use of this course a knowledge of C++ to a medium level is required, and experience in using AutoCAD is also an advantage. The ObjectARX 2000 SDK file, available as a free download from the Autodesk website, is also needed.

Ransen's ObjectARX Course costs $59.00 and can be ordered in the USA from: **Saelig Company LLC**, 1193 Moseley Road, Victor, NY 14564 USA, Fax: **716-425-3835**, Tel: **716-425-3753**, E-Mail: **saelig@aol.com**. For international orders and a demo version see the WEB site **http://www.ransen.com**

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Open Channel

by Joseph J. Carr

Spectrum Analyzers — Including One to Build

Spectrum analysis becomes possible when the various frequency components and noise are measured and displayed. Over the years, several approaches have been taken to spectrum analysis: Fourier analyzer, tunable filters, and spectrum analyzers.

Signals can be represented in a number of ways. The most familiar is the time domain representation shown in Figure 1A. This view of a pair of signals plots their amplitudes against time, so reveals their wave shapes (in this case, sinusoidal). From an amplitude-vs.-time display, one can tell the frequency (because $F = 1/T$), amplitude, and waveshape. An oscilloscope is normally used to view the time domain aspect of a signal.

Another view is the frequency domain shown in Figure 1B. This display plots amplitude-vs.-frequency, so the same two signals seen in Figure 1A will plot as a pair of spikes in Figure 1B. The comprehensive view of signals requires that we take a look at both time domain and frequency domains. Because they share a common axis – amplitude – we can view them orthogonally as in Figure 1C.

All continuous waveforms can be represented mathematically by a series of sine and cosine functions. Only the sinewave is pure in the sense that it contains only one frequency. All other waveforms, including sinewaves with even the smallest possible amount of distortion, possess a number of harmonically related frequency components. The specific harmonics, their amplitudes, and phases, determine the final shape of the overall complex wave. The complex wave can be described by a mathematical device called a Fourier series.

Using the Frequency Domain

If we were certain that all signals in a system were pure sinewaves, there was no modulation or heterodyne mixing taking place, and that all stages in the system are perfectly linear, then the time domain display seen on an ordinary oscilloscope would suffice for practical purposes. But that never happens. Real signals have distortion, undergo both modulation and frequency mixing, and never see a perfectly linear signal processing stage.

The principal uses of a spectrum analyzer are to examine noise, distortion, mixing action, and modulation. It is necessary to characterize signals going into and coming out of a system in order to understand how the system acts on the signal. By examining the "goes intos and goes out-ofs" we can characterize the system and determine its performance.

Noise. Figure 2A shows a frequency domain characterization of a noise signal. Understanding the noise spectrum allows us to either evaluate or design the system to best overcome its effects. The noise spectrum therefore permits us to spot problems in system performance, and design accordingly.

Harmonic Distortion. When a pure sinewave is passed through a non-linear stage, harmonic components are generated. These new frequencies are integer multiples of the fundamental frequency (2F, 3F, 4F ... nF). When a non-pure sinewave (which has its own harmonics) is processed in a non-linear stage, additional harmonics or increased harmonic amplitudes are created. Figure 2B shows the frequency spectrum of a waveform with multiple harmonics present. The tallest spike represents the fundamental frequency sinewave, while the smaller spikes are the harmonics.

Intermodulation Distortion. While harmonic distortion occurs on a single signal, intermodulation distortion (IMD) occurs when two or more signals mix in a non-linear circuit. When this occurs, additional frequencies are generated according to the rule $mF1 \pm nF2$, where m and n are either zero or integers. Figure 2C shows this action when two equal amplitude signals (F1 and F2) interact in a non-linear manner. The two small peaks are particularly interesting in amplifier and receiver designs because they fall close to F1 and F2 (other products fall very far away). These are the 2F1-F2 and 2F2-F1 products.

When undesired, this effect is called IMD, but when the desire is to translate frequencies in a mixer circuit, the effect is called heterodyning (one circuit's trash is another's treasure).

Modulation. A single frequency unmodulated signal will have a spectrum consisting of a single spike in the absence of distortion. But when information is imparted to the signal, additional products are created. These show up as a spectrum similar to Figure 2D. Here we see the result when a sinewave RF carrier is amplitude modulated by a sinewave audio tone. In this case,

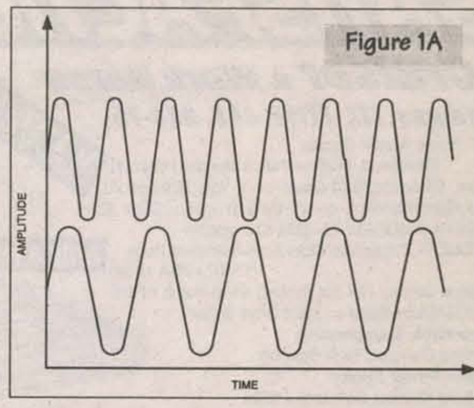

Figure 1A

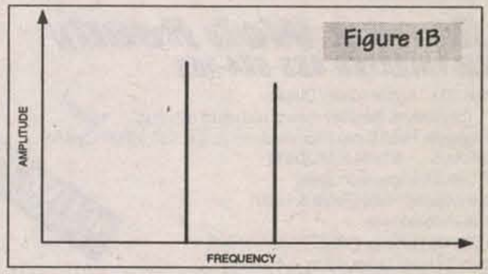

Figure 1B

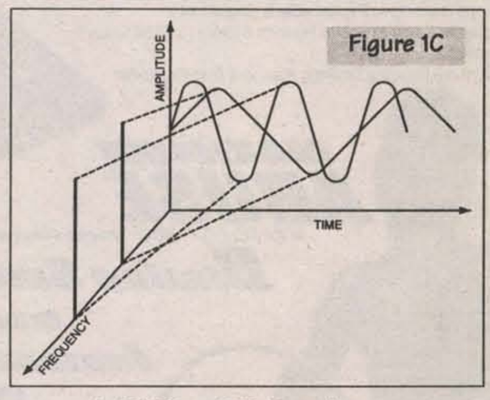

Figure 1C

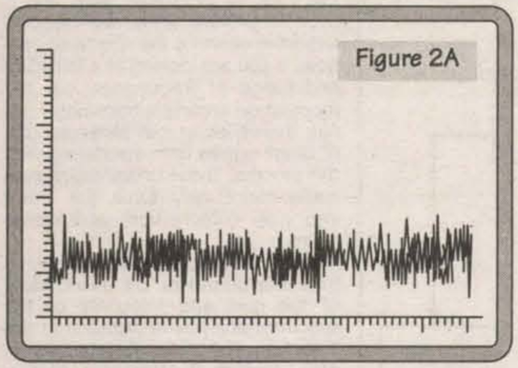
Figure 2A

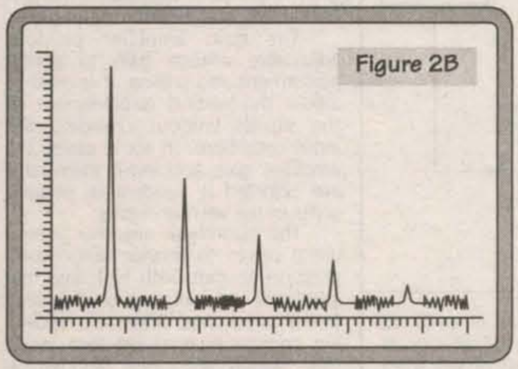
Figure 2B

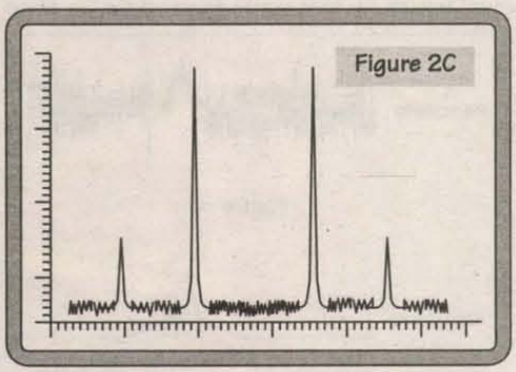
Figure 2C

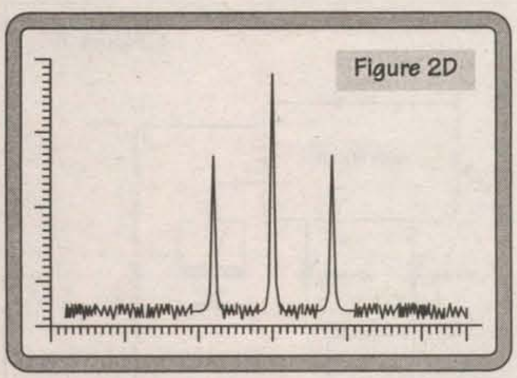
Figure 2D

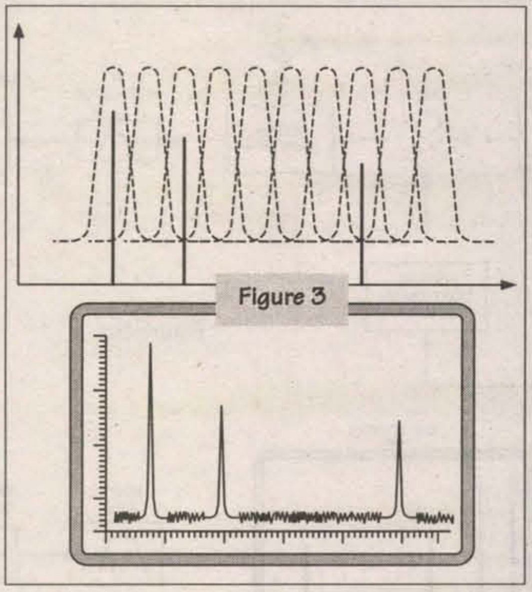
Figure 3

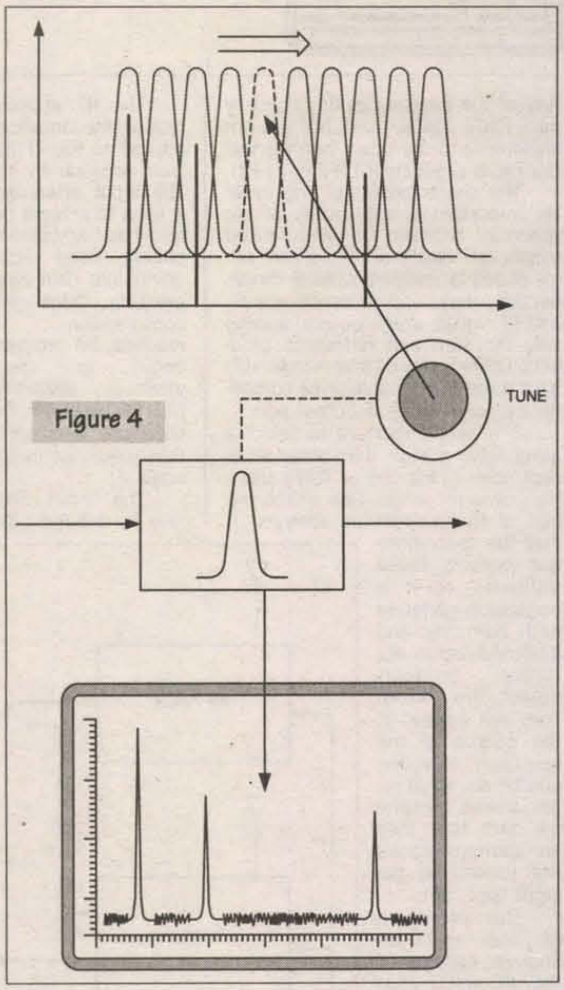

Figure 4

a mixing action takes place, as shown clearly on the spectrum trace. If an RF carrier Fc is modulated by an audio tone Fa, then the two products are Fc + Fa and Fc - Fa. These are called the upper and lower sidebands (USB and LSB), respectively.

Spectrum Analysis

Spectrum analysis becomes possible when the various frequency components and noise are measured and displayed. Over the years, several approaches have been taken to spectrum analysis: Fourier analyzer, tunable filters, and spectrum analyzers.

The Fourier analyzer is depicted in Figure 3A, while its display is shown in Figure 3B. The analyzer consists of a series of adjacent bandpass filters, each of which passes a small amount of spectrum. When the outputs of these filters are poled, it's possible to build the display shown.

There are a number of problems with the Fourier analyzer. First, it's not terribly flexible because the filters are fixed tuned. Second, the resolution depends on the filter bandwidth, which may not be consistent throughout the range of frequencies being measured. Finally, there is a restricted number of adjacent frequency filters that can be accommodated, especially where cost is a consideration. Finally, there may be interaction between the filters, causing a loss of performance.

The tunable filter approach is shown in Figure 4. A filter is designed to be tuned across the entire range of frequencies by manual means. In

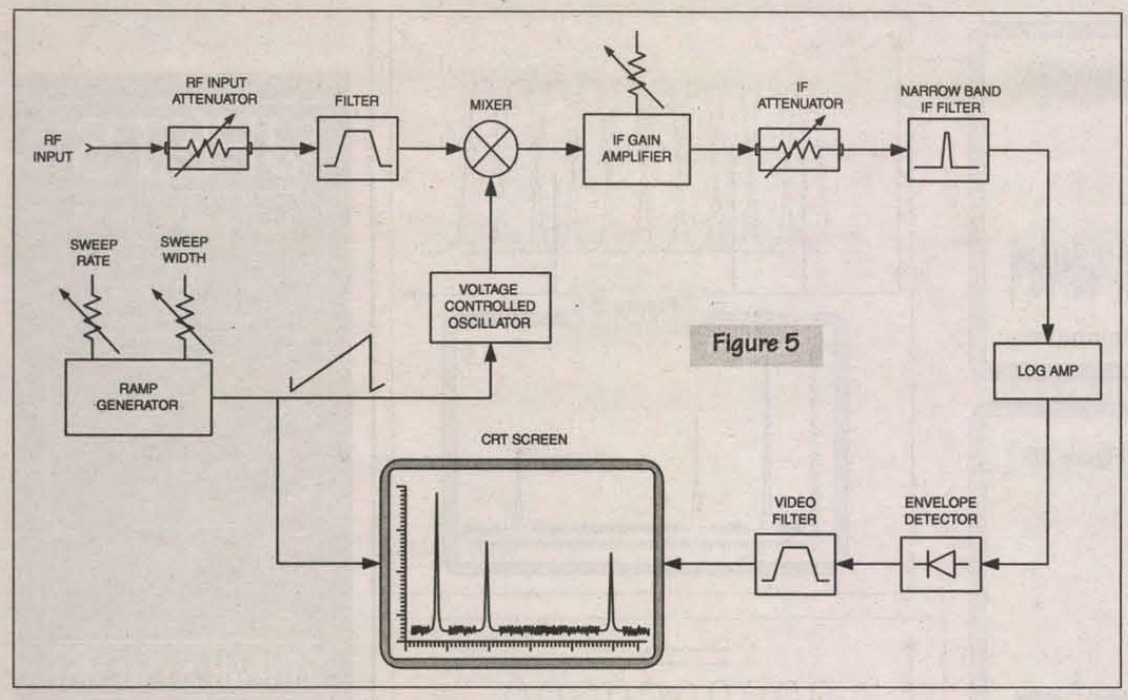

Figure 5

most cases, these instruments were actually special purpose radio receivers. When the output was calibrated, the instrument was called either a wave analyzer or tunable RF voltmeter.

Both of these approaches suffer from major faults, not the least of which is poor ease of operation. The modern spectrum analyzer solves these problems rather nicely.

The Spectrum Analyzer

The spectrum analyzer basically automates and improves the tunable RF voltmeter. Figure 5 shows the basic block diagram for a generic spectrum analyzer. It is a narrow band receiver that is swept tuned across the range of interest. A sawtooth ramp waveform is used to sweep tune the receiver, and to drive the horizontal deflection system of the oscilloscope. The output of the receiver is proportional to signal strength, and is applied to the vertical input of the 'scope. The result is the spectrum plot shown.

To understand the operation of the spectrum analyzer, let's take a look at each stage in its turn. The heart of the spectrum analyzer is the mixer and local oscillator (LO).

The LO is a voltage controlled oscillator (VCO) that produces an output frequency that is proportional to an applied input control voltage. In the case of the spectrum analyzer, the input voltage is a ramp, so the voltage will change as the ramp voltage rises. Because most VCO circuits have a quadratic relationship between the control voltage and frequency, it may be necessary in some cases to alter the tuning voltage waveform from a linear ramp to a shape that makes the sweep of the VCO output frequency look linear.

The mixer is a non-linear circuit that mixes the RF input signal (F1) with the LO signal (F2) to produce an intermediate frequency (IF) output. Any of the frequencies described by $mF1 \pm nF2$ can be used, but it is not reasonable to use other than the second-order products (F1+F2 or F1-F2).

The characteristics of the mixer are important to the quality of the spectrum analyzer. Double-balanced mixers are usually preferred over single-ended or single-balanced mixers because they tend to cancel the F1 and F2 signals in the output, leaving only the sum and difference products. Other forms of mixers invariably have a residual F1 and/or F2 component present in the IF output port.

It is very important to select a mixer with a high third-order intercept point (a.k.a. IP3 or TOIP) and a high dynamic range. One of the failings of cheap spectrum analyzers is that the mixer does not possess these attributes, so it is possible to generate both harmonic and intermodulation distortion products inside the mixer. They will appear at the output of the spectrum analyzer, and be displayed on the screen, despite the fact that they are spurious signals not present in the input spectrum.

The front-end of the spectrum analyzer consists of the mixer/LO plus any pre-processing done. There are two forms of pre-processing shown here: RF input attenuator and RF filter. Some spectrum analyzers might also have a preamplifier. It is not unreasonable to expect these stages to be switch selectable.

The RF attenuator is used to reduce the amplitude of all signals applied to the RF input of the spectrum analyzer by an equal amount. The input attenuator is used to prevent the mixer and any preamplifiers used from going into gain compression. Once gain compression is reached, IM products begin to creep upwards distorting the picture of the spectrum with spurs that were not in the original.

The input filter may be a band pass, low pass, or high pass filter, and is used to prevent unwanted frequencies from entering the spectrum analyzer. If you are looking at a fairly limited range of frequencies, say the modulation around a transmitter signal, then filtering can eliminate out-of-range signals from interfering with the process. Those unwanted signals could conceivably force the mixer into gain compression, and create spurs.

The IF section handles the signal from the output of the mixer. Most of the gain and selectivity of the spectrum analyzer is provided in the IF section. The principal stages are: IF gain amplifier, IF attenuator, narrow band filter, and logarithmic amplifier.

The gain amplifier provides adjustable voltage gain to permit adjustment and scaling. It is used to adjust the vertical displacement of the signals without changing the input conditions. In some cases, the amplifier gain and input attenuator are adjusted in tandem to prevent shifts in the vertical display.

The logarithmic amplifier (where used) serves to provide range compression so that both high and low amplitude products can be displayed at the same time. Otherwise, providing enough gain to see low amplitude signals will cause high amplitude signals to go off the top of the

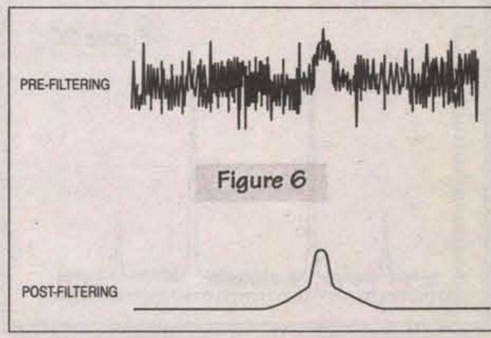

Figure 6

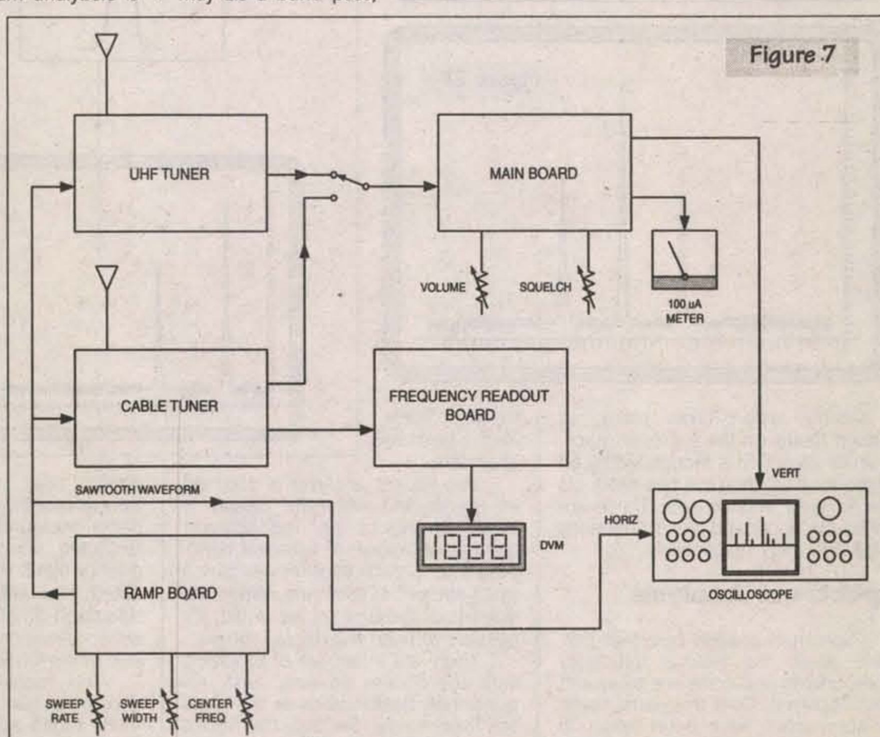

Figure 7

scale. Also, using a logarithmic amplifier permits the use of decibel notation on the CRT screen.

The video detector is an envelope detector that produces a DC output that is proportional to the signal strength at the frequency being measured. It produces the vertical deflection signal seen on the CRT screen. But this signal is often not too clean, and must be filtered. Figure 6 shows pre-filtering and post-filtering versions of a noisy waveform. The pre-filtering version is barely usable, if that.

Poor Man's Spectrum Analyzer

Ever wondered what to do with an old, worn out, low-frequency oscilloscope? I've seen a large number of 500-KHz to 5-MHz oscilloscopes on sale at hamfests and other places for a prayer and a dime (or some such low price). But what are they used for? Any self-respecting oscilloscope will have a 20 MHz or higher bandwidth, which is why the older models are basically in the decimal dust category. Hmmmm ... what to do with one of these "boatanchors?"

There is a solution. A number of years ago, I wrote a column in a magazine called *Ham Radio*. One of the projects I built for the column is a spectrum analyzer kit offered by Murray Barlowe of **Science Workshop,** P.O. Box 310N, Bethpage, NY 11714-0310; **(516) 731-7628**; FAX **(516) 796-1693**; E-Mail: **mbarlowe@hoflink.com**; web site **http://www.scienceworkshop.com/**. I recently ran across the Science Workshop web site, and found to my delight that the project is still being offered, but with some upgrades. I obtained the pieces from Science Workshop and did it again.

The Poor Man's Spectrum Analyzer (PMSA) got its start back in 1978 when Murray demonstrated it at the Dayton Hamfest. The PMSA (Figure 7) uses cable television tuners as the front end. Two frequency ranges are available: 0-500 MHz, and UHF above 500 MHz. These tuners are voltage controlled so that the television designer can build phase locked loop (PLL) tuning. The fact that they are voltage tuned means that they can be swept through their frequency ranges. When a sawtooth waveform is applied to the tuning voltage input on the tuners, the sweeping takes place.

The cable TV tuners output the converted signal on an IF frequency close to 53 MHz (normal to TV receivers). The SW-6006 main board is a receiver that will downconvert the 53-MHz IF signal to a low IF of 10.7 MHz, and then demodulate it. The bandwidth of the output signal is approximately 250 KHz, so there is a resolution problem that may be a problem on crowded bands. The problem does not prevent you from using the device to check the output of a transmitter for spurs and harmonics, however. Fortunately, there is a Switched Filter Upgrade kit (SW-6010) that permits selection of 250 KHz, 55 KHz, or 15 KHz bandwidths.

It should also be possible to use a regular VHF receiver as the IF, and get even better resolution. A number of general coverage receivers will go to the required range. Alternatively, there are ham radio six-meter band converters that can be used as well. However, my experience with the Science Workshop product indicated that the SW-6006 worked satisfactorily for my purposes.

The sawtooth waveform needed to sweep the tuner through the range (with Center Frequency, Sweep Width, and Sweep Rate controls) is provided by the Ramp Board (SW-6001).

One of the problems with the original PMSA that I built was the necessity of calibrating the frequency dial. I used a chart comparing 0-999 micrometer dial (connected to the tuning voltage potentiometer) readings to frequency. The current offering has a Frequency Readout Board (SW-6007) that converts the prescaler output of the cable-TV tuner to drive a digital voltmeter that serves as the frequency readout.

Frequency can also be measured using an optional Marker Generator (MSG-100). This is also a cable TV tuner in which the voltage tuned local oscillator is used to provide a signal to mix with the front-end signal. It puts a "pipper" on the oscilloscope display that indicates frequency. By measuring this frequency with a digital frequency counter, we can make accurate determinations of frequency.

Also available is a Tracking Generator upgrade (SW-5900). This type of instrument is basically a signal generator that tracks the spectrum analyzer center frequency. It can therefore be used to make frequency response measurements of circuits and devices. The tracking generator was a really neat addition to the system because it permits testing that is not possible with the PMSA alone.

The various pieces of the PMSA are available from Science Workshop in either kit form or wired and tested. Add a "K" to the kit number for kit, and "W" for wired.

The bottom line is that the Poor Man's Spectrum Analyzer is one way to get a reasonably performing spectrum analyzer without laying out a huge amount of cash. Will it do everything that a $30,000.00 professional model will? Nope, but that's not the question. The real question is: Will it do the jobs that you need it to do? **NV**

Connections ...

I can be reached by snail mail at P.O. Box 1099, Falls Church, VA 22041, or via E-Mail at CARRJJ@AOL.COM.

Events CALENDAR

JUNE 1999

JUNE 3-4-5

IN - INDIANAPOLIS - Antique Radio Swapmeet, Auction, Seminar. Indiana Historical Radio Society & Antique Wireless Assn., Herman Gross, 765-459-8308. E-Mail: w9itt@juno.com

JUNE 4-5

NE - SOUTH SIOUX CITY - Iowa State Convention. 3900 Club & Sooland ARA, Mike Nickolaus NF0N, 402-494-6070. E-Mail: nf0n@avalon.net Web: http://www.pionet.net/~k0brd/hamboree/

JUNE 4-5-6

NY - ROCHESTER - Atlantic Division & NY State Convention. Monroe County Fairgrounds. Fri: 12pm-5:30pm, Sat: 8:30am-5:30pm, Sun: 8:30am-1:30pm. Harold Smith K2HC, 716-424-7184; Fax: 716-424-7130 E-Mail: rochfst@frontier net.net Web: http://www.rochesterhamfest.org

JUNE 5

CA - SANTEE - ARC of El Cajon Ham, Computer & Electronic Swapmeet. Santee Drive-in. 619-561-0052

FL - MCCOY - Hamfest. Ft. McCoy ARC, Tom Bench KS4ZI, 352-546-3967. E-Mail: ks4zi@arrl.net Web: http://www.qsl.net/w4frc

IL - SPRINGFIELD - Hamfest. Illinois State Fairgrounds. 8am-1pm (flea 6am). VE Exams. Talk-in: 146.685 (-). Sangamon Valley RC, Ed Gaffney KA9ETP, 217-628-3697. E-Mail: egaffney@fgi.net Web: www.skylight1.com/svrc/

ME - HERMON - Hamfest. Hermon High School. 8am-1pm. VE Exams. Talk-in: 146.34/94, 146.52. Pine State ARC, Roger Dole KA1TKS, 207-848-3846. E-Mail: dolerw@juno.com

MI - GRAND RAPIDS - Hamfest. Hudsonville Fairgrounds. VE Exams. Talk-in: 147.160 link repeater system. Independent Repeater Assn., Kathy KB8KZH, 616-698-6627 4-7pm.

MN - ST. PAUL - Hamfest. TwinsLan ARC, Ann Foster N0LLC, 612-706-1761. E-Mail: tailgate@twinslan.org Web: http://www.twinslan.org/tailgate.html

MO - HOUSTON - Hamfest. Ozark Mountain Repeater Group, Bob Simpson N0NTC, 417-967-3535. E-Mail: n0ntc@train.missouri.org

NJ - TEANECK - Hamfest. Bergen ARA, Jim Joyce K2ZO, 201-664-6725. E-Mail: jjjoyce@cybernex.net Web: http://www.bara.org

JUNE 5-6

GA - MARIETTA - Hamfest. Jim Miller Park. Atlanta Radio Club, Ben Dasher KE4YZX, 404-869-6959, E-Mail: bendasher@mindspring.com Charles Golsen N4TZM, 404-252-3303 or 404-688-6278. E-Mail: cgolsen@atlanta.com Web: http://www.saf.com/arc

NE - CHADRON - Hamfest. Pine Ridge ARC, Lynn Bilyeu K0ODF, 308-432-2297. E-Mail: lynnb@bbc.net

OR - SEASIDE - SEAPAC NW Division Ham Convention. Seaside Convention Center, 1st St. VE Exams. Talk-in: 146.66 (-). Oregon Tualatin Valley ARC, Al Berg W7SIC, 503-640-5456; Randy Stimson KZ7T, 503-297-1175. E-Mail: rastimson@att.net Web: http://www.otv arc.org/events/hamfairs/seapac/index.htm

JUNE 6

CT - NEWINGTON - Flea Market. Newington High School, Willard Ave. (Rt. 173). 9am-1pm. FCC Exams. Talk-in: 145.45 & 146.52 simplex & 224.84, 443.05. Newington AR League, John Disarro KA1HQK, 860-666-8569; Joe Bottiglieri AA1GW, 860-666-9692. E-Mail: aalgw@arrl.net

IL - PRINCETON - Hamfest. Starved Rock RC, Frank Carraro KF9NZ, 815-856-3773. E-Mail: w9mks@qsl.net Web: http://www.qsl.net/w9mks/

IN - WABASH - Hamfest. Wabash County 4-H Fairgrounds, SR 13N. 6am. Talk-in: 147.03/147.63 & 442.325/447.325. Wabash County ARC, Ralph Frank, 219-563-8487 (W), 219-563-8489 (Fax), 765-833-7372 (H). E-Mail: wial@netusal.net Web: www.netusal.net/~qrziota/

MI - CHELSEA - Hamfest. Chelsea ARC, Don Wilke WW8M, 734-475-2359

NY - QUEENS - Hamfest. Hall of Science parking lot, Flushing Meadow Park Corona, 47-01 111th St. 9am-3pm. Talk-in: 444.200 repeat, PL 136.5, 146.52 simplex. Hall of Science ARC, Stephen Greenbaum WB2KDG, 718-898-5599. E-Mail: WB2KDG@Bigfoot.com

OH - MEDINA - Hamfest. County Fairgrounds, Community Center, 735 Lafayette Rd. 8am-3pm. Talk-in: 147.630 in, 147.030 out. Medina 2 Meter Group, Mike Rubaszewski N8TZY, 330-273-1519. E-Mail: m2mgroup@aol.com Web: http://members.aol.com/m2mgroup

The Events Calendar is a free service for publicizing electronic events such as amateur radio hamfests, flea markets, etc. If your organization is sponsoring an event and would like a free listing, contact us at least 60 days in advance. Include your flyer, estimated attendance, name of the person to contact, and phone number.

Complimentary issues are available upon request for distribution to your attendees. A street address for UPS is required.

While we strive for accuracy in our calendar, we can not be responsible for errors or cancellations. The information contained in this column is for the use of the readers of *Nuts & Volts* and may not be republished in any form without the written permission of T & L Publications, Inc.

All listing information should be sent to:
Nuts & Volts Magazine
Events Calendar
430 Princeland Court
Corona, CA 91719
Phone 909-371-8497
Fax 909-371-3052
E-mail events@nutsvolts.com

PA - BUTLER - Hamfest. Butler Farm Show Grounds, Rt. 68. 8am-4pm. Talk-in: 147.96/36. Breezeshooters ARC, H. Rey Whanger W3BIS, 412-828-9383. E-Mail: w3bis@freeww web.com Web: http://breezeshooters.net

VA - MANASSAS - Hamfest. Prince William County Fairgrounds, ½ mi S on Rt. 234. Talk-in: 146.97 (-) & 224.660 (-). Ole Virginia Hams ARC, Jack N4YIC, 703-335-9139, E-Mail: patnjack@erols.com; Mary Lu Blasdell KB4EFP, 703-369-2877, E-Mail: mblasd1638@aol.com

JUNE 11-12

GA - ALBANY - Convention. Albany ARC, Ricky McCrary KD4OZR, 912-438-9714. E-Mail: rm ccrary@planttel.net Web: http://www.isoa.net/aarc

JUNE 11-12-13

TX - ARLINGTON - HAMCOM. West Gulf Division Convention, Jim Haynie W5JPB, 214-351-3271. E-Mail: Chairman@hamcom.org Web: http://www.hamcom.org

WA - DRYDEN - Wenatchee Hamfest. Apple City ARC, Roger Eckhardt WB7SHL, 509-782-4977. E-Mail: dmeckhardt@juno.com Web: http://www.qsl.net/w7td

JUNE 12

CA - FONTANA - Inland Empire ARC Amateur Radio & Electronics Swapmeet. A B Miller High School. Bill 909-822-4138 eves

CANADA - ONTARIO - FERGUS - Hamfest. Guelph & Kitchener-Waterloo ARCs, Bill Smith VE3WHS, 519-821-6642. E-Mail: smith.ve3whs@sympatico.ca Web: http://www.kwarc.org/fleamarket

CT - GOSHEN - Hamfest. Fairgrounds, Rt. 63. Southern Berkshire ARC, Lee Collins K1LEE, 860-435-0051. E-Mail: collins@discovernet.net

ID - COEUR D'ALENE - Hamfest. Kootenai ARS, Jim Monroe, 208-667-4915. E-Mail: jmonroe@dmi.net

MA - FALMOUTH - Hamfest. Falmouth ARA, Ralph Swenson N1YHS, 508-548-6405. E-Mail: depsher911@aol.com Web: http://www.falara.org

MO - MACON - North Central MO Hamfest. Macon County ARC, Dale Bagley K0KY, 660-385-3629. E-Mail: dbagley1@istmacon.net or kfoster@istmacon.net Web: http://www.istmacon.net/~kfoster/hamfest.htm

NC - WINSTON-SALEM - Winston-Salem Classic Hamfest. Dixie Classic Fairgrounds. 7am-1pm. Talk-in: 146.64 (-) & 145.47 (-). Forsyth ARC, Tom Gallagher N4IOZ, 336-723-7388. E-Mail n4ioz@ibm.net Web: http://members.xoom.com/w4nc/Hamfest.htm

NY - CORTLAND - Hamfest. Skyline ARC, Andrew Slaugh KB2LUV, 607-753-0597. E-Mail: kb2luv@odyssey.net

PA - BLOOMSBURG - Convention. Columbia-Montour ARC, Dave Schack WC3A, 717-752-6851. E-Mail: wc3a@arrl.net Web: http://www.bafn.org/~cmarc

JUNE 12-13

NH - LANCASTER - Hamfest. Lancaster Fairgrounds, Rt. 3 North. 9am. VE Exams. Talk-in: 145.430 & 145.150 & 147.315. Moose Swappers, Russ Boyce N1YZE, 603-922-5514. E-Mail: cusvt@together.net

JUNE 13

IL - GRANITE CITY - Hamfest. Egyptian Radio Club, Tod West KB9AIL, 618-667-4592. E-Mail: Tod A WestSr@edwpub.com

IL - WHEATON - Hamfest. DuPage County Fairgrounds, 2015 Manchester Rd. (N of Roosevelt Rd. (Rt. 38), E of County Farm Rd.). VE Exams. Talk-in: K9ONA 146.52 & K9ONA/R 146.37/97 (107.2). Six Meter Club of Chicago, Joseph Gutwein WA9RIJ, 630-963-4922 or 708-442-4961. E-Mail: WA9RIJ@MC.NET Web: http://cyberconnect.com/orion/smcc.html

KY - INDEPENDENCE - Ham-O-Rama '99. Summit View Middle School, 5002 Madison Pike (KY 17) 8am-3pm. Talk-in: 147.255+ or 147.375+ repeaters. Northern KY ARC, Robert Blocher N8JMV, 513-797-7252. E-Mail: nkarc@juno.com

NY - BETHPAGE - Long Island Hamfair. Briarcliffe College, 1055 Stewart Ave. 8:30am-2pm. VE Exams. Talk-in: W2VL 146.85 repeater (136.5PL). Long Island Mobile ARC, Rich N2WJL, 516-520-9311. E-Mail: hamfest@limarc.org Web: http://www.limarc.org

OH - AKRON - Hamfest. Goodyear ARC, Robert J. Taylor KB8ZEC, 330-836-3282. E-Mail: rjtaylor@akron.infi.net

TN - KNOXVILLE - Hamfest & TN State Convention. National Guard Armory, 3330 Sutherland Ave. 9am-4pm. VE Exams. Talk-in: W4BBB 147.30 (+) & 224.50 (-) & 444.575 (+). Radio Amateur Club of Knoxville, David Bower K4PZT, 423-974-5064 (W), 423-670-1503 (H). E-Mail: rack@kormet.org or d.bower@ieee.org Web: http://www.korrnet.org/rack

JUNE 18-19-20

CANADA - ALBERTA - RED DEER - Hamfest. Central Alberta Radio League, Bob King VE6BLD, 403-782-3438. E-Mail: kingel@telusplanet.net or ve6bld@rac.ca Web: http://qsl.net/carl/

JUNE 19

CA - SANTEE - ARC of El Cajon Ham, Computer & Electronic Swapmeet. Santee Drive-in. 619-561-0052

CANADA - BC - KELOWNA - Hamfest. Orchard City ARC, 250-766-2179. E-Mail: ve7kng@rac.ca Web: http://www.okapagan.net/ocarc

CANADA - ON - MARMORA - Hamfest. Tri-County ARC, Paul Davidson VE3UUM, 613-472-3449. Pete Blakely VA3PGB, 613-473-1171. E-Mail: rhobson@blvl.igs.net Web: http://www.redden.on.ca/~tcarc/tricnty.htm

MI - MIDLAND - Hamfest. Midland County Fairgrounds, Gerstacker Fair Center. 8am-1pm. VE Exams. Talk-in: 147.00 (+) (W8KEA repeater). Midland ARC, Del Lafevor WB8FYR, 517-636-5097 (w), 517-689-3477 (h). E-Mail: lafevordel@aol.com Web: http://www.qsl.net/w8kea/MARCSWAP.htm

NJ - DUNELLEN - Hamfest. Columbia Park, near Rt. 529 & Rt. 28 intersection. 7am-2pm. Talk-in: 146.025/625 & 146.52 simplex. Raritan Valley RC, Bob Pearson WB2CVL, 732-846-2056 or Fred Werner KB2HZO, 732-968-7789 before 8pm. Web: http://www.w2qw.org

OH - MILFORD - Hamfest. Milford ARC, Chris Reinfelder KB8SNH, 513-753-5066. E-Mail: RAC Reinfelder@FUSE.NET

WV - BLUEFIELD - Hamfest. Brushfork Arm. East River ARC, Don Williams WA4K, 540-326-3338. Web: http://www.inetone.net/erarc/hamfest/

JUNE 20

CA - ORCUTT - Santa Maria Hamfest. Satellite ARC, Eric Lemmon WB6FLY, 805-733-4416. E-Mail: wb6fly@impulse.net

IN - CROWN POINT - Dad's Day Hamfest. Lake County Fairgrounds. 8am. VE Exams. Talk-in: 147.00, 146.52 & 442.075. Lake County ARC, Malcolm Lunsford W9MAL, 219-769-3925 (ph) or 815-361-1913 (fax). E-Mail: w9mal@cris.com

MA - CAMBRIDGE - Flea at MIT. Albany and Main Sts. 9am-2pm. Talk-in: 146.52 & 449.725/444.725 W1XM/R PL 114.8 (2A). Nick Altenbernd KA1MQX, 617-253-3776 (9-5). Web: http://web.mit.edu/w1mx/www/swapfest.html

MD - FREDERICK - Father's Day Hamfest. Frederick County Fairgrounds, 797 E. Patrick St. 8am-3pm. VE Exams. Talk-in: K3ERM 146.640 (-) & 147.060 (+) & 146.52 simplex. Frederick ARC, Carolyn Moroney N3VOK, 301-831-5060. E-Mail: n3vok@erols.com

MI - MONROE - Hamfest. Monroe County Fairgrounds. Monroe County Radio Communications Assn., Fred VanDaele KA8EBI, 734-587-7165 days or 734-242-9487 eves.

OH - MACEDONIA - Hamfest. Cuyahoga ARS, Rich James N8FIL, 1-800-404-2282. Web: http://www.cars.org

COMPUTER SHOWS

AGI Shows, 317-299-8827. E-Mail: info@agishows.com http://www.agishows.com

Blue Star Productions 612-788-1901 http://www.supercomputersale.com

Computers And You, 734-283-1754. www.a1-supercomputersales.com

Computer Central Shows 847-412-1900 & 1-888-296-6066. E-Mail: compcent@megsinet.net www.computercentralshows.com

Five Star Productions 810-890-0988 E-Mail: jeff@fivestar www.fivestarshows.com

Georgia Mountain Productions 706-838-4827. E-Mail: gamtnpro@blrg.tds.net georgiamountain.com

Gibraltar Trade Center, Inc. 734-287-2000. Taylor, MI.

Gibraltar Trade Center, Inc. 810-465-6440. Mt. Clemens, MI.

KGP Productions 1-800-631-0062, 732-297-2526. E-Mail: kgp@mail.com

MarketPro, Inc., 201-825-2229 http://www.marketpro.com

MarketPro, Inc., 301-984-0880. E-Mail: md@marketpro.com http://marketpro.com

Narisaam Computer Show 770-663-0983. E-Mail: narisaam@aol.com Web: http://www.shownsale.com

Northern Computer Shows 978-744-8440 E-Mail: inquiries@ncshows.com Web: ncshows.com

Peter Trapp Computer Shows, 603-272-5008. Web: www.petertrapp.com

JULY 1999

JULY 3

CA - SANTEE - ARC of El Cajon Ham, Computer & Electronic Swapmeet. Santee Drive-in. 619-561-0052

KY - TOMPKINSVILLE - Hamfest. The National Guard Armory, Hwy. 163 N. Talk-in: 146.775 repeater. Monroe County ARC, David Welch K4PL, 502-678-5784. J. Bunch, 502-678-5784. E-Mail: dwelch@glasgow-ky.com Web: http://monroearc.hypermart.net

NC - SALISBURY - Hamfest. Firecracker Hamfest. Civic Center. Rowan ARS, Ralph Brown WB4AQK, 704-636-5902. E-Mail: rbrown@salisbury.net Web: http://home.interpath.net/kk4lh/hamfest

PA - LEHMAN - Wilkes-Barre Hamfest. Luzerne County Fairgrounds, Rte. 118 (I-81 Exit 47B to Rt. 309 to Rt. 415 to Rt. 118). 8am. FCC Exams. Talk-in: 146.52 & 146.61. Murgas ARC, Stan Perry KE3TC, 570-735-2385; E-Mail: slperry@epix.net Bob N3FA, 570-288-3532

JULY 4

PA - BRESSLER - Firecracker Hamfest. Emerick Cibort Park, Penn St. 8am. VE Exams. Talk-in: 146.16/76 & 146.52 simplex. Harrisburg RAC, Richard Bordner W3NJB, 717-939-4825. E-Mail: n3njb@aol.com

JULY 9-10-11

CANADA - MANITOBA - BRANDON - Hamfest. International Peace Garden, Dave Snydal VE4XN, 204-728-2463. E-Mail: dsnydal@mb.sympatico.ca

JULY 10

CA - FONTANA - Inland Empire ARC Amateur Radio & Electronics Swapmeet. A B Miller High School. Bill 909-822-4138 eves

CANADA - ONTARIO - MILTON - Hamfest. Burlington ARC, Alan Montgomery VE3FCJ, 905-332-5282. E-Mail: ontariohamfest@canada.com Web: http://www.bigwave.ca/~ve3coj/barc/flyer

GA - GAINESVILLE - Hamfest. Lanierland ARC, Ken Parrish KN4UO, 770-867-9833. E-Mail: kn4uo@mindspring.com Web: http://www.qsl.net/kc4oxp/index.htm

IN - INDIANAPOLIS - ARRL Central Division Convention, Rick Ogan N9LRR, 317-251-4407. E-Mail: oganr@in.net Web: http://www.indyhamfest.com

MD - BRUNSWICK - Hamfest. Mid-Atlantic DX & Repeater Assn., Roy Bates N2CSQ, 301-834-9351. E-Mail: MADRA@qsl.net

ME - UNION - Hamfest. Fairgrounds. Pen-Bay ARC, Will Chadwick WC1W, 207-785-2739. E-Mail: wilchad@tidewater.net

MI - PETOSKEY - Swap & Shop. Emmet County Fairgrounds, US 31, 2 blks W of 131. 8am-1pm. VE Exams. Talk-in: 146.68 (-). Straits Area ARC, Tom W8IZS, 616-539-8459; Dirk KG8JK, 616-348-5043. E-Mail: kg8jk@qsl.net

MO - KANSAS CITY - Midwest Division Convention, Bob Roske WA0CLR, 816-436-0069. E-Mail: wa0clr@worldnet.att.net Web: http://members.tripod.com/~PHDARA/

NY - BATAVIA - Hamfest. Genesee fairgrounds. 6am-3pm. Talk-in: W2RCX 147.285+. "Gram," Harold Hay, 716-343-2844. E-Mail: wa2abq@aol.com

TX - TEXAS CITY - Hamfest. Tidelands ARS, Joe Wileman AA5OP, 409-945-6794

WI - EAU CLAIRE - Hamfest. Eau Claire ARC, Jim Staatz KG9MV, 715-838-9108. E-Mail: kg9mv@arrl.net Web: http://www.ecarc.org

WI - OAK CREEK - Swapfest. American Legion Post 434, 9327 S. Shepard Ave. 6:30am-2pm+ CDT. Talk-in: 146.52 (WA9TXE). South Milwaukee ARC, Inc., 414-762-3235

JULY 11

IL - PEOTONE - Hamfest. Will County Fairgrounds. Talk-in: 146.94. Kankakee Area Radio Society, Billie Kerouac KF9IF, 815-939-7548. E-Mail: dkbk@megsinet.net Web: http://www.geocities.com/capecanavera/hanger/5711

NY - PATCHOGUE - Hamfest. Mid-Island ARC, Mike Grant N2OX, 516-736-9126. E-Mail: globalcm@erols.com Web: http://www.qsl.net/mid-islandarc/hamfest.html

OH - BOWLING GREEN - Hamfest. Wood County ARC, Bob Boughton N1RB, 419-354-1811. E-Mail: boughton@bgnet.bgsu.edu Web: http://bravais.bgsu.edu/~boughton/wcarc.html

PA - KIMBERTON - Valley Forge Hamfest. Fire Co. Fairgrounds, Rt. 113 (S of Rt. 23). 8am. Mid-Atlantic ARC, Bill Owen W3KRB, 610-325-3995. E-Mail: hamfest-info@marc-radio.org Web: http://www.marc-radio.org/hamfest.html

PA - PITTSBURGH - Hamfest. Northland Public Library, 300 Cumberland Rd. 8am-3pm. Talk-in: 149.09 W3EXW. North Hills ARC, H. Rey Whanger W3BIS, 412-828-3694 (ph & fax). E-Mail: w3bis@freewwweb.com Web: http://nharc.pgh.pa.us/

JULY 16-17-18

MT - EAST GLACIER - Montana State Convention, Darrell Thomas N7KOR, 406-453-8574. E-Mail: n7kor@mcn.net Web: http://www.tlatech.com/hamfest/

JULY 17

CA - SANTEE - ARC of El Cajon Ham, Computer & Electronic Swapmeet. Santee Drive-in. 619-561-0052

CO - LOVELAND - Superfest. Larimer County Fairgrounds, 700 Railroad Ave. 8am-2pm. Talk-in: 145.115- or 146.85-. Northern CO ARC, 970-352-5304

LA - SLIDELL - Hamfest. Ozone ARC, Ronald Riviere WB5CXJ, 504-882-5067

NC - CARY - Mid-Summer Swapfest. Cary Community Center, 404 Academy St., Chapel Hill Rd. & Academy St. VE Testing. Talk-in: 147.15+.6. Cary ARC, POB 53, Cary, NC 27512; include SASE.

NY - FRANKFORT - Hamfest. Utica ARC, Bob Decker AA2CU, 315-797-6614. E-Mail: ktrnd@borg.com

Events CALENDAR

OH - WELLINGTON - Hamfest. Lorain County Fairgrounds. 8am-2pm. VE Exams. Talk-in: 146.10/70. Northern Ohio ARS, John Shaaf KC8AOX, 216-696-5709. E-Mail: kc8aox@qsl.net
PA - SALEM TOWNSHIP - Hamfest. Beach Haven Carnival Grounds (I-80 Exit 36 or 38 N to US-11). 8am. VE Exams. Talk-in: 145.130 (PL 77.0) & 146.52 simplex. Jonestown Mountain Repeater Assn, Charlie Hooker AD3L, 570-864-2571 or fax 717-864-2377; Rich N3YGL, 570-784-0488; Mike K3EVQ, 570-752-1334; Walter N3UAU, 570-822-0180. E-Mail: chooker@epix.net
TX - DENISON - North Texas Hamfest '99, Wilmer O. Kinsey WB5DCU, 903-893-5872. E-Mail: wb5dcu@gte.net
Web: http://homel.gte.net/wb5dcu/nortex99.html

JULY 18

IL - SUGAR GROVE - Hamfest. Waubonsee Community College, Rt. 47 at Harter Rd. (5 mi NW of Aurora). 8am. VE Exams. Talk-in: W9CEQ - 147.210 (+) PL 103.5/107.2 - AFAR repeater. Fox River Radio League, James Von Olnhausen N9UZC, 630-879-3042. E-Mail: n9uzc@amsat.org
Web: http://www.frrl.org/hamfest.html
MA - CAMBRIDGE - Flea at MIT. Albany and Main Sts. 9am-2pm. Talk-in: 146.52 & 449.725/444.725 W1XM/R PL 114.8 (2A). Nick Altenbernd KA1MQX, 617-253-3776 (9-5). Web: http://web.mit.edu/w1mx/www/swapfest.html
MO - WASHINGTON - Hamfest. Zero Beaters ARC, Dave Neal N0PNG, 314-532-2477 days, 314-458-3254 eves. E-Mail: Dave Neal@msn.com
Web: http://zbarc.usmo.com/
NJ - AUGUSTA - Hamfest. Sussex County ARC, Dan Carter N2ERH, 973-948-6999.
E-Mail: n2erh@email.com
Web: http://www.scarcnj.org
OH - VAN WERT - Hamfest. Van Wert County Fairgrounds, US Rt. 127 S. 8am-3pm. VE Exams. Talk-in: 146.85 (-). Van Wert ARC, Bob Barnes WD8LPY, 419-238-1877, Bob KA8IAF, 419-795-5763. E-Mail: barnesrl@bright.net
Web: http://www.bright.net/~barnesrl/w8fy.html

JULY 23-24

FL - MILTON - Hamfest. Milton ARC, Dean Clark WB6UKF, 850-626-9752.
E-Mail: acordc@worldnet.att.net
OK - OKLAHOMA CITY - Ham Holiday '99. Oklahoma State Fair Park (Hobbies, Arts & Crafts Bldg.), intersection I-40 & I-44. 5-8pm Fri., 8am-5pm Sat. Talk-in: 146.82. Central Oklahoma Radio Amateurs, Thomas Webb WA9AFM.
E-Mail: n1pn@swbell.net or tmwebb@telepath.net
Web: http://www.geocities.com/heartland/7332

JULY 23-24-25

AZ - FLAGSTAFF - Hamfest & ARRL AZ State Convention. Norm Martin KC7FNK, 520-297-9562. E-Mail: arcathill@aol.com
Web: http://www.hamsrus.com

JULY 24

NH - NASHUA - Hamfest. Res Ctr Church. NE Antique RC 617-923-2665
OH - CINCINNATI - Hamfest. OH-KY-IN ARS, Dana Laurie WA8M, 513-761-7388.
E-Mail: wa8m@arrl.net
Web: http://www.qsl.net/k8sch

JULY 24-25

SD - CLEAR LAKE - Hamfest. Deuel County ARC, Don Clifford N7AXW, 605-876-2671.
E-Mail: drc@itctel.com

JULY 25

CA - SANTA ANA - Swapmeet. ACP parking lot. Mary Russo 714-558-8813
MD - TIMONIUM - Hamfest. Timonium Fairgrounds, York Rd. off I-695, I-83. 8am. VE Exams. Talk-in: 147.030 (+) & 224.960 (-) & 448.325 (-). Baltimore Radio Amateur TV Society, 410-461-0086. E-Mail: brats@smart.net
Web: http://www.smart.net/~brats

JULY 30-31-AUGUST 1

OR - PORTLAND - Pacific Northwest DX Convention. Willamette Valley DX Club, Al Rovner K7AR, 360-256-7437 E-Mail: alanr@pacifier.com
Web: http://www.qsl.net/wvdxc

JULY 31

IN - HUNTINGTON - Hamfest. Huntington County 440 Repeater Group, Ray Tackett KC9DZ, 219-786-0029 or 219-786-0057.
E-Mail: rtackett@ctlnet.com
KY - BOWLING GREEN - Hamfest. Kentucky Colonels ARC, Fred Painter, KA4CFW, 502-842-3193. Web: http://kcarc.premiernet.net
NC - WAYNESVILLE - Hamfest. Haywood County Fairground. Western Carolina ARS, Carl Smith N4AA, 828-683-4251. E-Mail: wcars@dxpub.com
NV - RENO - Hamfest. Sierra Nevada ARS, Bill Massie K7NHP, 775-246-3756.
E-Mail: macm.yncsmassie@juno.com
OR - BANDON - Hamfest. Coos County ARC, Brian Howard W7MLT, 541-572-5623.
E-Mail: w7mlt@usa.net

AUGUST 1999

AUGUST 1

IN - ANGOLA - Hamfest. Land of Lakes ARC, Bill Brown WD9DSN, 219-475-5897.
E-Mail: sharon.l.brown@gte.net
OH - RANDOLPH - Hamfest. Portage ARC, Joanne Solak KJ3O, 330-274-8240. E-Mail: ljs olak@apk.net Web: http://parc.portage.oh.us
VA - BERRYVILLE - Winchester Hamfest. Clarke County Ruritan Fairgrounds. 6am. VE Exams. Talk-in: 146.82 (-) W4RKC repeater. Shenandoah Valley ARC, Guy Avey W3INT, 540-678-9970; Jane Barb KD4IET, 540-955-1745.
E-Mail: ibarb@visuallink.com. Web: http://www.Vvalley.com/svarc/hamfest or http://www.visuallink.net/shenvalleyarc

AUGUST 6-7

TX - AUSTIN - Texas State ARRL Convention. Austin ARC, Austin Repeater Org & Texas VHF-FM Society, Joe Makeever W5HS, 512-345-0800.
E-Mail: jomak@ibm.net
Web: http://www.repeater.org/summerfest/

AUGUST 6-7-8

SD - WATERTOWN - Dakota Division Convention. Lake Area Radio Klub, Jerry Hegg N0JH, 605-886-7151. E-Mail: n0jh@dailypost.com

AUGUST 7

CA - CHICO - Hamfest. Golden Empire ARS, Muriel Pope K6GSK, 530-342-4765.
E-Mail: k6gsk@w6rhc.org
CA - SANTEE - ARC of El Cajon Ham, Computer & Electronic Swapmeet. Santee Drive-in. 619-561-0052
IL - CARLINVILLE - Hamfest. Macoupin County Fairgrounds, Rt. 4, I-55 exit 60. 7am-12pm. Talk-in: 146.82- or 443.400+ 103.5PL. Macoupin County ARC, Tim Jones 217-627-2355. KA9VIV
E-Mail: jester25@ctnet.net. Jim Pitchford N9LQF, E-Mail: esda@ctnet.net
IL - QUINCY - Hamfest. Western Illinois ARC, Jim Funk N9JF, 217-336-4191. E-Mail: jfunk@adams.net Web: http://www.qsl.net/s9awe
ME - ST. ALBANS - Hamfest. Snow Mobile Club. Howard WA1SBI, 207-876-3702

Continued on page 65

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OSCILLATORS

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Filter, 10 Hz-3 MHz, 24 dB/octave
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Filter, 20 Hz-2 MHz, 24 dB/octave
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0.001 Hz-99.9 kHz, 48 dB/octave
KROHN-HITE 3750 LP/HP/BP/BR Filter, $600.00
0.02 Hz-20 kHz, 6/12/18/24 dB/oct.
KROHN-HITE DCA-10R 10 Watt Amplifier, Ohms $450.00
20 dB gain, DC-1 MHz, 600-1000
ROCKLAND 852 Dual Highpass/ $900.00
Lowpass Filter, 0.1 Hz-111 kHz
TEK AM502 Differential Amplifier, $475.00
0.1 Hz-1 MHz, TM500 series

RF & MICROWAVE

SPECTRUM ANALYZERS

HP 11517A/18A/19A/20A Mixer $600.00
Set, 12.4-40.0 GHz, for HP 8555A/8569A
HP 11970A WR28 Harmonic Mixer, 26.5-40 GHz $1,100.00
HP 11970K WR42 Harmonic Mixer, 18.0-26.5 GHz $1,100.00
HP 11970Q WR22 Harmonic Mixer, 33-50 GHz $1,400.00
HP 3585A Spectrum Analyzer, $4,500.00
20 Hz-40 MHz, 3 Hz min. res. bw.
HP 8559A/853A-001 Spectrum An., frame $3,750.00
0.01-21 GHz, 1 kHz res.,w/rackmount
HP 8565A-100 Spectrum Analyzer, $3,500.00
10 MHz-22 GHz, 100 Hz min. res.
HP 8569B Spectrum Analyzer, $7,500.00
10 MHz-22 GHz, 100 Hz min.res.bw.
TEK TR502 Tracking Generator, 0.1-1800 MHz, for 7L13/7L14 $950.00
TEK WM782V WR15 Harmonic Mixer, 50-75 GHz $1,500.00

NETWORK ANALYZERS

HP 11650A Network Analyzer Accessory Kit, APC7 $600.00
HP 35676A Reflection/Transmission Test Kit, 5 Hz-200 MHz $1,000.00
HP 8405A Vector Voltmeter, 1-1000 MHz $450.00
HP 85020A Directional Bridge, $650.00
10-4300 MHz, N(f) test port
HP 85027C Directional Bridge, $1,750.00
0.01-18 GHz, N(f) test port
HP 85044A Reflection/Transmission $1,500.00
Test Set, 300 kHz-3 GHz
HP 8756A Scalar Network Analyzer $2,500.00
HP R85026A WR28 Detector, $1,200.00
26.5-40 GHz, for HP 8757 series
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FLUKE 6060A/AN Synthesized Signal $1,500.00
Gen.,10 kHz-520 MHz, 10 Hz res.,GPIB
FLUKE 6060B/AK Synthesized $2,250.00
Signal Gen., 0.1-1050 MHz, 10 Hz res.
GIGATRONICS 1018 Synthesized Signal $4,500.00
Gen., 50 MHz-18 GHz, 1 MHz res.
GIGATRONICS 600/6-12 Synthesized $2,500.00
Source, 6-12 GHz, 1 kHz res., GPIB
GIGATRONICS 875/50 Levelled Multiplier, $2,500.00
x4, 50.0-75.0 GHz output, -3 dBm
GIGATRONICS 875/86 Levelled Multiplier, $3,750.00
26.5-40.0 & 50.0-75.0 GHz outputs
GIGATRONICS 900/2-8 Synthesized $2,500.00
Signal/Sweep Gen., 2-8 GHz, 1 MHz res.,GPIB
HP 11720A Pulse Modulator, 2-18 GHz, 80 dB on/off ratio $450.00
HP 3335A Synthesizer / Level Generator, 200 Hz-81 MHz $4,500.00
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HP 8640B Signal Generator, $1,000.00
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HP 8656B-001 Synth. Signal Gen., $2,500.00
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HP 8657A-002 Signal Generator, $3,250.00
0.1-1040 MHz, 10 Hz res., HPIB
HP 8660C/86602B-002 Synth. Sig. Gen., $2,750.00
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HP 8660C/86603A Synthesizer, $3,250.00
1-2600 MHz, AM / FM, w/86633B
HP 8672A Synthesized Signal Generator, $6,000.00
2-18 GHz, +3 dBm output
HP 8673G-004,008 Synth. CW Signal $12,500.00
Generator, 2-26 GHz, >+8 dBm output
HP 8684B Signal Generator, $3,500.00
5.4-12.5 GHz, AM/ WBFM/ Pulse

SWEEP GENERATORS

HP 8350A/83545A-002 Sweep Oscillator, $4,000.00
5.9-12.4 GHz, 70 dB step attenuator
HP 8350A/83570A Sweep Oscillator, $5,500.00
18.0-26.5 GHz, +10 dBm levelled
HP 8601A Generator/Sweeper, $400.00
0.1-110 MHz, +20 dBm levelled
HP 8620C Sweep Oscillator Frame $550.00
HP 86222B-002 RF Plug-in, $1,250.00
10-2400 MHz, +13 dBm levelled, 70 dB atten.
HP 86240C RF Plug-in, 3.6-8.6 GHz, +16 dBm levelled $700.00
HP 86241A-001 RF Plug-in, 3.2-6.5 GHz, +8 dBm levelled $300.00
HP 86242D-004,008 RF Plug-In, 5.9-9.0 GHz, +10 dBm levelled $300.00
HP 86250D RF Plug-in, 8.0-12.4 GHz, +10 dBm levelled $500.00
HP 86260A RF Plug-in, 12.0-18.0 GHz, +10 dBm unlevelled $500.00
HP 86260A-H04 RF Plug-in, 10.0-15.0 GHz, +10 dBm unlevelled $500.00
HP 86290A RF Plug-in, 2.0-18.0 GHz, +7 dBm levelled $1,750.00
WAVETEK 962 Sweep Generator, $1,250.00
1.0-4.0 GHz, markers, +12 dBm unlvld.
WILTRON 6647M Sweep Generator, $4,500.00
10 MHz-20 GHz, +10 dBm levelled

POWER METERS

ANRITSU MP-81B/ML-83A Power Meter, dBm $2,500.00
75-110 GHz (WR10), -20 to +20
BOONTON 4200-01A,03/&-4A x2 $950.00
Dual Channel Microwattmeter, w/(2) 1 MHz-7 GHz sensors
BOONTON 42B/41-4B Analog $375.00
Power Meter, with 1 MHz-12 GHz sensor
BOONTON 42B/41-4E Analog $500.00
Power Meter, with 1 MHz-18 GHz sensor
GENERAL MICROWAVE 476/4240A $300.00
Power Meter & Sensor, 0.01-18 GHz, -35 to +10 dBm
HP 435B/8481A Power Meter, $900.00
-30 to +20 dBm, 10 MHz-18 GHz
HP 435B/8482H Power Meter, $900.00
-10 to +34 dBm, 100 kHz-4.2 GHz
HP 436A/8481A Power Meter, $1,400.00
-30 to +20 dBm, 10 MHz-18 GHz
HP 8477A Power Meter Calibrator, for HP 432 series $500.00
HP K486A WR42 Thermistor Mount, $350.00
18.0-26.5 GHz, for 432 series
HP Q8486A Power Sensor, $1,500.00
33.0-50.0 GHz, WR22, for 435/6/7/8
HP R486A WR28 Thermistor $350.00
Mount, 26.5-40 GHz, for 432 series
HP R8486A WR28 Power Sensor, $1,500.00
26.5-40 GHz, for HP 435/6/7/8

RF MILLIVOLTMETERS

BOONTON 92B-opt.05 RF Millivoltmeter, $500.00
10 kHz-1.2 GHz, 75 Ohms scale
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10 kHz-2 GHz, -77 to +23 dBm, GPIB

AMPLIFIERS, MISCELLANEOUS

AMPLIFIER RES. 1W1000 Amplifier, $650.00
30 dB gain, 1-1000 MHz, 1 Watt output
BOONTON 82AD-opt.01A Modulation $750.00
Meter, AM, FM, 10-1200 MHz, GPIB
HP 415E SWR Meter $200.00
HP 465A Amplifier, 20/40 dB, $125.00
5 Hz-1 MHz, 1/2 Watt/50 Ohms
HP 8447A Amplifier, 20 dB, 0.1-400 MHz, $375.00
5 dB NF, +6 dBm output
HP 8447E Amplifier, 22 dB, 0.1-1300 MHz, +13 dBm output $750.00
HP 8901A Modulation Analyzer, 150 kHz-1300 MHz $2,500.00
HP 8901B-1,2,3 Modulation An., $3,000.00
0.15-1300 MHz, rear input, OCXO, ext.LO
HP 8970A Noise Figure Meter $4,000.00
HUGHES 1177H02F000 TWT $1,500.00
Amplifier, 4.0-8.0 GHz, 10 Watts output
ROHDE & SCHWARTZ ESH2 $5,000.00
Test Receiver, 9 kHz-30 MHz

COAXIAL & WAVEGUIDE

AMERICAN NUCLEONICS AM-432 $95.00
Cavity Backed Spiral Antenna,LHC, 2-18 GHz,TNC(f) *NEW*
AVANTEK AMT-400X2 WR28 Active $450.00
Doubler, 13-20 GHz +10 dBm in, +10 dBm out
BAYTRON 3-28-300/10 WR28 $300.00
Directional Coupler, 10 dB, 26.5-40 GHz
BIRD 6735-300 1 kW Load, $650.00
25-1000 MHz, LC(f), with wattmeter
CONTINENTAL MW. RAE28-K-M WR28 x K(m) Endfire Adapter $225.00
FXR/MICROLAB S3-02N Triple $125.00
Stub Tuner, 200-1000 MHz, 100 Watts max., N(m/f)
GR 874-LTL Constant Impedance $400.00
Trombone Line, 0-44 cm, DC-2 GHz
HP 11590A-001 Bias Network, 1.0-18.0 GHz, APC7 $450.00
HP 11636A 2-Way Power Divider, DC-18 GHz, N(m/f/f) $300.00
HP 11692D Dual Directional Coupler, 22 dB, 2-18 GHz $800.00
HP 33321K Programmable Step $475.00
Atten., 0-70 dB, DC-26.5 GHz, 3.5mm
HP 33327L-006 Programmable Step $1,200.00
Attenuator, 0-70 dB, DC-40 GHz, 2.9mm
HP 774D Dual Directional Coupler, 20 dB, 215-450 MHz $275.00
HP 777D Dual Directional Coupler, 20 dB, 1.9-4.1 GHz $275.00
HP 778D-011 Dual Dir. Coupler, 20 dB, $450.00
100-2000 MHz, APC7 test port
HP 8431A 2-4 GHz Band Pass Filter, N(m/f) $150.00
HP 8494G-002 Programmable Step $350.00
Attenuator, 0-11 dB, DC-4 GHz, SMA
HP 8495H-002 Programmable Step $400.00
Attenuator, 0-70 dB, DC-18 GHz, SMA
HP 8497K-004 Programmable Step $750.00
Attenuator, 0-90 dB, DC-26.5 GHz
HP K281C-012 WR42 x APC3.5(m) Adapter $300.00
HP K382A WR42 Direct Reading $2,900.00
Attenuator, 0-50 dB, 18-26.5 GHz
HP K422A WR42 Flat Broadband Detector, 18.0-26.5 GHz $350.00
HP K532A WR42 Frequency Meter, 18.0-26.5 GHz $450.00
HP K870A WR42 Slide Screw Tuner, 18.0-26.5 GHz $275.00
HP K914B WR42 Moving Load, 18.0-26.5 GHz $300.00
HP Q752D WR22 Directional Coupler, 20 dB, 33-50 GHz $650.00
HP R382A WR28 Direct Reading $2,000.00
Attenuator, 0-50 dB, 26.5-40 GHz
HP R422A WR28 Crystal Detector, 26.5-40 GHz $400.00
HP R532A WR28 Frequency Meter, 26.5-40 GHz $500.00
HP R752A WR28 Directional Coupler, 3 dB, 26.5-40 GHz $450.00
HP R752C WR28 Directional Coupler, 10 dB, 26.5-40 GHz $450.00
HP R752D WR28 Directional Coupler, 20 dB, 26.5-40 GHz $450.00
HP R914B WR28 Moving Load, 26.5-40 GHz $250.00
HP V365A WR15 Isolator, 25 dB, 50-75 GHz $750.00
HP V752D WR15 Directional Coupler, 20 dB, 50-75 GHz $650.00
HP X870A WR90 Slide Screw Tuner $150.00
HUGHES 45712H-1000 WR22 Frequency Meter, 33-50 GHz $900.00
HUGHES 45714H-1000 WR15 Frequency Meter, 50-75 GHz $900.00
HUGHES 45716H-1000 WR10 Frequency Meter, 75-110 GHz $900.00
HUGHES 45721H-1000 WR28 Direct $900.00
Reading Attenuator, 0-50 dB, 26.5-40 GHz
HUGHES 45724H-1000 WR15 Direct $1,000.00
Reading Attenuator, 0-50 dB, 50-75 GHz
HUGHES 45732H-1200 WR22 Level Set $250.00
Attenuator, 0-25 dB, 33-50 GHz
HUGHES 45772H-1100 WR22 Thermistor Mount, $400.00
-20 to +10 dBm, 33-50 GHz
HUGHES 45775H-1100 WR12 $800.00
Thermistor Mount, -20 to +10 dBm, 60-90 GHz
HUGHES 47316H-1111 WR10 Tuneable $600.00
Detector, 75-110 GHz, positive polarity
HUGHES 47741H-2310 WR28 Phase $2,000.00
Locked Gunn Osc., 32.000 GHz, +18 dBm
HUGHES 47742H-1210 WR22 Phase $2,750.00
Locked Gunn Osc., 42.000 GHz, +18 dBm
HUGHES 47974H-1000 WR15 SPST $375.00
PIN Switch, 250 MHz speed, 60-62 GHz response
KRYTAR 2616S Directional Detector, $200.00
1.7-26.5 GHz, K(f/m)/SMC
M/A-COM 3-19-300/10 WR19 $450.00
Directional Coupler, 10 dB, 40-60 GHz
MIDWEST MICROWAVE 3537 DC $40.00
Block, 0.1-12.4 GHz, SMA(m/f) *NEW*
MINI-CIRCUITS ZFDC-20-4 Directional $25.00
Coupler, 19.5 dB, 1-1000 MHz, SMA(f)
NARDA 3000-SERIES Directional Couplers $150.00
NARDA 3024 Bi-Directional Coupler, 20 dB, 4-8 GHz $300.00
NARDA 3090-SERIES Precision High Directivity Couplers $225.00
NARDA 368BNM Coaxial High $500.00
Power Load, 500 Watts, 2.0-18 GHz, N(m)
NARDA 3752 Coaxial Phase $1,000.00
Shifter, 0-180 deg./GHz, 1-5 GHz
NARDA 3753B Coaxial Phase $1,000.00
Shifter, 0-55 deg./GHz, 3.5-12.4 GHz
NARDA 4000-SERIES SMA Miniature Directional Couplers $75.00
NARDA 4226-10 Directional Coupler, $275.00
10 dB, 0.5-18.0 GHz, SMA(f)
NARDA 4227-16 Directional Coupler, $325.00
16 dB, 1.7-26.5 GHz, 3.5mm(f)
NARDA 4242-20 Directional Coupler, $100.00
20 dB, 0.5-2.0 GHz, SMA(f)
NARDA 4247-20 Directional Coupler, $200.00
20 dB, 6.0-26.5 GHz, 3.5mm(f)
NARDA 4247B-10 Directional Coupler, $200.00
10 dB, 6.0-26.5 GHz, 3.5mm(f)
NARDA 4799 Level Set Attenuator, $135.00
0-15 dB, 4-18 GHz, SMA(f)
NARDA 5070-SERIES Precision $300.00
Reflectometer Couplers
NARDA 765-10 10 dB Attenuator, 50 Watts, $165.00
DC-5 GHz, N(m/f)
NARDA 769-30 30 dB Attenuator, 150 Watts, $275.00
DC-6 GHz, N
NARDA 792FF Variable Attenuator, 0-20 dB, 2.0-12.4 GHz $375.00
NARDA 794FM Direct Reading Variable $375.00
Attenuator, 0-40 dB, 4-8 GHz
OMNI-SPECTRA 2085-6010-00 Crystal $50.00
Detector, 1-18 GHz, negative polarity, SMA(m/f)
PAMTECH KYG1014 WR42 Junction $250.00
Circulator, 18.0-26.5 GHz
SONOMA SCIENTIFIC 21A3 WR42 $75.00
Circulator, 20 dB, 20.6-24.8 GHz
SPACEK LABS K-2X Frequency $350.00
Doubler, 9.0-13.25 GHz in/ 18.0-26.5 GHz out
TRG B510 WR22 Direct Reading $1,000.00
Attenuator, 0-50 dB, 33-50 GHz
TRG B528 WR22 Direct Reading $1,250.00
Phase Shifter, 0-360 deg.,33-50 GHz
TRG V551 WR15 Frequency Meter, 50-75 GHz $600.00
TRG W551 WR10 Frequency Meter, 75-110 GHz $750.00
WAVELINE 100080 WR28 Terminated $200.00
Crossguide Coupler, 30 dB
WEINSCHEL DS109 Double Stub Tuner, 1-13 GHz, N(m/f) $150.00
WEINSCHEL DS109LL Double Stub Tuner, 0.2-2.0 GHz, N(m/f) $150.00

COMMUNICATIONS

HP 4935A-001 Transmission Test $700.00
Set, 20 Hz-110 kHz, battery option
HP 59401A HPIB Bus Analyzer $700.00
TEK 1410R NTSC Gen., w/SPG2 $800.00
sync. generator, TSG7 color bars
TEK 1411R PAL Gen.,w/SPG12 sync; $750.00
TSG11 color bars;TSG13 linearity
TEK 1411R PAL Test Gen., $1,000.00
w/SPG12,TSG11,TSG13,TSG15,TSG16
TEK 1411R PAL Test Gen., $1,100.00
w/SPG12,TSG11,TSG12,TSG13,TSG15,TSG16
TEK 1411R-opt.04 PAL Test Gen., $1,400.00
w/SPG12,TSG11,TSP11,TSG13,TSG15,TSG16
TEK 147A NTSC Test Signal Generator, $800.00
with noise test signal
TEK 148 PAL Insertion Test Signal Generator $700.00
TEK 520A NTSC Vectorscope $750.00
TEK 521A PAL Vectorscope $750.00

MISCELLANEOUS

FLUKE 2180A RTD Digital Thermometer $500.00
HP 7090A Measurement Plotting System $1,500.00
P.A.R. 5206-95,98 Two-Phase $1,500.00
Lock-in Amp., 2 Hz-100 kHz, GPIB
TEK TM5006 5000-series 6-slot $600.00
Programmable Power Module
TEK TM504 500-series 4-slot Power Module $175.00
TEK TM506 500-series 6-slot Power Module $250.00
TEK TM515 500-series 5-slot Traveller Power Module $275.00

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Switching Power Supply

by D. P. Roberts

Provides Safe, Steady 5 Volts From Vehicle's 12-Volt System

Powering a 5-volt circuit (like a single-board computer or BASIC Stamp project) off a car or truck's 12-volt electrical system is not as straightforward as you might think. A poorly designed 5-volt power supply can be the death of your automotive project.

In this article, I describe vehicular power-supply problems and present a simple solution: a modular switching regulator plus a few external components that yield a safe, efficient 5-volt supply at up to 1 ampere.

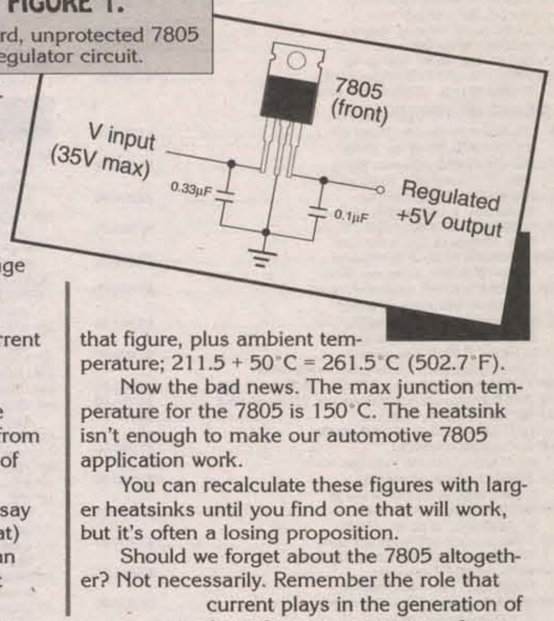
If you don't need high-current output, you can use a variation on the same circuit to armor an inexpensive linear voltage regulator against vehicular power gremlins.

Let's look at the problems that make a vehicle's 12-volt system so hostile to 5-volt regulators.

Linear Voltage Regulators Get Hot

When I need to drop some higher voltage down to 5 Vdc, I automatically reach for a three-terminal linear regulator IC like the 7805. These are cheap and easy to use, often requiring nothing more than a couple of capacitors to work (Figure 1).

FIGURE 1.
Standard, unprotected 7805 regulator circuit.



In the process of reducing the input voltage, 78xx-type regulators convert excess energy to heat. When the input voltage is close to the output voltage or the current draw is low, this heating may not even be noticeable. But when the voltage and/or current is high, the regulator can get very hot.

An example: With 14 volts input and 5 volts output, there's a 9-volt drop across the 7805 regulator. If you draw 1 ampere (1A) from the circuit, the 7805 converts 9 watts (9W) of electrical energy to heat (watts = volts x amperes). This is no good; the 7805 specs say that without a heatsink, the max power (heat) dissipation for this guy is less than 2W (at an ambient temperature of 50°C/122°F, less at higher temperatures).

How much would a heatsink help? Finding out requires a little math, but it's not painful.

Manufacturers of power semiconductors and heatsinks publish "thermal resistance" figures for their components. To determine the temperature rise inside the component (at the semiconductor junction, where the heat originates), you add up all the thermal resistances between the junction and free air and multiply by the power. Add the temperature rise to the ambient temperature, and you've got the actual temperature inside the component.

For a 7805 in the TO-220 package, thermal resistance is 4°C/W (read "degrees Celsius per watt") from the junction to the heatsink tab. A fairly typical TO-220 heatsink has a thermal resistance of about 19°C/W to free air. There's also about a 0.5°C/W thermal resistance between the TO-220 tab and the heatsink.

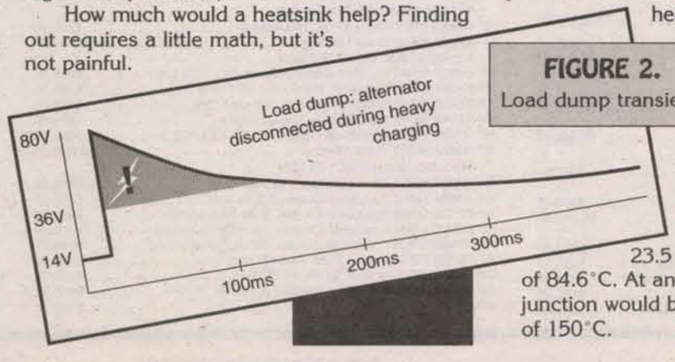
Multiplying the total thermal resistance (4 + 19 + 0.5 = 23.5) by the power dissipation (9W) gives the temperature rise in °C, 23.5 x 9 = 211.5°C. Actual temperature at the junction is that figure, plus ambient temperature; 211.5 + 50°C = 261.5°C (502.7°F).

Now the bad news. The max junction temperature for the 7805 is 150°C. The heatsink isn't enough to make our automotive 7805 application work.

You can recalculate these figures with larger heatsinks until you find one that will work, but it's often a losing proposition.

Should we forget about the 7805 altogether? Not necessarily. Remember the role that current plays in the generation of heat. Less current means fewer watts means cooler components.

FIGURE 2.
Load dump transient.



If the current drawn from the 7805 averages 0.4A (400 milliamperes; mA) or less, the power dissipation becomes 3.6W or less. Multiply that by the small heatsink thermal resistance of 23.5 and you get a temperature rise of 84.6°C. At an ambient temp of 50°C, the junction would be 134.6°C, just within the max of 150°C.

Switching Voltage Regulators Stay Cool

Linear voltage regulators like the 7805 get hot because they are obliged to do something with the electrical energy that's drawn from the input but not delivered to the output. What they do is convert that energy to heat.

Switching regulators attack the problem differently. As the name implies, they switch on and off, applying the input voltage to an inductor, which stores the energy in its magnetic field. Control electronics vary the proportion of switch on and off time to regulate the output voltage to a desired level. An output capacitor smooths out the ripple caused by the switching.

The advantage of this approach is that there's very little voltage drop across the switching element. Since power (watts) = volts x amperes, low voltage drop means very little power converted to heat.

Hobbyists tend to avoid switching supplies. The math required to design them, the parts required to build them, and the careful construction required to make them work properly are all a little intimidating. As we'll see later, a neat little module solves all of these problems and allows us to use a professionally designed switcher in our vehicular application.

Before we get to the circuit, let's look at the other problem with vehicle power systems.

Vehicular Electrical Spikes and Surges

Take a look at Figures 2, 3, and 4. These graphs (based on illustrations from the excellent book *The Circuit Designer's Companion*, by Tim Williams, Newnes/Butterworth Heinenman) are a rogues' gallery of surge and spike conditions that routinely occur in a car's electrical system.

Any electronic device that draws power from the car battery must be protected against these nasties. I've shaded portions of each graph to indicate the conditions that violate the operating conditions for the 7805 (and most other voltage regulators). If the voltage regulator isn't protected, it will eventually fail, possibly subjecting the 5-volt devices downstream to 14 volts, and probably incinerating them faster than a fuse can blow.

From the graphs, we can see that there are basically two problems: reversed polarity (from inductive switching and field decay), and overvoltage (load dump). Fortunately, neither of these conditions last very long; less than a tenth of a second, worst case.

Application-Note Inspired Circuit

When I set out to design my power-supply circuit, I knew I wanted to use a switching regulator to avoid having a sizzling-hot heatsink somewhere under the dashboard. I also knew that I didn't want to design a switcher. Consulting the Digi-Key catalog, I found that a company called Power Trends makes a series of switching regulator modules designed to replace linear 7805s in many applications. Perfect!

Even better, at the Power Trends web site (www.powertrends.com), I found an application note called "Vehicular Power Adapter Using ISRs (integrated switching regulators)." I took their design suggestions, made a couple of minor improvements, and built the circuit shown in Figure 5.

The circuit is designed so that you can use either a 7805 linear regulator or the Power Trends 78ST105HC integrated switching regulator. Note that I've provided two parts lists, since slightly different component values are required depending on which way you go.

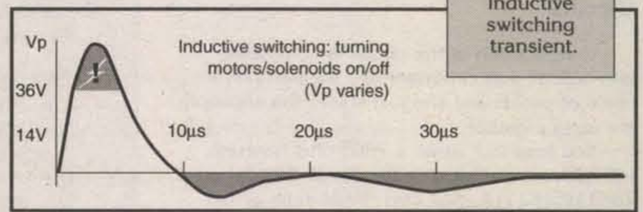


FIGURE 3. Inductive switching transient.

Most of the components in my circuit are simply insurance against various kinds of misbehavior of the vehicle electrical system and/or regulator components. Diode D1 blocks negative spikes, while D2 (a zener diode) clips off positive spikes exceeding 36 volts. Capacitor C2 is the only one required for proper operation of the 78ST105HC, but Power Trends recommends the input capacitor (C1) to prevent switching noise from being coupled back into the vehicle's electrical system (possibly fouling up radio reception, etc.).

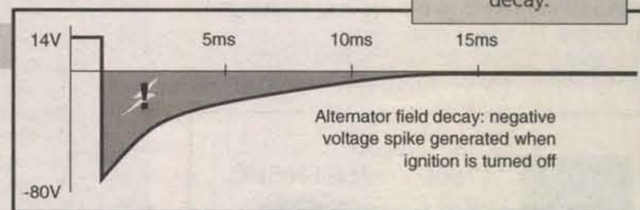


FIGURE 4. Alternator field decay.

I added the small-value cap C3 after a little poking around with an oscilloscope. I wasn't happy with the amount of ripple on the output (about 400 millivolts; mV), so I added a 0.1µF ceramic cap across the output. The ripple dropped to less than 100mV. Power Trends says that higher-value ceramic caps (1µF or more) can further reduce ripple, but such caps are not common, and 100mV ripple is acceptable for digital applications.

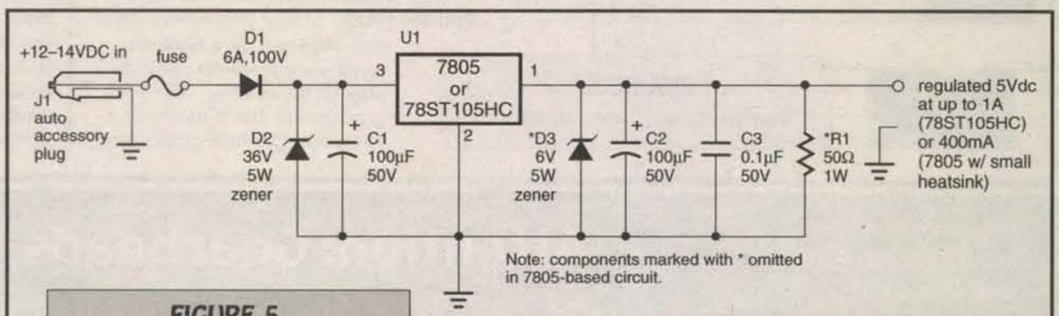


FIGURE 5. Vehicular power supply circuit.

I added zener diode D3 to clip off any spikes that might exceed 6 volts on the output. This diode is shown in the Digi-Key application diagrams for the 78ST105HC, but not in the Power Trends documentation. Either way, if the regulator were to somehow fail with a short-circuit from input to output, the 6-volt zener diode would conduct and help to blow the fuse. A dollar well spent.

My last added component is R1. Typical of many switching regulators, the 78ST105HC requires a certain minimum current draw in order to remain in regulation. Otherwise, its output voltage could rise beyond the specified 5 volts. That minimum is 100 mA. R1 draws 100mA at 5 volts so, even with the load disconnected, the output will remain in regulation. If the load is such that it never draws less than 100mA, R1 can be omitted.

To connect my creation to the vehicle electrical system, I opted for a cigarette-lighter plug. It came with a 5A fuse, but I substituted a 2A unit. Changing the fuse is just a matter of unscrewing the knurled nose cone of the plug. A nice feature of the plug specified in the parts list is that it has a built-in power LED. If the ignition is off, the fuse is blown, or the plug isn't properly seated in the lighter jack, the LED remains dark.

Linear voltage regulators like the 7805 get hot because they are obliged to do something with the electrical energy that's drawn from the input but not delivered to the output.

Building and Using the Supply Circuit

Construction of the circuit is completely non-critical; you can assemble the parts on a piece of perf board and just solder the appropriate wires together.

You may use either a 7805 plus heatsink (400mA max output) or the Power Trends 78ST105HC (1A max out). Make sure to use the parts from the appropriate parts list. If you use the 7805, make sure to use a heatsink, and position the supply in a location where there's free air circulation.

I strongly recommend that you use a fuse in series with the +12V input to the supply. Depending on which circuit you tap for the input, the vehicle's fuses are probably rated too high (10A or more) to provide any meaningful protection for your circuit.

That's all there is to it. For me, building this power supply was an important stepping stone. I have a bunch of projects in mind that involve using a Parallax BASIC Stamp II to collect data and display it on a Seetron serial vacuum-fluorescent display (VFD) module. The VFD is gorgeous, but it draws a lot of current (500mA peak), and it's fairly expensive ($159.00; www.seetron.com). Rather than risk destroying the module with a crummy power supply, I decided to build this project. I'm happy to report that the module has been running for weeks off the switching (78ST105HC) version of this project without a hiccup. **NV**

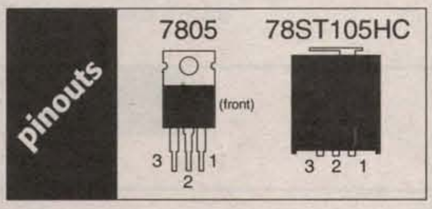


FIGURE 6.
Pinouts for U1, 5-volt regulators.

Parts List 1: Switching Supply (1A output)

All part numbers refer to Digi-Key (1-800-digikey or www.digikey.com)

C1,C2—100µF, 50V electrolytic capacitor (part no. P1353-ND)
C3—0.1µF, 50V monolithic ceramic capacitor (part no. P4923-ND)
D1—silicon rectifier diode, 6A, 100V (part no. 6A1MSCT). Note: it's permissible to use a smaller diode, 2A or more.
D2—zener diode, 36V ±5%, 5W (part no. 1N5365BMSCT)
D3—zener diode, 6V ±5%, 5W (part no. 1N5340BMSCT)
J1—Auto accessory (cigarette lighter) plug (part no. ZA5073-ND)
R1—50-ohm, 1W resistor (part no. ALSR1F-50-ND)
U1—5V, 1.5A integrated switching regulator (part no. 78ST105HC)
fuse—2A, 250V normal-blow fuse (part no. F119-ND)

Parts List 2: Linear Supply (400mA output)

All part numbers refer to Digi-Key (1-800-digikey or www.digikey.com)

C1,C2—100µF, 50V electrolytic capacitor (part no. P1353-ND)
C3—0.1µF, 50V monolithic ceramic capacitor (part no. P4923-ND)
D1—silicon rectifier diode, 6A, 100V (part no. 6A1MSCT)
D2—zener diode, 36V ±5%, 5W (part no. 1N5365BMSCT)
D3—zener diode, 6V ±5%, 5W (part no. 1N5340BMSCT)
J1—Auto accessory (cigarette lighter) plug (part no. ZA5073-ND)
R1—not used
U1—5V, 1.0A linear voltage regulator (part no. NJM7805FA-ND)
Heatsink—aluminum heatsink, bolt to U1 (part no. HS191-ND)
fuse—1A, 250V normal-blow fuse (part no. F115-ND)

by Ray Marston

THE 'OPTO' IN OPTOELECTRONICS (Part 4)

Ray describes the basic operating principles of LEDs and lasers in this final episode of the series.

The first three episodes of this mini-series described the basic nature, behavior and applications of light and light-beam manipulators such as mirrors, prisms, lenses, and fiber optic cables, with particular regard to their use in modern optoelectronic systems. This month's concluding episode describes the basic (atomic level) operating principles of LEDs and lasers, with particular emphasis on modern laser diodes.

LEDs and LASERs

INTRODUCTION

The two basic types of light-generating devices most widely used in modern optoelectronics are the LED and the laser. (The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation.)

LEDs and lasers differ in two major respects. First, the LED is a semiconductor device that emits light as a consequence of a current-in, photons-out power conversion process, whereas the laser is a tuned-cavity resonator device that may use a gas, liquid, or solid substance as its active medium and emits light as a result of a photon multiplication process.

The second major difference between the two types of devices is that the LED emits broad-band light in which its photons are randomly-generated and are not directly phase-related, whereas the laser emits a stimulated narrow-band *coherent* type of light in which its emitted photons are — *at the moment of their birth* — of the same wavelength and phase as their parent photons.

Because of its coherence, the laser light can be focused into a far smaller spot than that of a LED, thus enabling it to generate very high local power densities. A perfect 0.5mW IR laser beam can, for example, be focused into a minute spot measuring only 1.6μm in width (roughly equal to 1/30th of the width of a human hair), in which the IR power density has a value of about 12kW/cm^2 within the focused area.

To begin to understand the basic light-generating principles of LEDs and lasers, it is necessary to first learn some basic facts about the nature of atoms and about photon generation, as follows.

ATOM AND PHOTON BASICS

All solids, liquids, and gases are composed of chemical elements, of which there are 109 different known kinds. Each of these elements are made up from clusters, chains, or lattices of atoms, and the atom is thus the basic building block of all matter.

All atoms take the basic form illustrated in *Figure 1* and consist of a positively-charged central nucleus (made up of protons and neutrons) that is surrounded by a number of *bands* of orbiting negatively-charged electrons. Normally, the positive nucleus charge and the negative electron charge balance one another, thus giving the atom a neutral overall charge; the atom is said to be *stable* under this condition.

Within the atom, each orbiting electron has a finite kinetic energy value, which determines the distance of its band's orbit from the central nucleus; the individual electron bands are thus known as *energy bands*; their energy is measured in electron-Volt (eV) units. Electrons orbiting in energy bands close to the central nucleus have lower energy values than those in the outer bands. The atom's outer electron-occupied energy band is known as the *valence* band.

Beyond the atom's valence band lays a normally-empty high-energy *conduction* band. If an electron that is orbiting in the valence band gains enough extra energy, it moves upward into the conduction band but, as it does so, it leaves behind a positively-charged *hole* in the valence band; the energy-gain process thus creates an electron-hole pair. The atom is said to be in a *quisi-stable* or *excited* state under this condition. When the atom is in this excited state, an electron will readily move downward from the conduction band into the

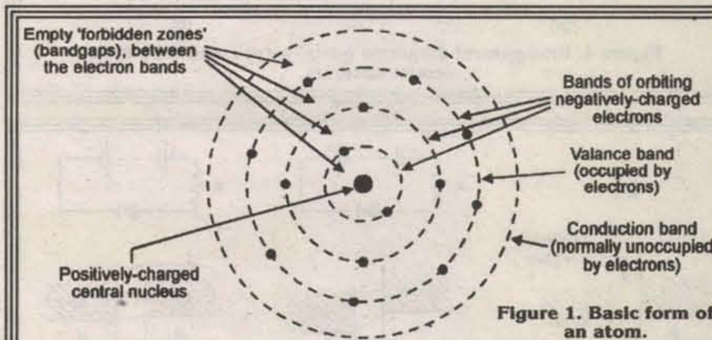


Figure 1. Basic form of an atom.

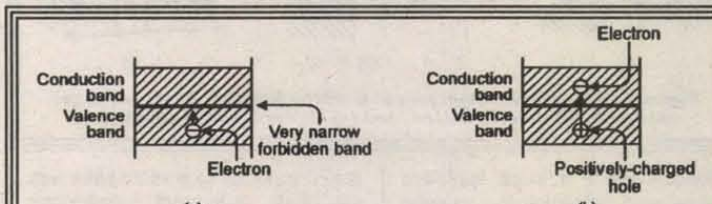


Figure 2. Energy-level diagrams relating to a conductor such as copper. (a) An electron can easily move upwards from the valence band, but (b) leaves a positively-charged hole behind.

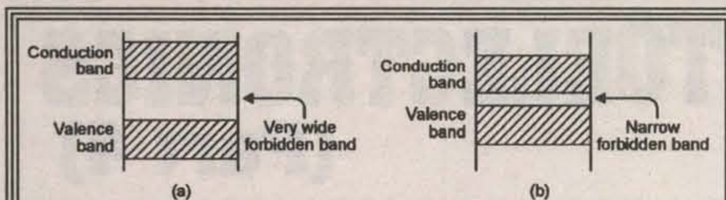


Figure 3. Energy-level diagrams relating to (a) a typical electrical insulator and (b) a typical semiconductor.

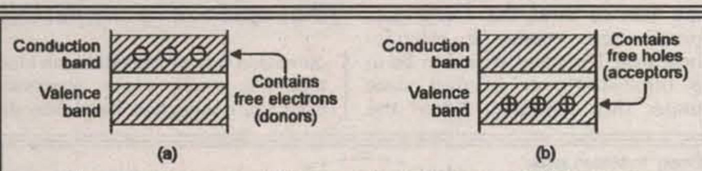


Figure 4. Energy-level diagrams for (a) n-type and (b) p-type semiconductors.

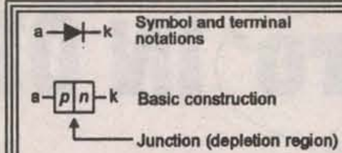


Figure 5. Symbol and basic construction of a silicon junction diode.

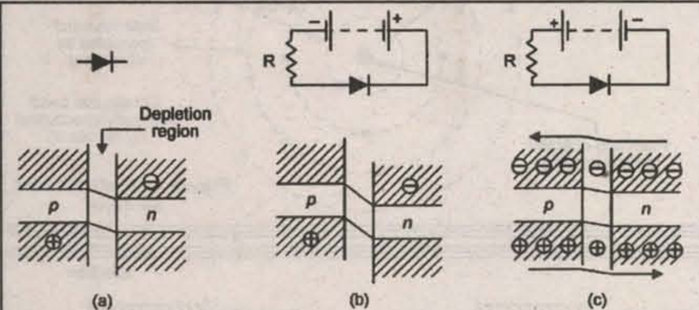


Figure 6. Energy-level diagrams of a silicon junction diode under (a) unbiased, (b) reverse biased, and (c) forward biased conditions.

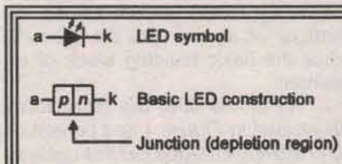


Figure 7. Symbol and basic construction of a conventional LED.

valence band if it loses sufficient energy, and anihilates the valance band's positively-charged hole in the process.

In a piece of matter composed of many atoms, the atoms may be linked together in a matrix-like way via their individual conduction bands. In this case, electrons that are not tied to specific atoms (*free electrons*) may travel freely through the material via the linked conduction bands.

The spaces between the atom's energy bands are known as *forbidden* zones or *bandgaps*. Electrons can not exist in forbidden zones, but can – if subjected to sufficient energy change – jump through them to reach an adjacent energy band. When an electron jumps downwards through a bandgap (from the conduction band to the valence band), it loses an amount of energy equal to the difference between the two energy band eV values, and this loss is accompanied by the emission of a sub-atomic particle (such as a phonon or photon) with an identical energy value.

From the optoelectronics point of view, all useful photon and electron activity takes place in the vicinity of the atom's valence and conduction bands, and all such activity can thus be represented by simple energy-level diagrams such as those shown in *Figures 2* and *3*, each of which depicts a narrow 'slice' section taken through the two bands.

Figure 2(a) shows the basic energy-level diagram of an atom of a conductive material such as copper. Here, the forbidden zone is so narrow that the valence and conduction bands almost merge into one another, and electrons can – under the influence of an external potential – easily move into the conduction band from the valence band, in which case, the vacated valence position is filled by a positively-charged hole, as shown in *Figure 2(b)*.

Once the electron enters the conduction band, it is no longer bound to the atom, and is free to travel through the conductive material (via the linked outer bands of adjacent atoms) as an electric current.

Figure 3(a) shows the energy-level diagram of an atom of a typical insulation material. Here, the forbidden zone is very wide, thus blocking the flow of electrons into the conduction band and preventing the flow of current through the material. Finally, *Figure 3(b)* shows the energy-level diagram of an intrinsic (naturally-occurring) semiconductor material such as silicon, which has a narrow forbidden zone and thus has conduction characteristics mid-way between those of a conductor and an insulator. Unlike a normal conductor, however, the semiconductor's resistance has a negative (rather than positive) temperature coefficient.

LED OPERATING PRINCIPLES

Conventional LEDs work in the same basic way as normal silicon junction diodes, but use special semiconductor materials to produce the light-emitting diode's photon-generating characteristics.

Silicon junction diodes are based on two different extrinsic (artificially modified) types of crystalline silicon; one type is very lightly doped with a material such as phosphorus, which has the effect of adding a number of spare electrons (*donors*) to the conduction band of the silicon's crystal lattice, as shown in the material's energy-level diagram of *Figure 4(a)*; this material is known as an *n*-type semiconductor, since it carries an excess negative charge. The other type of silicon is lightly doped with boron, which has the effect of adding a number of spare holes (*acceptors*) to the valence band of the silicon lattice, as shown in the energy-level diagram of *Figure 4(b)*; this material is known as a *p*-type semiconductor, since it carries an excess positive charge.

In a junction diode, the *n*-type and *p*-type materials are fused together in the manner indicated in the greatly simplified diagram of *Figure 5*, which also shows the diode's circuit symbol. Since both halves of the diode are made from the same basic material (silicon), the device is often called a *homojunction* diode. *Figure 6* shows the diode's energy-level diagrams under *(a)* unbiased, *(b)* reverse biased, and *(c)* forward biased conditions. In these diagrams, the junction between the *n*-type and *p*-type materials is named the *depletion* region.

The energy level of the junction diode's positively-charged *p*-type material is inherently higher than that of the negatively-charged *n*-type material, as shown in *Figure 6(a)*. Consequently, if the diode is reverse biased as shown in *Figure 6(b)*, the energy level difference between the *p*-type and *n*-type material becomes even greater, inhibiting any significant flow of electrons or holes between the two materials via the depletion region.

Under this reverse-biased condition, the only currents that flow through the diode are small temperature-sensitive leakage ones and (if the junction is directly exposed to an external light source) small photon-induced currents.

Alternatively, if the diode is forward biased as shown in *Figure 6(c)*, the energy level difference between the *p*-type and *n*-type material falls to near-zero at a forward bias value of about 0.6V, enabling electrons and holes to flow freely between the two materials via the depletion region. An electric current thus flows through the forward biased junction; it actually flows through the covalence bands (valence bands that are linked in adjacent atoms) within the silicon matrix, and often generates a phonon particle at the moment of exchange; the phonon energy is dissipated within the crystal lattice as vibrant heat.

Conventional LEDs use the same basic homojunction form of construction and work in the same basic way as normal junction diodes, but use special semiconductor materials (rather than silicon) that emit photons (rather than phonons) when forward current flows through the material's lattice. *Figure 7* shows the circuit symbol and the basic construction of a conventional LED, and *Figure 8* shows the LED's energy-level diagram under forward biased operating conditions.

In *Figure 8*, when current is flowing through the forward biased junction, most free electrons and free holes travel through the depletion (junction) area in the normal way, but some electrons don't have enough energy to stay in the conduction band and drop down (via the forbidden bandgap zones of individual atoms) into the valence band and annihilate a hole.

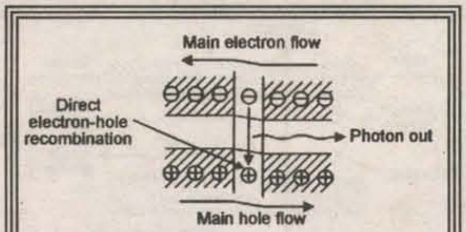


Figure 8. Energy-level diagram of a conventional LED under forward biased operating conditions.

The electron energy lost in this process is converted into a photon, which is radiated from the LED as a light particle. LED electrical power-in to optical power-out conversion efficiency is low, typically in the range 0.01% to 1.5%, and is greatly influenced by the photon's wavelength.

The LED's photon wavelength, λ (in nm) is dictated by the bandgap energy (eV, = the difference between the valence and conduction band energy values) of the LED's semiconductor material, and these two parameters are related by the easily-remembered formula $\lambda = 1240/eV$, and $eV = 1240/\lambda$. Thus, a LED that generates a red output at a wavelength of 645nm has a bandgap energy value of 1.92 eV.

Figure 9 shows some practical LED wavelength/bandgap-energy relationships values, together with basic details of the types of semiconductor material used to make various LEDs. The basic semiconductor material determines the approximate energy value of the bandgap; the actual value is fine-tuned by suitably doping the material.

Semiconductor material	LED color	Wavelength λ (nm)	Bandgap energy (eV)
Gallium Nitrogen (GaN)	Blue	430	2.88
Silicon Carbide (SiC)	Blue	480	2.58
Gallium Phosphide (GaP)	Green	565	2.19
Aluminum Gallium Phosphide (AlGaP)	Yellow	595	2.08
Aluminum Gallium Phosphide (AlGaP)	Orange	620	2.00
Aluminum Gallium Arsenide (AlGaAs)	Red	645	1.92
Gallium Aluminum Arsenide (GaAlAs)	Infrared	880	1.41
Gallium Arsenide (GaAs)	Infrared	950	1.31

Figure 9. Table of LED wavelength/bandgap-energy relationships.

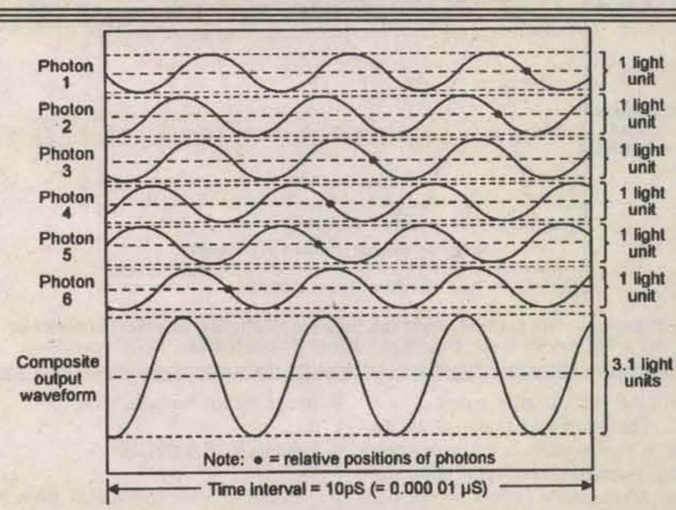


Figure 10. Six typical random (spontaneous) photon waveforms emitted by a 850nm IR LED, together with their composite 'light' waveform.

Note that the bandgap values quoted in *Figure 9* are 'mean' (rather than absolute) ones. In reality, the bandgap energy of an atom is not fixed, but varies from moment to moment, depending on the instantaneous depths of individual electrons within its valence-conduction bands. These energy variations are fairly small (usually within ± 2% of mean), but (since a photon's wavelength is directly related to bandgap energy) cause the LED's output to have a finite 'minimum

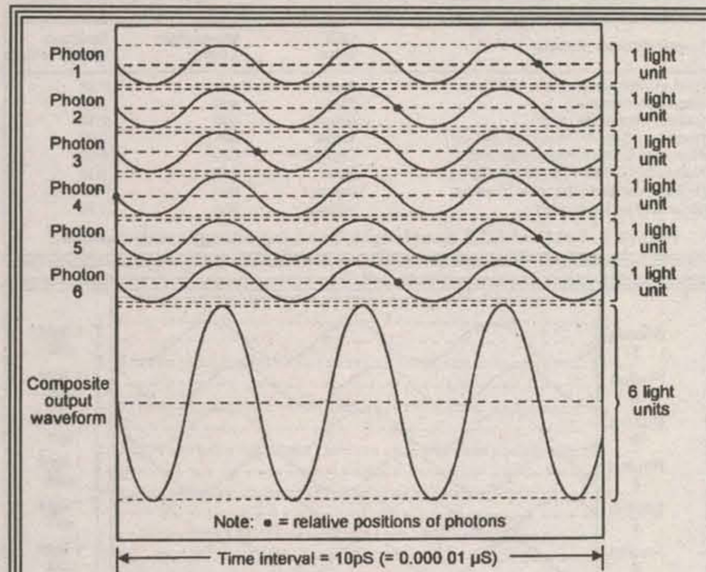


Figure 11. Six typical coherent (in-phase) photon waveforms emitted by a 850nm IR laser, together with their composite 'light' waveform.

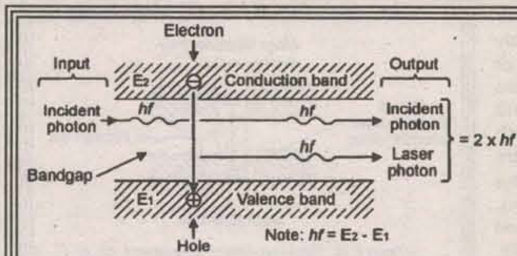


Figure 12. Basic atomic operation of the lasing process.

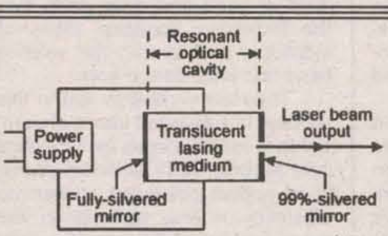


Figure 13. Basic elements of a complete laser unit.

spectral bandwidth' value.

The simple LED described earlier in this section is a surface-emitting homojunction type that uses the same basic material on both sides of its junction. In practice, many modern LEDs use different materials on the two junction sides, and are thus known as heterojunction LEDs; most such LEDs have two-stage internal junctions, and are known as double-heterojunction LEDs. Some special LEDs (designed to easily interface with fiber optic cables) are 'edge-emitting' types that emit a narrow beam of light from the side of the semiconductor material, rather than a broad beam from its face.

LASER BASICS

LEDs emit individual photons in a quite random or *spontaneous* fashion, whereas lasers emit photons in a *stimulated* fashion in which the birth of each new photon occurs on the arrival of a parent photon. In a laser, each new photon is — at the moment of its birth — a duplicate of its parent photon, with the same basic wavelength and (more importantly) an identical phase. Light composed of in-phase photons is known as *coherent* light, and can be focused far more sharply than other types of light.

Figure 10 shows six typical 'random' photon waveforms emitted by a LED, together with their composite light output waveform (equal to the sum of the six photon waveforms), and *Figure 11* shows a similar set of coherent waveforms emitted by a laser. Each diagram spans a 10pS (10 picosecond) time interval (1pS = 1 millionth of a μS) and depicts six newly-generated IR photons with wavelengths of 850nm (= a frequency of 353,000MHz) and an amplitude value of '1 light unit.' The typical relative position of each photon is indicated by a small black dot.

Note in *Figure 10* that the waveforms of photons 1 and 5 are in exact anti-phase and thus have a combined value of zero, and that all remaining photon waveforms are out of phase with one another and (in this particular case) have a combined value of 3.1 light units. In practice, the pattern of the six photon waveforms changes continuously as new photons enter the time frame from the left and others leave the frame on the right, and this causes the instantaneous phase and amplitude of the composite output waveform to vary over a wide range. As a consequence of these rapid phase and amplitude variations (intermodulation), the LED's light output is very impure and has a fairly wide spectral bandwidth.

By contrast, the six laser-generated photon waveforms shown in *Figure 11* are all exactly in-phase, and the composite output waveform thus has a fixed phase relationship and has a constant amplitude of 6 light units. The laser's light output is thus very pure, with a very narrow spectral bandwidth. Typically, a modern 850nm IR LED has a half-power spectral bandwidth (i.e., the bandwidth at which the light power output falls to half of its maximum value) of about 80nm. Modern 850nm laser diodes, on the other hand, have typical half-power spectral bandwidths of 0.5nm to 5nm, and their light outputs are thus far purer than those of LEDs.

LASER OPERATING PRINCIPLES

The basic *atomic* operating principle of the laser is in some ways similar to that of the LED. In both cases, a photon is generated in an excited atom when an electron in its conduction band loses energy and drops down into the atom's valence band, annihilating a hole and generating a photon in the process. In the LED, this process occurs randomly, when the electron's energy decays below a critical value.

In the laser, however, the process is initiated by photonic stimulation, in which an external photon *with an energy value equal to that of the atom's bandgap* enters the atom's bandgap and, by a quantum process known as negative absorption, makes the electron lose energy and drop down into the atom's valence band, thereby annihilating a hole and generating an identical photon.

Figure 12 illustrates the basic atomic operation of the 'lasing' process. Here, the incident (arriving) photon, which has an energy value identical to that of the atom's conduction-valence bandgap (= *hf*), enters the bandgap from the left side of the diagram and makes the electron drop down and annihilate the hole, thereby generating a new 'laser' photon, which also has an energy value of *hf*. The incident and laser photons, which have identical phase and frequency-wavelength values, then emerge together on the right side of the diagram.

Note from the above descriptions that lasing action can only occur if the atom is in an excited state at the moment that the incident photon arrives, and if the incident photon's energy value equals that of the atom's bandgap. Also note that, if lasing action does occur, the excited atom gives an effective 2:1 overall photonic power gain, but drops out of the vital 'excited' state after generating a single photon.

In a practical laser, the actual lasing medium (which contains vast numbers of atoms capable of giving lasing action) may take the form of a gas, a liquid, or a solid material, in which the lasing atoms may be raised into an excited state by electrical, chemical, or optical means.

In laser jargon, the process of feeding energy into the medium to hold its atoms in an excited state is known as *pumping*, and the situation in which most of the medium's atoms are in the excited state is known as a situation of *population inversion*. Thus, the medium must be pumped to create population inversion, which is a prerequisite of laser action. Lasing action can only begin if the medium's energy input exceeds a certain *pumping threshold* value; to give continuous lasing, the medium must be continuously pumped.

Figure 13 shows the basic elements of a complete laser unit. One of these is the actual lasing medium, which must be reasonably translucent. Another is a power supply that is used to pump the medium into a state of population inversion and initiate the lasing action. The final unit is a resonant optical cavity, made of two mirrors set at opposite ends of the lasing medium so that photons can repeatedly bounce back and forth through the medium; one mirror is fully reflective; the other has a small (equal to about 1% of the mirror's surface area) translucent hole in its center.

In *Figure 13*, lasing begins when — with the medium pumped up to its threshold value — a suitable internally- or externally-generated incident photon hits an excited atom and initiates the birth of an identical photon. This pair of photons then travel to the right, hit the end of the cavity, then reflect back and forth through the cavity, repeatedly passing through the lasing medium and initiating the generation of more photons in each pass, so that the photon flow rapidly builds up into a flood that can easily be controlled via the power supply.

Photons that strike the translucent hole at the center of the cavity's right-hand mirror emerge (*bleed off*) from the laser unit in a narrow and coherent beam that can be focused into a minute and intense spot by an external lens.

The optically-resonant cavity is a vital part of the laser system. It is highly wavelength-selective and gives high optical gain (resonance) only to signals with an integer number of half-wavelengths that fit exactly into the cavity's *optical* length (equal to the product of its physical length and refractive index value).

The cavity's length is inevitably many times longer than the (roughly 1000nm) optical wavelength of the basic laser beam, and it thus has a huge number of optical operating *modes* (wavelengths at which resonance may occur). In a cavity with an optical length of 2mm, for example, the first mode occurs at a wavelength of 4mm, the 10th at 0.4mm, the 100th at 40μm, the 1000th at 4000nm, the 4705th at 850.16nm, the 4706th at 850nm (a commonly-used IR wavelength), and the 4707th at 849.8nm.

The optical cavity's frequency response thus consists of a series of sharp comb-like peaks (known as *mode lines* in laser jargon), as shown in *Figure 14(a)*. In the above example, at wavelengths around 850nm, these peaks are spaced roughly 0.2nm apart. In some practical lasers (including many laser diodes), the lasing medium's basic (unfiltered) output has the type of frequency response shown in *Figure 14(b)*, and spans dozens of these peaks; in such cases, the cavity's laser-beam output thus has the type of frequency response shown in *Figure 14(c)*.

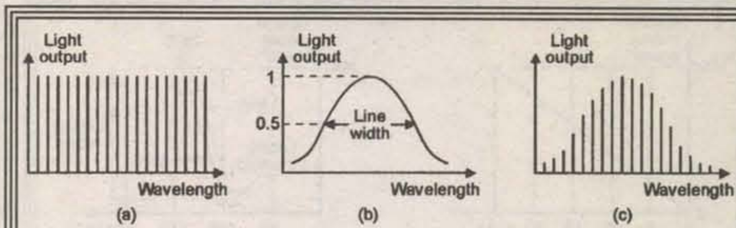


Figure 14. Typical frequency response of (a) a laser's optically-resonant cavity, (b) the unfiltered output of a lasing medium, and (c) the resulting laser-beam output of the cavity.

In laser jargon, the half-power spectral bandwidth of a laser output is called its *linewidth*. Lasers with linewidths that fit into a single mode line are known as *single mode* lasers; ones with linewidths that span more than one mode line (as in the case of *Figure 14(c)*) are known as *multi mode* lasers.

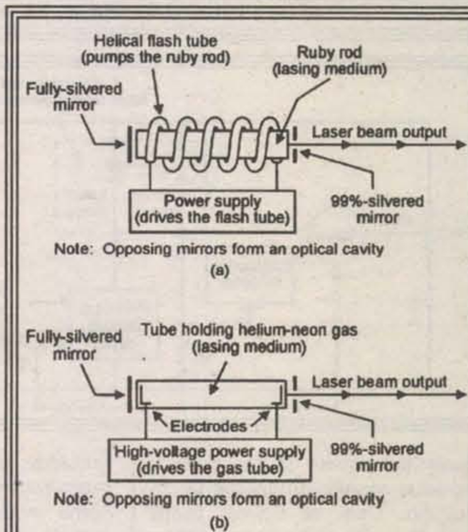


Figure 15. Basic functional diagrams of (a) ruby and (b) helium-neon lasers.

All practical lasers have finite linewidths and (since they contain a spectrum of frequencies) their beams can remain fully coherent (in-phase) for only a limited number of wavelengths after their initial creation. This dimension is known as the beam's *coherence length*, and

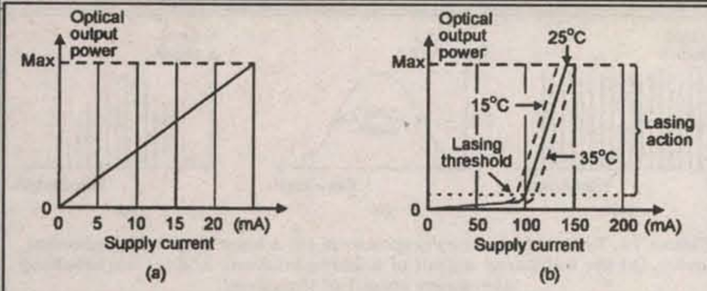


Figure 16. Typical supply-current to optical-output-power graphs of (a) a normal LED and (b) a laser diode.

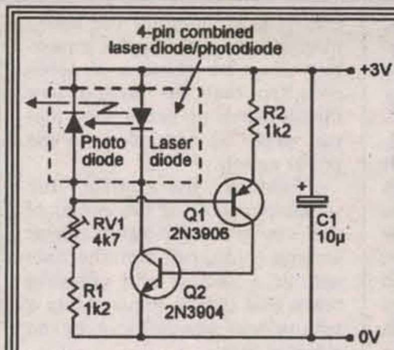


Figure 17. Simple way of using a four-pin combined laser diode/photodiode unit in a cw laser transmitter.

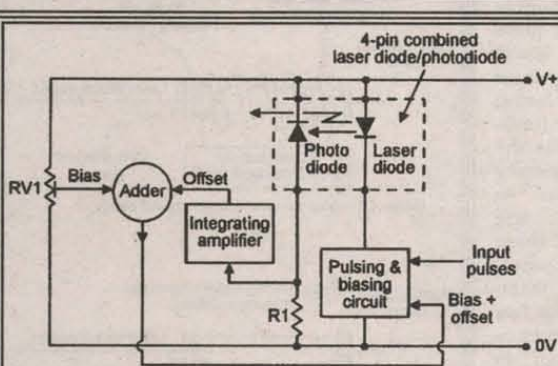


Figure 18. Basic circuit of a pulsed cw laser transmitter using a four-pin combined laser diode/photodiode unit.

equals the square of the beam's mid-value wavelength divided by its linewidth. Thus, an 850nm beam with a linewidth of 2nm has a coherence length of only 0.36mm.

LASER TYPES

The world's first working optical laser was demonstrated by an American, Theodore Maiman, in mid-1960. Known as a ruby laser, it has the basic form shown in *Figure 15(a)* and consists of a small rod of synthetic ruby crystal (the lasing medium), with mirrored ends that form the optical cavity; the rod is surrounded by an electrically powered helical flash tube, which acts as the medium's energy pump. When the flash tube is operated, its white light pumps the rod's atoms into an excited state, and a brief burst of lasing action commences a few milliseconds later, causing a brief pulse of red laser light to emerge from one end of the tube.

The ruby laser provides only brief pulses of laser light. The first laser to give continuous-wave (cw) operation was the helium-neon (He-Ne) gas laser, which was first demonstrated in late 1960 and has the basic form shown in *Figure 15(b)*. Here, the high-voltage supply pumps the gas molecules into an excited conductive state in which sustained lasing action takes place (typical supply voltages are 8kV for starting, 1.5kV when running); lasing takes place primarily at a wavelength of 632nm and the device thus generates a bright red laser beam.

He-Ne lasers are still widely used; most have maximum optical output powers in the range 0.5 to 10mW; the outputs have typical linewidths of a mere 0.002nm and beam coherence lengths of 200mm. Some modern He-Ne lasers have outputs that can be electronically modulated (but not pulsed) at frequencies up to 1MHz.

Many other types of laser have appeared since 1960. Most have severe practical disadvantages (such as very brief working lives, excessive cost, fragility, or bulkiness, or severe thermal operating requirements) or are meant only for laboratory or military use. Some are designed specifically for use in optical welding or cutting operations, and are not suitable for use in general 'electronic' applications. Most have input-to-output power conversion efficiencies of only 0.001 to 0.5 percent (a 1mW He-Ne laser, for example, typically needs an input power of 20W).

The laser best suited to use in general electronic applications is the so-called 'laser diode,' which (in most low-power types) acts like a laser version of the double heterojunction side-emitting LED, with a built-in resonant optical cavity. It is compact, robust, has a typical working life of 50,000+ hours, and is reasonably easy to use.

A laser diode produces a cw laser beam that can be pulse or analog modulated at frequencies up to many hundreds of MHz, has a typical input-to-output power conversion efficiency of 1.5%, and is commercially available in versions giving maximum optical power outputs ranging from 0.1mW to several watts, at a variety of red and infrared wavelengths. Single mode types have typical linewidths of less than 0.5nm; multi mode types have typical linewidths in the range 2nm to 5nm.

Figure 16(a) shows the typical supply-current to optical-output-power graph of a normal LED, and *Figure 16(b)* shows that of a laser diode. The LED's graph is quite linear, and the optical output power is directly proportional to the LED's supply current value. The laser diode has a more complex performance graph; at supply currents well below the lasing threshold value, it acts like a normal LED and generates random photons, but at currents well above the lasing threshold, it gives true lasing action and generates coherent photons. When operating at the actual lasing threshold level, it generates both random and coherent photons.

Note in *Figure 16(b)* that, at any fixed lasing current values, the optical output power is very sensitive to variations in the laser diode's temperature. Most practical laser diode units (modules) incorporate sensing and control circuitry that stabilizes the optical output power by auto-adjusting the lasing drive current. Most modern units of this type use special laser diodes that have an integral monitoring photodiode; *Figure 17* shows a four-pin version of such a unit, together with a simple way of using it as a cw laser transmitter.

In *Figure 17*, the photodiode's reverse current (and thus the voltage on Q1 base) is proportional to the laser beam's intensity. Q1 acts as a voltage-controlled constant-current generator that supplies base drive to Q2 which, in turn, provides drive current to the laser diode.

The overall action is such that, if the laser intensity falls below a value preset via RV1, the photodiode-derived Q1-base voltage also falls, thereby increasing Q1's current drive to Q2 base and causing Q2 to increase the drive current to the laser diode, which responds by increasing its laser intensity.

The reverse process occurs if the laser intensity rises above the preset value. The circuit thus auto-regulates the laser beam intensity.

Figure 18 shows a basic way of using the four-pin combined laser diode/photodiode unit in a pulse modulated cw laser transmitter. Here, the pulsed output of the laser-monitoring photodiode is converted into a DC offset voltage via an integrating amplifier, is combined with an RV1-derived pre-set DC bias voltage via an adder, and is fed to one input of the laser-driving pulsing and biasing circuit, which has its other input driven by external pulse-coded waveforms. The RV1-derived DC bias voltage is set so that — in the absence of input pulses — the laser diode is biased at its lasing threshold value (rather than fully off), thus giving a very fast switching action.

LASER APPLICATIONS

WARNING. Sensible safety precautions must always be taken when using lasers; the output beam of even a 0.5mW type can cause severe optical damage if aimed (deliberately or accidentally) at a human eye.

Low-power (up to 5mW) lasers are readily available in 'module' form, comprising the actual laser plus its drive circuitry and optics. They have a multitude of practical applications. Simple cw types, using the basic type of circuit shown in *Figure 17*, can — if generating a visible red beam — be used as laser pointers, spirit levels, or alignment aids, or as the basis of bar-code readers. Alternatively, infrared types can be used in a wide range of security applications, activating an alarm or initiating some other action when a person, animal, object, vehicle, smoke, or fog breaks or reflects the beam. When reflected from a solid surface, the cw beam can also be used to detect minute vibrations of the surface.

All CD and CD-ROM players incorporate a small cw laser module that (aided by various lenses and servo-drivers) automatically scans the spinning CD and picks out the information contained in the tracks (which are spaced only 1.6µm apart) of its coded sub-surface data pits, which are each a mere 0.1µm deep and 0.8µm to 3.5µm long, retrieving the data at a rate of over 4,000,000 bits per second.

Laser modules that are designed for use as modulated cw types can be used in all of the types of 'security' applications already mentioned, plus various speed- and distance-measuring applications. They are particularly useful in long-haul fiber optic communication and data-transfer systems, in which (because of their very small spectral bandwidths) they can greatly outperform LEDs.

Single mode IR laser diodes, for example, have spectral linewidths of only 0.5nm, compared to 80nm for LEDs, and their signals thus suffer far less material dispersion than those of LEDs when traveling through long lengths of fiber optic cable. **NV**

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DSS Satellite Comm.
411-E 18th St. #C
Oakland 94606
Electro Mavin
2985 E. Harcourt St.
Rancho Dominguez 90221
Ford Electronics
8431 Commonwealth Ave.
Buena Park 90621
Harding Way News
113 W. Harding Way
Stockton 95204
Harold's Newsstand
524 Geary St.
San Francisco 94102
Hi-Fi Doctor
1814 E. Ball Rd.
Anaheim 92805
HSC Electronic Supply
4837 Amber Ln.
Sacramento 95841

3500 Ryder St.
Santa Clara 95051

5681 Redwood Dr.
Rohnert Park 94928
Hyatt Electronic Surplus
371 N. Johnson Ave.
El Cajon 92020
JK Electronics
6395 Westminster Ave.
Westminster 92683
Laurel Park News
4346 Laurel Canyon Blvd.
Studio City 91604
Lion Electronic Labs
4948 E. Townsend Ave.
Fresno 93727
Netseller
7207 Arlington Ave. Ste. G
Riverside 92503
Op Amp Technical Books
1033 N. Sycamore Ave.
Los Angeles 90038
Panorama Electronics
8737 Van Nuys Blvd.
Panorama City 91402
Sandy's Electronics Supply, Inc.
20655 Soledad Cyn. Rd. #15
Santa Clarita 91351
Sav-On Electronics
13225 Harbor Blvd.
Garden Grove 92643
SIERRA MADRE NEWSSTAND
55 N. Baldwin Ave.
Sierra Madre 91024
The Red Barn
Hwy. 299
Bieber 96009
Tower Books
211 Main St.
Chico 95928

7840 Macy Plaza Dr.
Citrus Heights 95610

1280 E. Willow Pass Rd.
Concord 94520

630 San Antonio Rd.
Mountain View 94040

1600 Broadway
Sacramento 95818

5950 Florin Rd.
Sacramento 95823

2538 Watt Ave.
Sacramento 95821

Tower Records/Video
220 N. Beach Blvd.
Anaheim 92801

2520 Durant
Berkeley 94704

212 F St.
Davis 95616

5703 Christie Ave.
Emeryville 94608

2052 Redwood Hwy.
Greenbrae 94904

6310 E. Pacific Coast Hwy.
Long Beach 90803

2280 Market St.
San Francisco 94114

3205 20th Ave.
San Francisco 94132

2525 Jones St.
San Francisco 94133

871 Blossom Hill Rd.
San Jose 95123

Video Electronics
3829 University Ave.
San Diego 92105

CANADA
Com-West Radio Systems Ltd.
8206 Ontario St. #100
Vancouver, BC V5X 3E3
Muir Communications Ltd.
3214 Douglas St.
Victoria, BC V8Z 3K6

COLORADO
TH Electronics
216 Commerce Dr., Unit 2
Ft. Collins 80524
Tower Records/Video
2500 E. 1st Ave.
Denver 80206

CONNECTICUT
Archway News
64 Bank St.
New Milford 06776
Electronic Service Products
437 Washington Ave.
North Haven 06473

DELAWARE
Newark Newsstand
70 E. Main St.
Newark 19711

DISTRICT OF COLUMBIA
Tower Records
2000 Pennsylvania Ave.
Washington 20006

FLORIDA
Alfa Electronic Supply
1502 S. St. Rd. #7
Hollywood 33023
Al's News
8219 S.W. 124th St.
Miami 33156
Bob's News & Books
1515 S. Andrew Ave.
Fort Lauderdale 33316
Clarks Out of Town News
303 S. Andrews Ave.
Fort Lauderdale 33301
Mike's Electronic Distributing Co.
1001 N.W. 52nd St.
Fort Lauderdale 33309
Skycraft Parts & Surplus, Inc.
2245 W. Fairbanks
Winter Park 32789
Sunny's At Sunset, Inc.
8260 Sunset Strip
Sunrise 33322

GEORGIA
Tower Records
3400 Around Lenox Dr. N.E.
Atlanta 30326

HAWAII
SolarWorks!
525 Lotus Blossom Ln.
Ocean View 96737
Tower Records
4211 Waialae Ave.
Honolulu 96816

611 Keeaumoku
Honolulu 96814

IDAHO
The Current Source
5159 Glenwood
Boise 83714

ILLINOIS
Tower Records/Video/Books
383 W. Army Trail Rd.
Bloomingdale 60108
2301 N. Clark St. #200
Chicago 60614

1209 E. Golf Rd.
Schaumburg 60173

INDIANA
Harbourtown Sales
108 Park 32 W. Dr.
Noblesville 46060

KANSAS
Hollywood At Home
9063 Metcalf Ave.
Overland Park 66212
Lloyd's Radio & Electronic, Inc.
220 W. Harry St.
Wichita 67213

LOUISIANA
Lakeside News
3323 Severn Ave.
Metairie 70002

MARYLAND
Silicon Valley Electronics
2014-A Industrial Dr.
Annapolis 21401
Tower Records/Video
2566 Solomons Island Rd.
Annapolis 21401

1601 Rockville Pike #210
Rockville 20852

MASSACHUSETTS
Newsbreak, Inc.
579 G.A.R. Hwy. Rt. 6
Swansea 02777
Tower Records #172
360 Newbury St.
Boston 02115

MICHIGAN
Little Professors Book Center
22174 Michigan Ave.
Dearborn 48124
Purchase Radio Supply, Inc.
327 E. Hoover Ave.
Ann Arbor 48104
Tower Records
1214 S. University Ave.
Ann Arbor 48104

MINNESOTA
Radio City, Inc.
2633 County Road 1
Mounds View 55112

MISSOURI
Accurate Instruments
11201 E. 24 Hwy.
Independence 64054
Electronics Exchange
8644 St. Charles Rock Rd.
St. Louis 63114

NEVADA
Amateur Electronic Supply
1072 N. Rancho Dr.
Las Vegas 89106
Less Buster's Electronics
2930 N. Las Vegas Blvd.
VSTG-22
North Las Vegas 89030
Radio World
1656 Nevada Hwy.
Boulder City 89005
Tower Records/Video
4580 W. Sahara Ave.
Las Vegas 89102

6450 S. Virginia
Reno 89511

NEW JERSEY
JR Tech Systems
1309 Hwy. 71
Belmar 07719

NEW YORK
All Phase Video Security, Inc.
70 Cain Dr.
Brentwood 11717
Ham Central
3 Neptune Rd.
Poughkeepsie 12601
Hirsch Sales Corporation
219 California Dr.
Williamsville 14221
Tower Records/Video
105 Old Country Rd.
Carle Place 11514

350-370 Route 110
Huntington 11746

1961 Broadway
New York 10023

383 Lafayette St.
New York 10003

OHIO
Compustuff
241 Great Oaks Trl.
Wadsworth 44281
Digital One
7603 Mentor Ave.
Mentor 44060
Footsteps
4925 Jackman Rd. Store #58
Toledo 43613
Hosfelt Electronics, Inc.
2700 Sunset Blvd.
Steubenville 43952
Keyways, Inc.
204 S. 3rd St.
Miamisburg 45342
Leo's Book Shop
330 N. Superior St.
Toledo 43604
Powermaxx, Inc.
1587 U.S. Route 68 N.
Xenia 45385

OKLAHOMA
Steve's Books & Magazines
2612 S. Harvard
Tulsa 74114
Taylor News & Books
133 W. Main, Ste. 102
Oklahoma City 73102

OREGON
News & Smokes
2295 W. Main St.
Medford 97501
News & Smokes #8
259-C Barnett Rd.
Medford 97501
Norvac Electronics
7940 S.W. Nimbus Ave. Bldg. 8
Beaverton 97005

960 Conger
Eugene 97402

1545 N. Commercial N.E.
Salem 97303
Powell's Technical Bookstore
33 N.W. Park
Portland 97209
Tower Books
1307 N.E. 102nd Ave.
Portland 97220

PENNSYLVANIA
Bedford St. News
308 Bedford St.
Johnstown 15901
Genes Books, Inc.
King of Prussia Plaza
King of Prussia 19406
Lehman Scientific
85 Surrey Dr.
Wrightsville 17368
Tower Books
425 South St.
Philadelphia 19147
Tower Records
340 W. Dekalb Pike
King of Prussia 19406

SOUTH CAROLINA
555 Electronics
5646 Farrow Rd.
Columbia 29203

TENNESSEE
Tower Books
2404 W. End Ave.
Nashville 37203

TEXAS
BDL News, Inc.
809 Pierce
Houston 77002
Electronic Parts Outlet
3753-B Fondren Rd.
Houston 77063
Mouser Electronics
958 N. Main St.
Mansfield 76063
Tanner Electronics
1301 W. Beltline #105
Carrollton 75006
Tower Records
2403 Guadalupe St.
Austin 78705

VIRGINIA
American Computer Clearance
1609 Rhoadmiller St.
Richmond 23220
Tower Records/Video/Books
4110 W. Ox Rd. #12124
Fairfax 22033

1601 Willow Lawn Dr.
Richmond 23230
8389 E. Leesburg Pike
Vienna 22182

WASHINGTON
A-B-C Communications, Inc.
17541 15th Ave. N.E.
Seattle 98155
Bohica Concepts
214 2nd St.
Morton 98356
Cody Books Ltd.
1125 Fir Ave.
Blaine 98230
Service Request
3304 W. Rowan Ave.
Spokane 99205
Supertronix
16550 W. Valley Hwy.
Seattle 98188
Tower Books
10635 N.E. 8th St.
Bellevue 98004

20 Mercer St.
Seattle 98109

WISCONSIN
Amateur Electronic Supply, Inc.
5710 W. Good Hope Rd.
Milwaukee 53223
Greenfield News & Hobby
6815 W. Layton Ave.
Greenfield 53220
Cudahy News & Hobby Ctr.
4758 Packard Ave.
Cudahy 53110

WYOMING
Western Test Systems
2701 Westland Ct. #B
Cheyenne 82001

PRECISE, KENSINGTON LABS, XY STAGE.

Model 8500-6X, 6"X6" of high performance travel. One of the best linear stages available. Highly repeatable, ultra-precise. Precision ground surfaces result in unmatched laboratory-grade performance. Linear glass scale, internally attached to the table, eliminates all drivetrain errors not measurable when an encoder is attached to the motor. System provides up to 0.025µm res. over 100 mm. Built from stress relieved 7075 aluminum. Crossed-roller bearings for excellent stiffness, load capacity and lifetime. Combined with a very low friction preloaded leadscrew and DC servo motor drive provides 20,000 hour MTBF. 100 mm/sec maximum speed and >50kg load capacity. Size: 15"L x 9"W x 2.75"H

Regular price > $4Kea. X&Y stage with motors no drivers. USED, Very good condition. **8500-6, XY LINEAR STAGE $1795**

BAYSIDE, RIGHT ANGLE, GEARHEAD DRIVE

PERFORMANCE SPECS:

Gearhead Model	Torque in-lb (Nm)	Peak Torque in-lb (Nm)	Input Speed RPM	Backlash arcmin	Eff. %
NR 23	50 (6)	100 (11)	4,000	30	92

Moment of Interia kg-m2 (oz-in-sec2)	Max. Weight lb kg	Radial Load lb N	Axial Load lb N
8x10-5 (6x10-7)	3 (1.4)	150 (670)	100 (440)

SPECIAL............$89ea. or 2 for $169

ULTRA MINI and WEATHERPROOF, "LIPSTICK" CAMERA

Sleek black anodized, alum. housing, O-Ring sealed & RAINPROOF. Adj. tilting mount. 1/3" CCD, 380 Lines, 0.3 Lux, AGC, Auto Shutter. 9-12VDC @100mA, 4mm, f1.8, 78° FOV real glass lens, NTSC video. <1ounce! IR SENSITIVE. 23mmdX50mm, 36" cable with BNC video & DC barrel jack. **GM-200K-STD...........$99**

PINHOLE Model. So tiny you can install it directly into a door. Only a 0.9" diameter hole! Specs as above. 90° FOV Pinhole lens. 1/2 once! Size only 23mm d.x35mm long. Think of the places you could put this little jewel.

GM-200K-PH lens.....$99

DOVER AIR BEARING X/Y TABLES, ULTRA PRECISE,

Like New, The ultimate in precision motion control. These are leadscrew operated air bearing tables with 1-20 Microns typical repeatability. Straightness, less than 1 micron each axis, angular error, less than 1 arc/sec. Squareness, less than 5 arc/sec. Three models available. Model "A" has 6"x6" travel with 2 type 23BLS-021-02, 4.85A 24V Rapidsyn stepper/ encoders. Type "B" is as above without motors. Type "C" has 4"x5" travel with two Compumotor LE57-51-MTR steppers. No controllers.

TYPE "A"...$1200, TYPE "B"...$949, TYPE "C"...$849

TINY, PRECISE, PORTESCAP, SWISS, GEARMOTOR

State of the art "ironless" type, mini motor. Model B: M11-210-54-0 with approx: 40:1 spur gearbox. Size: 16mm d. x 43mm L with 2mm diam. x 6mm L, flatted shaft, solder terminals.

	VIN	IIN	RPM
B:	6V	8mA	141
	12V	12mA	290

LIMITED QUANTITY TYPE B: $15ea. or 2 for $27

NEW, LASER DIODE MODULES

SPECIFICATIONS: DC Power: 4.5 - 9V, @65mA
Power out: 4.5mw max.
Range: 400-800 Meters
Glass Collimator
Size: 0.41"diam.x0.7"L

Shown Actual Size

The best value for commercial, Subminiature, laser modules. Glass collimating lens provides 1.5mRad performance. (divergence comparable to HeNe lasers.) Wide input, internal surface mount, 4.5 to 9VDC power supply. Excellent thermal characteristics. Machined brass.

650nm 5X Brighter...$29, 635nm 10X Brighter...$69, *635F with adustable focus...$89

TEK 475, 200 MHz portable, Dual trace, Delayed sweep............$649ea.

ALL PORTABLE SCOPES INCLUDE PROBE, MANUAL and COVER. TEST EQUIPMENT RECONDITIONED & CALIBRATED, 6 MONTH WARRANTY

ARMY TELEPHONE SET, TA-1/PT

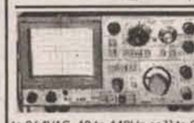
For Secure Y2K Communications

Like new, direct from depot storage in original boxes. The portable & lightweight handset phone is sound powered, has a built in push to talk ring generator, buzzer volume, and visual indicator for silent call signal. NO BATTERIES or EXTERNAL POWER REQUIRED. Any two conductor wire is all that is needed for interconnection and communication between two phones. Voice transmission range is up to 4 Miles. Freq. Response: 300 Hz to 4000Hz. Operating temp. -40 to +131F. Complete with hard field case and complete manual. An excellent collectors item.

Special.......$49ea. or 2 for $89

TEKTRONIX 335, MINI SCOPE,

Can be AC or DC Powered.



The 35MHz bandwidth and 1mv/Division vertical sensitivity combine to make this compact dual trace scope a true field service performer. Size:13.6"Lx9.3"W x4.4"H Weight: 10.5 lbs. Can be operated from 90 to 264VAC, 48 to 440Hz or 11 to 28VDC. External jack for DC input. Package includes probe, manual, calibration and 6 month warranty. **New..$3K Now....$549**

FAIRLY LARGE CAPs, New, SPRAGUE, 36DX Series

Three values, Aluminum electrolytic, available. All include mounting clamp:

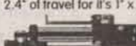
Type A, 3500uf @ 450VDC $20ea. 2 for $39
Type B, 1400uf @ 450VDC $18ea. 2 for $39
Type C, 7400uf @ 200VDC $15ea. 2 for $29
Concord Elect., Type D, 2500uf @ 450VDC $15ea. 2 for $29

END FIELD of VIEW GUESSWORK! 3.5 to 8mm VARI-FOCAL LENS

Brand New, super f1.8 lens allows you to smoothly adjust from a 97° FOV @ 3.5mm to a 44° FOV @ 8mm. Now you can frame your area of interest just the way you want it! Standard CS-Mount with adjustable focus and iris. **SPECIAL.....$99ea. or 2 for $189**

MINI, LINEAR MOTORIZED MOUNT,

This high quality mini slide provides 2.4" of travel for it's 1" x 1" alum. plate riding on two 0.18" diam steel rods. Motion is via a toothed belt drive from a 1.8° per step, 8 ohm stepper motor. 1 full step - about 0.008" of travel. Overall size: 6"L x 3.5"W x 2.5"H, Dual optical end of travel sensors. Alum. construction. **SPECIAL..............$24ea. or 5/$99**



NEW, KEITHLEY/ACCULEX, DP-2000, 4 1/2 DIGIT,

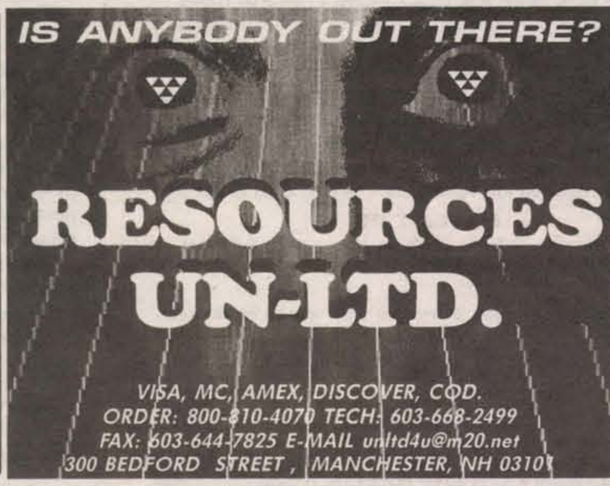
LCD, Digital Panel Meter

Industrial quality 5VDC powered, 19,999 count DPM with 1/2" digits. Requires only 15mW and only 0.73" space behind panel. Perfect for any application requiring precision and portability. User selectable range control provides +/-200mVDC and +/-2VDC option. Auto polarity, overange, selectable decimal point and display hold functions. Full differential inputs. 100M Ohm input imped. on 200mV range. 1M ohm on 2V range. Snap in mounting. Stability 100ppm/deg C.

Regular price....$99ea. **SPECIAL.......$39.00ea. 2 for $69**

MAXON, Rare Earth Magnet, PRECISION DC GEARMOTOR, 35:1, 2- stage, Planetary gearbox.

Maxon P/N: RE035-071-34EAC200A. All metal construction with mounting ears. Approximately 100RPM at the gearbox output and 4000RPM at the direct output. (dual shaft design) Direct shaft is 3.9mm diam. X 18mm Long. Geared Shaft size: 6mm diam. x 18mm long. Overall size:35mmO.D. x 109"L not including shafts. Ball bearing outputs. Torque 2.25Nm continuous. Nominal operating voltage: 24VDC @ 40W. No load current 45.7mA, Max. Cont Current: 1.5A. A fantastic motor and always a sellout! **Maxon, Special....$39ea.**



NEW, "STEALTH CAM", MICRO, with AUDIO!

The sleek aluminum housing fits like a glove! Removeable mounting bracket and a 1.3M cable with BNC vid., RCA aud., (internal mic) & DC barrel jack for, no sweat hook up. Why fool around with an open P.C. board? Now you can have the "STEALTH CAM". 1/3" CCD, 410 Lines, 0.3 Lux, AGC, Auto Shutter. Pwr. from 9 to 12VDC @110mA, 250k pixels, Std. model, 4mm, 78° FOV lens, Pinhole model, 90° FOV. A real glass lens. Focus from 10mm to infinity. NTSC video out. Only 1.7 ounce! SENSITIVE to IR. Size Std: 30mm sq. x 29mm d. PH is 16mm d. **WARNING:** Don't confuse these models with LOW RESOLUTION, HIGH LUX C-MOS CAMERAS.

GM-2000S-STD, w/aud. $79.00
GM-2000S-PH, w/aud................$79.00

4 HEAD TIME LAPSE VCR, Records 24 HOURS!

Used, refurbished, late model VICON model 424's at only 2/3 off the regular price. On screen programming, time/date stamp, audio, index search. power loss recovery and alarm inputs. Excellent, with manual. **VICON 424, Special............$399ea.**

NEW! DAYLIGHT to LOW LIGHT MINI CAM, w A/I LENS

For those applications that must work from dawn 'till dusk, this is it. Rugged aluminum housing with dual mounting sockets. Specs: 1/3" CCD, 420 lines resolution, 0.1 Lux sens., AGC, Auto shutter. 12VDC @120mA. Take full advantage of camera sensitivity with the super, 4mm, f1.4, 78° FOV Auto Iris lens included. Video out on BNC. Size: 50mm sq. X 65mm long. Power adapter included. Ready to go!

GM-510-A/I....$199ea. or 2 for $369

HIGH RESOLUTION OPTICAL ENCODERS

2500ppr, 10,000ppr Quadrature! DRC MODEL 25-S351-817-2500, amp. shaper output. Size: 2.5"d, 1/4" ball bearing with shaft seal. Continous rotation., 3000 RPM max. Alum. housing, 5V powered with zero reference out, 18" cable. **USED........$39ea.**

CHECK THIS! ULTRA MINI, WEATHERPROOF & COLOR!

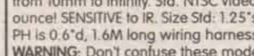
NEW "COLOR LIPSTICK" camera. For those applications that must be color, this is it. Black anodized, aluminum, housing is O-Ring sealed & RAINPROOF. Adjustable tilting mount included. Specs: 1/3" CCD, 400 Lines resolution, <1 Lux sensitivity, AGC, Auto Shutter. 12VDC @180mA, 4.3mm, 78° FOV lens, A real glass lens. Std. video out. Size: 32mm diam. X 65mm long. 24" leads with RCA jack and DC jack. With pwr. adapter. Ready to go!

SPECIAL this MONTH, GM-400K...............$219ea.

NOW YOU CAN SEE WHAT THE "FISHES ARE DOIN' GO UNDERWATER (down to 60 ft. Waterproof B&W CAMERA with INTERNAL, INFRA-RED ILLUMINATOR!

Sleek black anodized, BRASS, housing is O-Ring sealed & WATERPROOF. Adjustabe mount included. Specs: 1/3" CCD, 400 Lines resolution, 0.05 Lux sensitivity, AGC, Auto Shutter. Operates on 12VDC @225mA, 4mm, 78° FOV lens, A real glass lens. NTSC video out. Superior construction. SENSITIVE to IR. Ultra small Size only: 1.25"diam. X 2" long. With 60 ft. cable. Great for general outdoor use also. SPECIAL, **GM-300KIR................$199ea.**

Brand New, Video Motion Sensor.



Model VM10. Attach to any standard video signal and you've got an electronic "watchman" diligently watching the entire scene. Or any adjustable sized area within the scene. Such as a doorway or even a drawer or cabinet. A state of the art security aid. The unit will close a contact when it senses a change. Use it to turn on a VCR or call the hounds. Auto or manual reset. Compact, ac powered. Adjustable sensitivity. Video loop through jack. **NEW VM-10........$189.**

low-cost MICRO CAMERA, w/audio

1/3" CCD, 410 Lines Res., 0.3 Lux sens., AGC, Auto Shutter. Pwr. from 9 to 12VDC @100mA, 250k PIXELS, Std. model, 4mm, 78° FOV lens, Pinhole, 90° FOV. A real glass lens. Both focus from 10mm to infinity. Std. NTSC video out. 1/2 ounce! SENSITIVE to IR. Size Std: 1.25"sq. x 1"d. PH is 0.6"d, 1.6M long wiring harness with connectors included. **WARNING:** Don't confuse these models with LOW RESOLUTION, HIGH LUX C-MOS CAMERAS. Six different models.

GM-1000A-STD......$60 GM-1000A-STD/Aud.....$65
GM-1000A-PH........$60 GM-1000A-PH/Aud.......$65
GM-1000A-CMNT..$60 GM-1000A-CMNT/Aud.$65

Micro Lenses for GM1000 series

2.5mm, 150°............$22	8.0mm, f2.0............$22
4.3mm, 78° f1.8.......$22	12.0mm, f2.0..........$22
6.0mm, f2.0..............$22	5mm, 70°PH...........$22

C-MOUNT LENSES

LOW LIGHT	STANDARD
16mm, f1.6, 15° FOV $39	4mm, 80° FOV $24
8mm, f1.3, 40° FOV $49	8mm, 40° FOV $24
4mm, f1.4, 78° FOV $49	12mm, 28° FOV $24

6V@12AH SEALED, RECHARGEABLE, BATTERY

New Panasonic, LCR6V12PI. Tough to get at a discount. Very compact. Two top mounted 1/4" faston connectors. Perfect for high drain projects. Size: 5.9"L x 3.7"H x 1.9"D **2 for $20, or 10 for $89**

NEW, 2.4GHz VIDEO + STEREO AUDIO TRANSMITTER with SONY, CCM-PC5 COLOR CAMERA.

Originally sold for $500! Now available for a fraction of that price. Great looking styling. Camera has a very stable, adjustable tiliting base, front panel LED pwr. indicator and sensitive built in electret mic, providing excellent audio and video performance from one compact package. Simply connect camera to the completely self contained 2.4GHz transmitter. All cables supplied. You can transmit up to 700 feet clear line of sight! Companion matching receiver works with any TV or VCR. Internal patch antennas. Camera has adjustable focus 6mm lens. (1" to infinity, macro capable) Auto power off when the privacy shutter is closed. Power is 7-13VDC. (all pwr. adapters and cables included) 1/3" CCD, 330Lines res. 35% better than standard VHS! Can als be used to transmit VCR opulput to another TV for remote viewing.

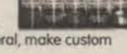
SPECIAL, 2.4GHz SONY-ASTROVIEW....$189ea. or 2 for $339
addtl. 2.4GHz TRANSMITTER/RCVR. less Camera...$129ea.

MOTORIZED ZOOM LENS SPECIAL, 6X mag. and auto iris !

New, fabulous hi-res. optics with std. C-Mount. Superior Fujinon and Vicon lenses. Normally cost from $600 to $1500. There is no substitute for a good lens! All drive motors will operate from 6-12VDC. The Auto iris has a built in amp which works with any cameras video output for control.

Type B-6, 12.5 to 75mm, 6X, f1.2	$179 or 2 for $349
ZOOM LENS CONTROLLER, NEW	$169

10V @ 2.5 AH SEALED, LEAD ACID, PACK



Each pack consists of five, 2 Volt cells. Each cell the size of a std. 'D' battery. They are arrainged as 1X5 cells. Enclosed in an ABS outer shell. (removed for photo) Mint condition. Perfect for robotics and other high drain applications. Buy several, make custom packs of any rating. Size: 7.5"L x 2.8"H x 1.5"D

5-five packs for $20, 30 for $99

Write in 59 on Reader Service Card.

ELECTRONICS Q & A

With TJ Byers

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.
Feel free to participate with your questions, as well as comments and suggestions.
You can reach me at:
TJBYERS@aol.com
TJBYERS@juno.com
or by snail mail at
Nuts & Volts Magazine,
430 Princeland Ct.,
Corona, CA 91719.

What's Up:

• Our continuing look at switching power supplies: two flyback converters this time and an efficient benchtop power supply.
• Tips on the Variac, and
• relays galore, including a
• driveway announcer and
• semiconductor-less timers/latches. Plus the usual search for unusal items, like a • NASA appliance controller and a
• cordless modem for notebooks, and more.

Robot On The Run

Q. I'm looking for a low-cost RF transceiver for use in a mobile robot project. The transceiver must be able to handle video, audio, and digital data. In addition, it should have a range of 1000' or more. Can you suggest products that might fit the bill?

K.A. Delahoussaye
via Internet

A. What you're looking for is commonly used in wireless security systems, where both video and sound are transmitted from one or more remote sites to a central control area. They usually operate in the 2.4 GHz range, and typically have a range of 1000'. Because you want to put this into a robot, I suggest a board version of this setup. It'll save you weight and money over a cabinet version. You can buy 2.4 GHz wireless transmitter and receiver boards from **Matco, Inc. (800-440-0299; http://www/mat-co.com)**, model number ASK2000TR (**page 73**). They boast four-channel auto-scan video and two audio inputs which may be used for digital data. The cost is $129 for the pair.

Cordless Modem

Q. Do you know of a nifty way to hook-up a laptop computer to a cordless phone so that it could be used "no strings attached" while outdoors?

Andy Gerkman
via Internet

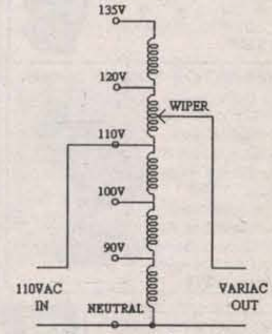
A. Yep, a very nifty solution from Panasonic called the KX-TCL100 Data Link. Basically, it's a 900-MHz link between your notebook PC and any RS-11 phone jack, in other words, a cordless phone all by itself. The Data Link consists of two pieces. Simply plug the rechargeable, battery-operated portable (sending) unit into your computer's modem RJ-11 port, then plug in the base receiver into a landline phone jack ... and you're home free. When fully charged, the Data Link battery provides 2.5 days of stand-by service (it receives, too) and up to 2.5 hours of on-line time. The rub is that it sells for about $200, depending on where you shop (I've seen it as low as $169). Actually, there's nothing to stop you from plugging your cordless handset into the laptop and doing the same thing. The problem is finding the wires that equal the red and green connections of the base receiver. Here I can't help, because each wireless handset is different. However, if you can locate the handset microphone wires, I believe you can interface those wires to your modem's output connector (red/green wires) with a 1:1 telephone interface transformer. Of course, you'll have to obtain the dial tone manually by pressing the Talk button before beginning transmission. Like I said, I think this will work, but don't quote me. I'd try it myself, but my girlfriend won't let me saw the handset in half to test my theory. Jeeze, and after all the things I do for her.

Variac Basics

Q. I recently acquired a General Radio model VBT-10 Variac. It is 5" in diameter by 2-3/4" high and weighs a "ton." I'd like to enclose it in some type of housing with a meter to indicate the output voltage and need your opinion on this project. There is a diagram on the unit showing a winding in a 270° circle with connections at both ends of the winding and four taps in between. Of course, there's also a connection for the wiper. I wired one of these about 20 years ago, but have since forgot how I did it. Do you know how? (P.S. Do you know what happened to General Radio?)

Roy E. Kneale
via Internet

A. The Variac is what's called an autotransformer, that is, it has only a primary, not a secondary, winding. The AC line connects to the bottom of the winding and one of the taps, as shown.



Which tap depends on your line input voltage. The Variac output voltage is a ratio of the input voltage. In the drawing above, the output voltage will be 115VAC. Moving the wiper up increases the output voltage and moving the wiper down decreases it. Your Variac has a rating of 10 amps — about 135 watts. Just remember that the output isn't isolated from the AC line, and you must treat it accordingly.

Now for some history. In 1915, Melville Eastham and four investors founded the General Radio Company in Cambridge, MA to manufacture radio measuring instruments and parts. During WWI, the company expanded its manufacturing capacity to meet the needs of the war effort. One of their products — a precision variable condenser — was used by Major Edwin H. Armstrong to tune his first superheterodyne receiver. After the war, GR intensified its focus on the development of precision measuring instruments, including the first commercially available oscilloscope and the Variac — both of which found major uses in WWII. In the 1950s, GR built a new manufacturing plant in West Concord, MA, and closed the Cambridge facility. The company later moved to Lexington, MA, where they remain today as GenRad Corporation.

Sensitive Magnetometer

Q. Attached is an interesting circuit that appears to sense changes in magnetic fields with a high degree of sensitivity. Any thoughts about where one would locate the mu-metal rod that is the key element of the circuit? The circuit is about 30 years old.

David LaBorde
Fort Walton Beach, FL

A. I have both good news and bad news for you. Good news: Mu-metal, also known as Permalloy, is readily available. A nickel-iron alloy (77% nickel, 15% iron, with traces of copper, magnesium, and molybdenum), mu-metal has extremely high magnetic permeability at very low field strengths (i.e., the earth's magnetic field). Because of this property, it's often used as a magnetic shield for sensitive instruments like superconductor sensors and can be found to some extent in many CRT monitors. Bad news: the piece of mu-metal you need for this project is about the size of a toothpick — about 2-1/4" long by .004" thick. Trying to buy this tiny bit of wire from a vendor or jobber isn't easy because they sell the stuff by the pound. Here are three contacts that may be willing to give you a piece if you ask nicely, but don't hold your breath.

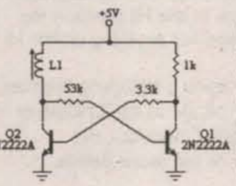
Eagle Alloys Corp.
1-800-237-9012
http://www.eaglealloys.com/index.shtml

Reade Advanced Materials
East Coast: 401-433-7000 West Coast: 775-352-1000
http://www.reade.com/Products/Categories/alloys.html

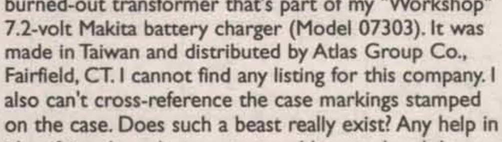
Magnetic Shield Corporation
1-888-766-7800
http://magnetic-shield.com/index.html

But like I said, mu-metal is plentiful, especially in monitors and oscilloscopes. So what I suggest is canvassing your local TV repair shops and see if one of them has an old monitor or scope destined for the dumpster, and ask if you can salvage the mu-metal shield first. What you'll need to do now is find a seam or edge that's readily available and, using metal shears or hacksaw, cut it to the length you need. The actual size isn't that critical, though, and you may want to experiment with different pieces for best performance. What is important is the coil itself, which has to be wound on a phenolic or plastic tube 3/16-inches in diameter and 2 1/4-inch in length.

Now for those readers who are dying to see the circuit David is talking about, here it is.



As shown, two NPN transistors form a simple astable multivibrator that oscillates at a center frequency of 11 kHz. It works on the principle of magnetic core saturation. At power-on, Q1 turns on and begins to "charge" the L1 core. When the core saturates, Q1 turns off and Q2 turns on. The magnetic field now collapses, turning Q2 off and Q1 on, causing the cycle to repeat itself. The oscillation frequency is determined by the saturation point of L1's core. As it turns out, mu-metal is a very easily saturated material that's susceptible to external magnetic influence. When a magnet is brought near the mu-metal, the saturation point changes, depending on the magnet's polarity. In one direction the saturation point is reduced, and the output frequency is lowered. In the other direction, the saturation point is strengthened and the output frequency increases. To demonstrate the sensitivity of this design, let me say that the force of the earth's magnetic field will change the frequency from 8 kHz to 14 kHz by simply rotating the coil horizontally from N-S to W-E. Here are the details of the coil.



Makita, Alive And Well

Q. As a long-time subscriber of *Nuts & Volts*, I'm sending you a plea for help. I need to replace a burned-out transformer that's part of my "Workshop" 7.2-volt Makita battery charger (Model 07303). It was made in Taiwan and distributed by Atlas Group Co., Fairfield, CT. I cannot find any listing for this company. I also can't cross-reference the case markings stamped on the case. Does such a beast really exist? Any help in identifying the voltage output and how to breakdown the cryptic markings on the charger would be very much appreciated. My belief is that they are dead and long gone.

George K. Coyne
via Internet

A. Nope, Makita is quite alive and well (I have some of their tools). They can be reached at **800-462-5482; http://www.makita.com/**, and have a repair shop in San Jose, CA. Moreover, I called the San Jose number and got a real live person who knew what I was talking about — Brownie points for Makita! While your particular model is no longer listed among the living, they'll be happy to sell you an upgraded version of the same.

NASA Chills Out

Q. This is in response to a reader who, a few months ago, asked about a circuit that reduces the amount of power consumed by appliances like a refrigerator or freezer. I'm sorry, my hard disk ate your name and address, but I hope you'll know who you are when you read the following answer.

Name lost
mia culpa

A. The device you're looking for is a NASA invention that was designed to minimize the amount of energy used aboard the Space Shuttle for refrigeration and other cooling devices — way before the Shuttle was but a gleen in its daddy's eye. Basically, it's a power-factor controller that controls the phase angle of the voltage and current supplied to an AC motor for maximum efficiency. I've heard of savings up to 20%, but don't quote me because it depends on the age of your appliance. Bottom line is that you can now check it out for yourself at a very low $3.98 from **Electronic Goldmine (800-445-0697; http://www.goldmine-elec.com), page 56.** The part number is G9946, and it works best with appliances made before 1992.

Benchtop Power Supply Improved

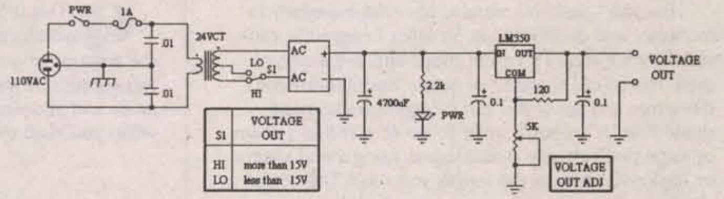
Q. I've constructed a variable-voltage DC power supply using an LM350 and a 24-volt, 2.5-amp power transformer. The LM350 is attached to a finned heatsink which is additionally cooled with a small CPU fan. One day, I hooked the power supply to a Variac (a continuously variable AC transformer) and reduced the line voltage from 110 down to 80 volts, and discovered that the power transformer and LM350 ran much cooler — even at full load. I have since tried to duplicate this using voltage dropping resistors, but unsuccessfully. Is there any way to reduce the input voltage without having to haul this monsterous Variac around? Perhaps putting a 60W bulb in series with the AC line?

Pete Haas
Kent, OH

A. What you're experiencing is what engineers call "power dissipation." Simply put, it's a way of converting unwanted electricity into heat — the way an electric stove does. Let's say that the input voltage to the LM350 is 33.6 volts (1.4 x 24V for full-wave rectification) and the output voltage is 24 volts, then the voltage drop across the LM350 is about 10 volts. If the load draws 1 amp, the LM350 has to dissipate 10 watts of power (P = EI = 10 x 1 = 10 watts). Now let's reduce the output voltage to 5 volts, which means the voltage drop across the LM350 is now 29 volts. If the load draws 1 amp, the regulator must dissipate 29 watts of heat — three times more than before.

What you inadvertently discovered is that by reducing the input voltage, the chip runs cooler. Let's see why. By reducing the input to 80 volts, you've lowered the input voltage to the LM350 from 33.6 volts to 24 volts. This decreases the voltage drop across the LM350 from 29 volts to 19 volts when powering a 5-volt load at 1 amp. That's a 33% reduction in heat generated! Moreover, the efficiency of the power supply is now improved because less power is wasted as heat. Need proof? Just comparing watts in to watts out, for a 110-volt input the total power drawn from the AC line at 5 volts, 1 amp (5 watts) to the load is 33.6 watts (1 amp x 33.6 volts), for an overall efficiency (no other losses) of 15%. Compare that to an efficiency of 21% (1 amp x 24 volts = 24 watts) for an 80-volt input.

Now for a solution to your heat problem. You mentioned adding a 60W bulb in series with the AC input to reduce heat (actually, I'd use a 25W bulb). Well, it'll reduce the heat generated by the LM350, but what about the heat the light bulb generates? Here's a better answer. The way you describe the power transformer, I'm sure it has a center tap, and I'm positive you're using a bridge rectifier, which means the center tap is unused. Simply break one of the AC secondary connections from the transformer to the bridge rectifier, and insert a HI/LO switch, as shown below.



S1	VOLTAGE OUT
HI	more than 15V
LO	less than 15V

For the convenience of our readers, I've included the rest of the schematic for the variable-voltage power supply, which can provide up to 3 amps at 30 volts. Anyway, when the switch is connected to the full secondary (HI position), the input voltage to the LM350 is 33.6 volts. In the LO position (center tap), the LM350 input voltage is 16.8 volts. If we run this voltage through our power and efficiency equations for 5 volts at 1 amp, we get a 12-volt drop across the regulator for a 12-watt power dissipation and an efficiency of 30%. Impressive, huh? All that for the cost of a switch. Shift the switch in the HI position for output voltages above 15 volts, and in the LO position for anything under 15 volts.

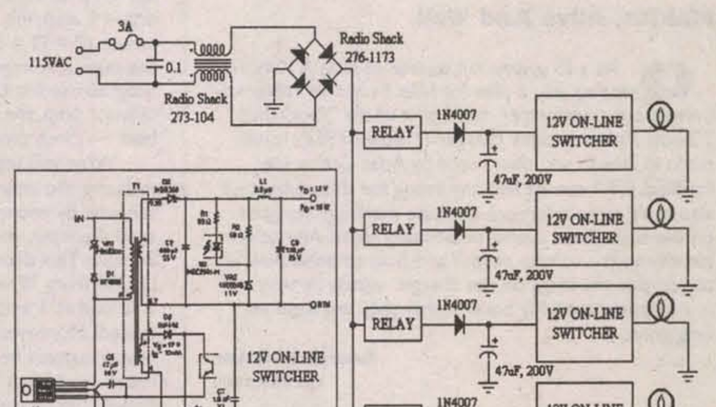
However, there are other solutions, specifically using a switching inverter in place of the transformer tap then inputting that voltage to the LM350, an arrangement that can push the efficiency to over 80%. Check out the "Switching Voltage Regulator Basics" series on page 76 for more details.

Low-Power Off-Line Regulator

Q. I built a signaling device which uses four 12V, 1A bulbs and requires a large power transformer. I recently bought some low-voltage 60W halogen lights for my den that run off a very small wall transformer — or so I thought. Curiosity got the best of me, and I just had to open it up. Inside I found a small switching power supply that does everything my bulky transformers do! Can you show me how to build a simple switching power supply for my device? It uses solid-state relays to switch 12VAC.

Paul Frankle WD4LIQ
via Internet

A. Like the question above, what you need is a switching voltage regulator. When working off an AC line, this type of converter is called an off-line regulator, and you'll find one in every desktop PC or workstation. Basically, what it does is convert the 115VAC into DC, run it through a pulse-width modulator driving an isolation transformer, then rectify it into low-voltage, high-current DC. Your situation is unique in that you want low-voltage, high current AC because you're using incandescent lamps and triac-operated solid-state relays. That by itself puts some restrictions on the regulator because the frequency has to be within the switching range of the relay. In other words, the traditional 150 kHz off-line regulator moves too fast for your relays to react. What I'd do rather than switching the low-voltage is to make four 15W switching power supplies and turn them on and off as needed. Here's how it's done.



The circuit is based on a TOP201 switching regulator, a three-terminal device that needs just one external capacitor for flyback operation. The switching frequency is 100 kHz, and the transformer weighs just ounces. Oh, the transformer. Here it is.

Core Type:
Siemens N67
Part # 66208A

1110-T1	Number of turns	Wire size	Comments
Primary	65T	AWG #32	Triple insulated
12V secondary	6T	AWG #26	Bifilar
Bias secondary	6T	AWG #24	Bifilar

For more information on winding off-line switching transformers, access **Power Integration's** website **(http://www.powerint.com)** and download the very informative "Flyback Transformer Design for TOPSwitch Power Supplies" and "TOPSwitch Flyback Transformer Construction Guide" application notes. You can buy the TOPSwitch regulators and transformer cores from **Component Distributors, Inc. (800-777-7334; E-Mail: sanjose@compdist.com)**.

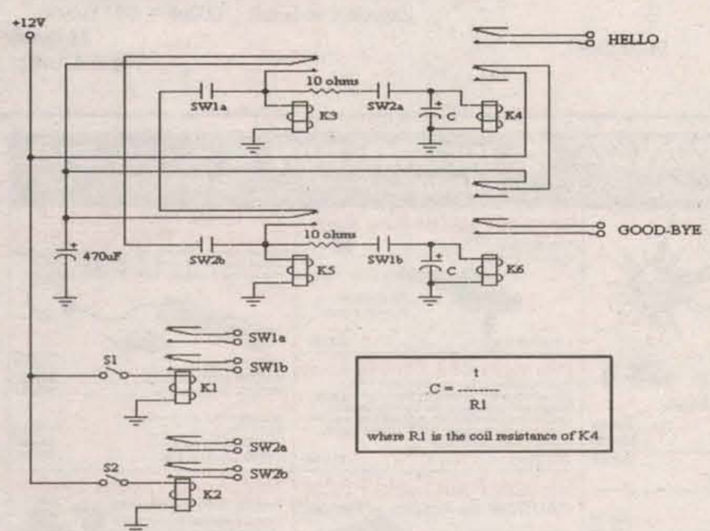
You Say Good-Bye, And I Say Hello

Q. I am disabled and can no longer use my hands for such things as working with tiny parts, circuit boards, etc., but can still work with 14 gauge wires, with cerain limitations. Therefore, I'm looking for an easy-to-connect pre-assembled switching unit to satisfy my needs.

I have a very simple driveway announcer system that sounds a car horn when a vehicle passes over a tape switch and closes the circuit. At present, the horn honks upon entering or exiting. I want a system to play one tape for 10 seconds upon entering and a different tape when exiting — kind of a "Hello" and "Good-bye" message. I want to expand my existing system such that there will be two tape switches (one at the very entrance and one 20' closer in), two audio tape players, and a switching unit, so that when a car pulls IN, the first tape plyer will be activated for about 10 seconds, and when the car pulls OUT, the other tape player would activate for about 10 seconds. Can you help?

Lane D. Honn
Alamosa, CO

A. This design was challenging and quite refreshing because I had to use relays, which you can probably handle, instead of integrated circuit logic. Here's my answer.



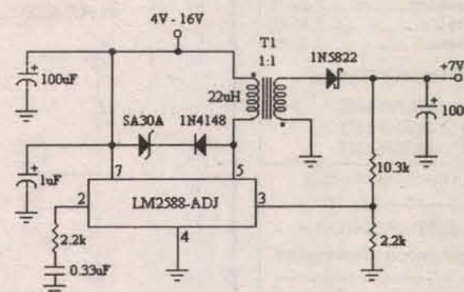
The circuit consists of four relays wired in a set-reset flip-flop configuration. When switch S1 is closed, relay K1 pulls in and closes contacts SW1a and SW1b. This activates K3, which latches so that the relay won't drop out when S1 opens. This applies power to SW2a. When it is tripped, relay K4 pulls in and momentarily closes the contacts to the "HELLO" recording. At the same time, another set of K4 contacts breaks the power to K3, which now releases and resets the circuit for the next car. Relays K5 and K6 are wired identically, with the switches reversed so that SW2b activates the set relay (K5) and SW1b activates the reset relay (K6), which triggers the "GOOD-BYE" recording. To prevent the rear wheels from triggering SW1 again and starting the "HELLO" circuit, a capacitor is placed across K4 and K6. You'll need to measure the time it takes for a car to completely pass over the trip switch, then select the capacitor value using the formula $C = t / R1$, where R1 is the DC resistance of the relay. If it takes one-half second for the car to pass and the resistance of the relay is 150 ohms (RadioShack 275-206), then the value of C is 3300uF. The 10-ohm resistor limits the surge current to the capacitor, which slowly discharges through the relay and temporarily holds it closed. As for the tape player, I recommend the Digital Voice Record and Playback Kit from RadioShack (276-1326). This prewired kit records and plays up to 20 seconds of sound — speech, music, sound effects, etc. — at the touch of a button or, in this case, a relay contact.

Flyback Switching Regulator

Q. I read with great interest your replies to the two DC-to-DC conversion querys in the Feb. '99 column. I would be interested to know what you'd recommend when the input voltage swings from 4 volts to 30 volts, yet the output has to be regulated at 7 volts ±10%. How can I do this with some margin of safety in an automotive environment?

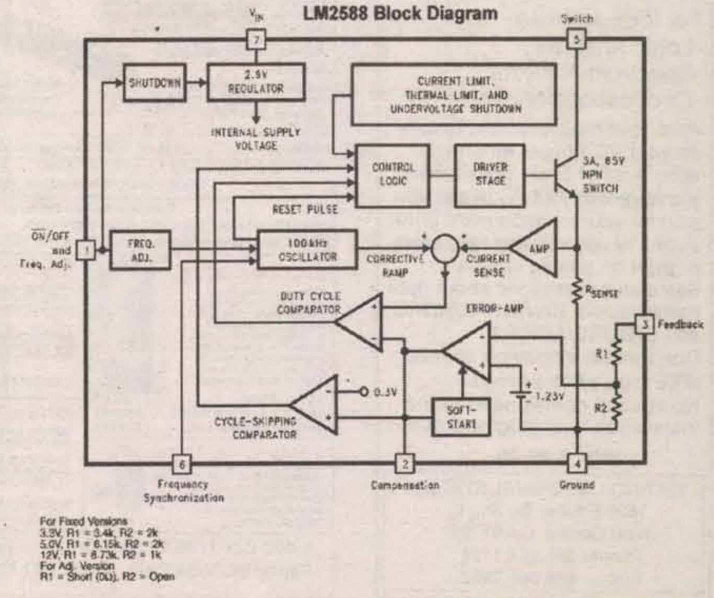
Will Byers
via Internet

A. The answer is a switching voltage regulator configured in the flyback mode. I direct your attention to the companion article "Switching Voltage Regulator Basics — Part 2" on page 76. The flyback transformer does two things: It allows the input voltage to be either above or below the output voltage, plus it isolates the load from the power source — just what you need for an automotive environment. You didn't specify the current requirements, so (given the voltage) I suspect it's about 1 amp, in which case, I'd use the LM258x series of switching regulators from **National Semiconductor (http://www.national.com)**. They are available from **Digi-Key (800-344-4539; http://www.digikey.com)** and **QuestLink (http://www.questlink.com)**, and cost less then $10. For this design, I've selected the LM2588, which has an input range of 4 to 40 volts and can switch up to 5 amps.



I chose this chip because it has a built-in NPN power transistor and requires a minimum number of external components. Also inside the chip is a 100-kHz oscillator that's used to turn the power transistor on and off. When the transistor is on, current flows through the primary winding, which builds up a magnetic field. When the transistor turns off, current flow ceases and the magnetic field collapses and transforms its energy to the secondary winding. The output is then rectified by a Schottky diode and filtered. The output voltage is held constant at 7 volts to within ±4% via the feedback input (pin 3) and external divider resistors.

LM2588 Block Diagram



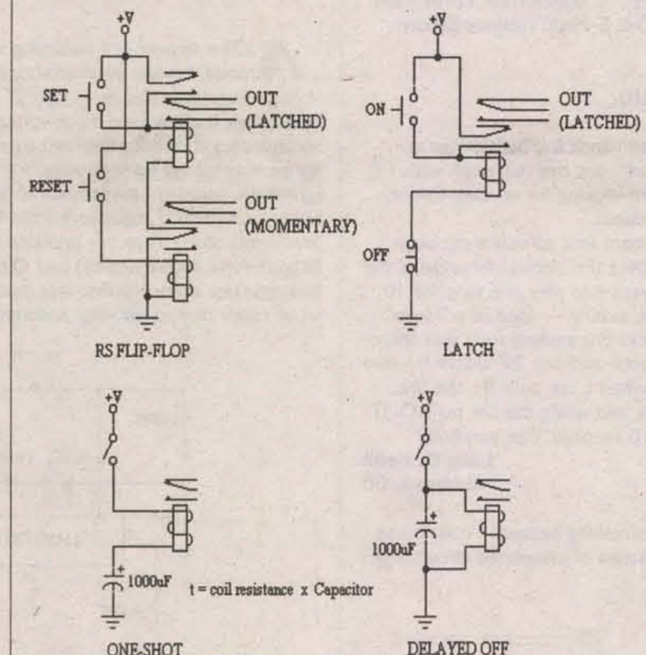
When building this circuit, you must attach the 1uF filter capacitor as close to pin 7 as possible, otherwise you risk damage to the regulator. The flyback transformer has a 1:1 truns ratio with a 22 uH primary, and is available from a number of vendors.

LM2588 Flyback Transformer

Manufacturer	Part Number	Comments
Coilcraft	Q4434-B	
Coilcraft	Q4435-B	Surface mount
Pulse	PE-68411	Surface mount
Renco	RL-5530	
Schott	67141450	

More Relays

Since Mr. Honn's question, I got into a relay mode for a couple days while playing with them again for the first time. I thought I'd pass on some other relay configurations that I've collected over the years that you might find useful.



The first circuit is an RS flip-flop. When the set button is pressed, the top relay pulls in and latches. Pressing the reset button engages the bottom relay, causing the top relay to drop out. The latching circuit next to it is somewhat similar, but only has a single relay and a single output. Pressing the "on" switch engages the relay and latches it; pressing "off" breaks the current flow and disengages the relay. The one-shot relay is identical to a monostable multivibrator or timer IC, like the 555. When the switch is turned on, current flows through the relay coil and capacitor, charging the capacitor. As the capacitor reaches full charge, the current isn't enough to sustain the relay, and the relay drops out. The delayed-off relay does the opposite: It holds the relay on for a short time after the switch is opened. When the switch is opened, the capacitor discharges through the relay coil and holds it closed. When the capacitor is fully discharged, the relay opens. The times for these two circuits are determined by the formula $t = RC$, where R is the resistance of the relay coil in ohms and C is the size of the capacitor in farads (1000uF = .001 farads).

TJ Byers
Q & A Editor

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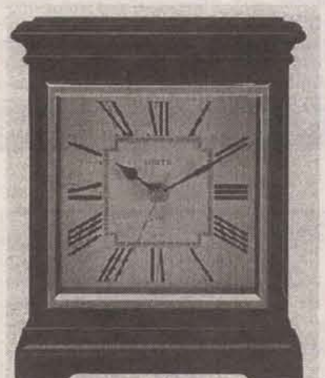

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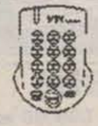

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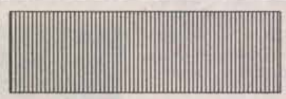

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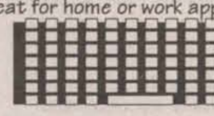

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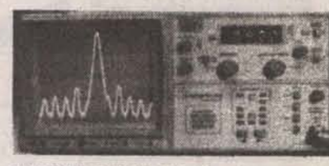

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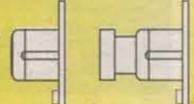

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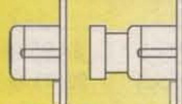

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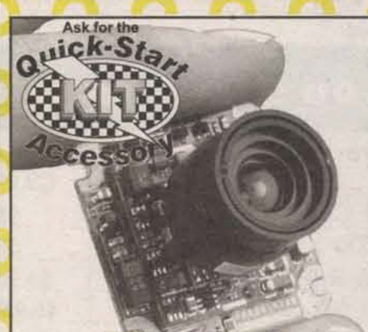

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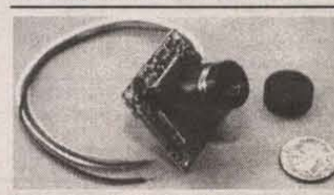

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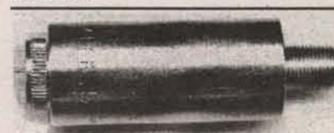

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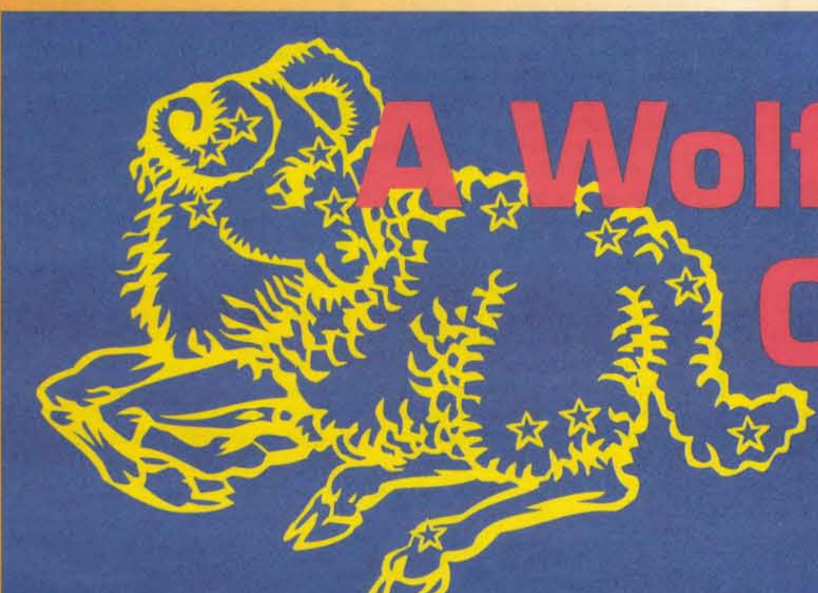


A Wolf in PIC's Clothing?

by Al Williams WD5GNR

If you've experimented with BASIC Stamps, you know how easy they are to use. Just plug them into a 9V battery, a PC cable, and you are off and running. However, as your projects grow, the Stamp can't always keep up. Maybe you need interrupts, or faster processing. You might want to use onboard ADCs or DACs. At this point, most people turn to the PIC microprocessor family from Microchip.

The PIC is certainly not as easy to use as the Stamp. However, it is a lot more powerful. Depending on the type of PIC you get, you'll also gain access to onboard peripherals. Some PICs have onboard EEPROM, UARTs, ADCs, I2C interfaces, and other useful devices. The result is that many Stamp users eventually migrate to PICs — at least for the more taxing projects.

In this article, I'll show you a new microprocessor from a company named Scenix. Their Scenix SX chip is compatible with a PIC, but has even more features. Not to mention that it can run about as fast as a PIC with a 200MHz clock!

Interested? You can get started with the SX for very little money, and you can own the top-of-the-line development system that includes real-time debugging and emulation for just a few hundred dollars. While you examine the chip, you'll also see a PC data acquisition circuit that does analog-to-digital conversion and high-speed serial output all in software.

When Does 50=200?

If you read the SX data sheet, you'll find that the current parts operate at 50MHz. How does this equal to 200MHz? The secret lies in how the PIC handles its internal clock. Suppose you have a 16F84 (a common PIC chip) connected to a 4MHz crystal. True, the clock speed is 4MHz, but the chip only executes most instructions every four cycles, which reduces your true clock speed to 1MHz.

The SX can operate in compatibility mode, where it also uses four clock cycles for most instructions. However, it also has a turbo mode that executes most instructions in one cycle. Combined with a 50MHz clock, this works out to be roughly equivalent to a 200MHz PIC! I say roughly because some instructions take eight real clock cycles on a PIC, but only require three cycles on the SX in turbo mode, so the actual throughput is even higher. Not satisfied with 50MHz? A 100MHz device is on its way and may even be available by the time you read this.

Differences and Similarities

The SX resembles a PIC16C5x processor. The instruction set is a superset of the 16C5x. If you are used to using the 16F84 processor, you will see there are a few slight differences since the 16F84 uses a slightly different core than the 16C5x. The SX has several new instructions, and all of the old 16C5x instructions. The chips are pin-compatible (in both 18- and 28-pin variants). Besides that, the SX has 136 bytes of RAM and 2K of program storage — more than most of the 16C5x family.

Unlike a 16C5x, however, the SX has EEPROM memory — no UV eraser required. There are new instructions that let you take advantage of new features, a larger hardware stack, and enhanced I/O capabilities. Interrupts are significantly easier to handle, too.

The SX automatically saves and restores its own context. If this isn't enough, you can also enable an internal RC oscillator that runs up to 4MHz with no external components. Remember, in turbo mode, that's like a 16MHz PIC.

The Virtual Peripheral Concept

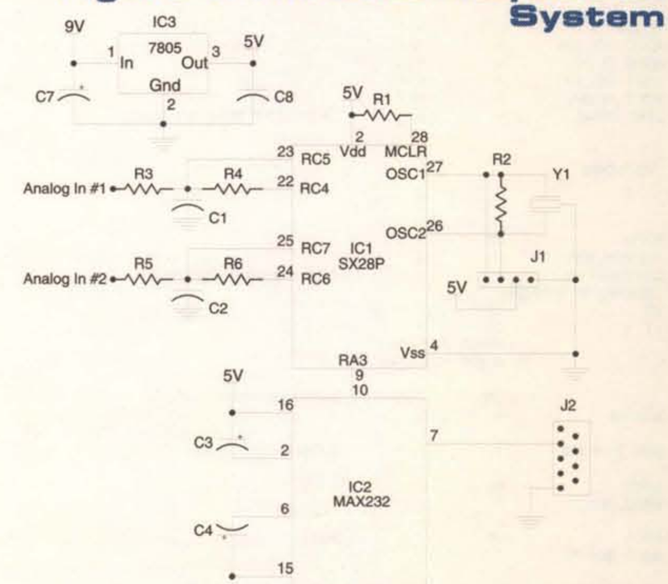
The key to Scenix's game plan is virtual peripherals (VPs). What this means is that the SX doesn't have fancy onboard I/O — no UARTs, no SPI interface, no ADCs. Instead, Scenix concentrates on making the processor ultra-fast. The only unusual I/O device on the chip is an analog comparator.

Does this mean you can't use all these I/O capabilities? Not at all. Scenix supplies software modules that implement popular I/O devices in software (VPs). Present VPs include UARTs, ADCs, touch-tone generation and recognition, PWM output, and more.

Is this better? That depends on your point of view. Software routines mean a bit more work for you as a developer. They also take away processing time from your application. However, the flexibility is enormous. If you don't like the way a piece of hardware works, you can't easily change it. You certainly can't swap out, for example, a UART for an ADC. Changing a VP is as easy as altering the code.

As for speed concerns, the SX is fast enough to do quite a few things at once. If you were planning on using, for example, a 20MHz PIC,

Figure 1. The Data Acquisition System



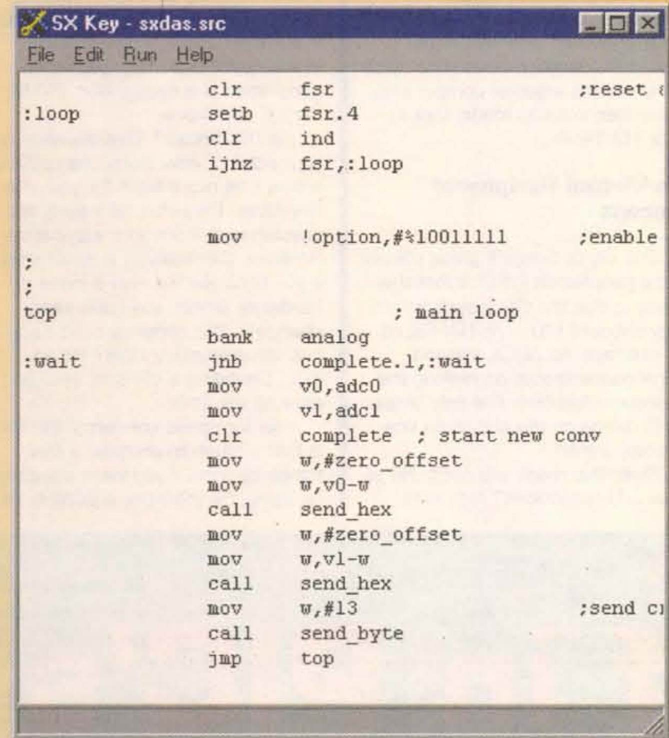


Figure 2. The SX-Key Editor

the SX (in turbo mode) is 10 times faster so, in theory, it should be able to handle your program, plus do nine more tasks of the same complexity.

Development Tools

One thing that makes the PIC a popular choice is that there are many cheap programmers for the PIC. In fact, you can find plans on many web sites to build your own programmer for a few dollars. Although there aren't as many free and cheap programmers for the SX yet, they do exist (see the resource box accompanying this article). I built the fluffy programmer (which uses a PIC to program the SX) in about a half-hour from parts I had around the lab.

The official development tool is from Parallax (the company that makes BASIC Stamps). They sell several versions of the SX Key and also an inexpensive SX Blitz. The Blitz is very serviceable as a programmer, but the Key is what you really want.

The SX Key plugs into your PC serial port and programs the SX chip in circuit. It also can generate clock pulses to run the system in real time. Better still, it can debug the software in the chip at full speed. You can start and stop the target system, examine registers, and even set breakpoints. This is full-speed hardware emulation.

Of course, you can get this type of emulation for the PIC, too. It requires special bondout chips and hardware that costs between $600.00 and $1,500.00. The basic SX Key hardware is around $240.00. The full-blown top-of-the-line system is around $335.00. The only catch is that you must let the Key supply your clock, you must have the watchdog timer off, and you have to have around 138 free program instructions in the device.

Getting Started

Just to try things out, I decided to build a simple data acquisition system with the Scenix SX. I wanted the board to read voltages on four different pins and send the results to a PC at 19.2K baud. To simplify the PC software, I wanted to avoid sending binary data. The output for each channel is two hex digits representing about 20mV per count. Each packet ends with a carriage return. This allows the PC to synchronize with the system. Since each packet is five bytes long, the system should be able to send 380 conversions-per-second which is quite fast for many purposes.

Some versions of the SX Key also contain an SX Demo board. This board has an RS232 level translator, and four pins that are suitable for analog input (remember, the analog-to-digital will all happen in software). I decided to make my circuit compatible with the board so it'd be easy to build the circuit, or just use the board as-is.

You'll find the complete code in Listing 1. If you are familiar with Microchip's assembler, you may find the syntax confusing. The SX-Key uses an assembler that resembles 8051 assembly. However, the basic machine code is identical (except, of course, for the SX's unique instructions). It is possible to use the Microchip assembler. However, you'll want to use the Key's debugging capabilities, so you might as

Listing 1. The Data Acquisition System

```
;
; Device
;
        device  pins28,pages1,banks8,oschs
        device  turbo,stackx,optionx
        id      'DAS2'
        reset   reset_entry
;
;
; Equates
;
tx_pin          =       ra.3
adc0_out_pin    =       rc.4
adc0_in_pin     =       rc.5
adc1_out_pin    =       rc.6
adc1_in_pin     =       rc.7
zero_offset     =       8       ; subtracted from raw counts
;
;
; Variables
;
                org     8

temp            ds      1
number_low      ds      1
complete ds     1               ; bit 0 = 1 when complete
; holding for voltages
v0              ds      1
v1              ds      1
                watch v0,8,uhex
                watch v1,8,uhex

                org     10h     ;bank0 variables
analog          =       $

port_buff ds    1               ;buffer - used by all

adc0            ds      1       ;adc0
adc0_acc ds     1

adc1            ds      1       ;adc1
adc1_acc ds     1

adc_count       ds      1       ; count for both ADCs

                org     30h     ;bank1 variables

serial          =       $

tx_high         ds      1       ;tx
tx_low          ds      1
tx_count  ds    1
tx_divide ds    1


                org     0
;
;
; Interrupt routine - virtual peripherals
;
interrupt
                bank    analog

; shifting the input bits aligns them with the output bits
                mov     w,>>rc                  ; read capacitor voltage
                not     w                       ; invert
                and     w,#%01010000            ; write to output
                mov     port_buff,w             ; store it
                mov     rc,w                    ; and update pins

                sb      port_buff.4             ;adc0
                incsz   adc0_acc                ;if it was was high, inc acc
                inc     adc0_acc
                dec     adc0_acc                ; inc/inc/dec prevents roll
                sb      port_buff.6             ;adc1
                incsz   adc1_acc                ;if it was high, inc acc
                inc     adc1_acc
                dec     adc1_acc
                inc     adc_count               ;done (8 bits)?
                jnz     adc_out
; Done so store results
                mov     adc0,adc0_acc
                mov     adc1,adc1_acc
                setb    complete.1              ;set complete flag
; clear for next pass
                clr     adc0_acc
                clr     adc1_acc
adc_out
; Begin UART VP
                bank    serial

                clrb    tx_divide.4             ;serial transmit
                inc     tx_divide               ;only execute every 16th time
                mov     w,tx_divide
                and     w,#$10
                sz
                test    tx_count                ;busy?
                clc                             ;ready stop bit
                sz                              ;if busy, shift bits
                rr      tx_high
```

well get used to using the Key's assembler.

The UART VP

The Scenix web site shows several UART VPs. Actually, one of these VPs implements eight 19.2K UARTs! That's a bit of overkill for this application. There is another VP, however, that you can configure to operate between 2400 and 230.4K baud.

Nearly all VPs operate as an interrupt routine (usually from a timer interrupt). That means you'll often need to tweak them to work together. There are several things you must consider when integrating VPs with your program:

- How often must an interrupt occur for this VP to work?
- Does this VP require a constant time between interrupts?
- Does this VP use any resources already in use?

A UART, for example, requires a certain interrupt period to operate correctly. The typical VP interrupt handler does what it needs to do and then adds a negative number to the real-time clock counter. This forces the next interrupt to occur exactly when the interrupt routine wishes, even if the interrupt routine doesn't always take the same amount of time to execute. Of course, for this to work, the longest path through the interrupt handler must take less time than the interrupt period.

Consider this example: Suppose your real-time clock increments every 20nS (as it will if you have a 50MHz turbo clock with no prescale). If you do nothing, you'll get an interrupt every 5.12uS (256 counts). But what if you want an interrupt every microsecond? That should be easy — all you need to do is to preload the counter with -50. Then when the clock generates 50 counts (1uS), the counter will go to 0 and the interrupt will trip again.

There are two ways you could

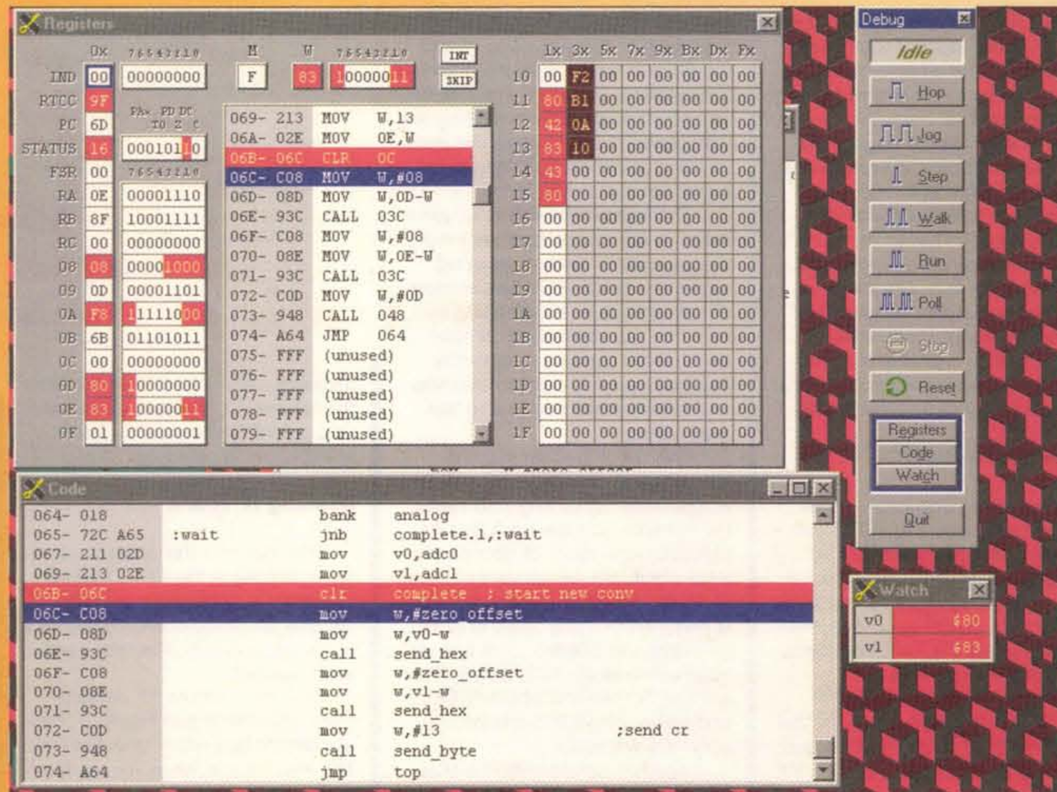


Figure 3. Debugging the System

```
                sz
                rr      tx_low
                sz                                  ;if busy, dec counter
                dec     tx_count
                movb    tx_pin,/tx_low.6            ;output next bit

                mov     w,#-163                     ;interrupt every 163 clocks
                retiw

;
; Data
;
; required to output HEX numbers
_hex            dw      '0123456789ABCDEF'
;
;***************
;* Subroutines *
;
; Send hex byte (2 digits)
;
send_hex
                mov     number_low,w                ; save W
                mov     w,<>number_low              ;send first digit
                call    :digit

                mov     w,number_low                ;send second digit

:digit  and     w,#$F                               ;read hex chr
                mov     temp,w
                mov     w,#_hex
                clc
                add     w,temp
                mov     m,#0
                iread                               ; read from program mem!
                mov     m,#$F

; fall into send byte
;
;***************
;
;
; Send byte via serial port
;
send_byte       bank    serial

:wait           test    tx_count                    ;wait for not busy
                jnz     :wait

                not     w                   ;ready bits
                mov     tx_high,w
                setb    tx_low.7

                mov     tx_count,#10        ;1 start + 8 data + 1 stop bit

                ret

;********
;* Main *
;********
;
;
; Reset entry
;
reset_entry     mov     ra,#%1000                   ;init ra
                mov     !ra,#%0111
                clr     rc                          ;init rc
                mov     !rc,#%10101010
                mov     m,#$D                       ;set cmos input levels
                mov     !rc,#0
                mov     m,#$F

                clr     fsr                         ;reset all ram banks
:loop           setb    fsr.4
                clr     ind
                ijnz    fsr,:loop

                mov     !option,#%10011111          ;enable rtcc inter-
rupt
;
;
top                                                 ; main loop
                bank    analog
:wait           jnb     complete.1,:wait            ; wait for data ready
                mov     v0,adc0                     ; capture it
                mov     v1,adc1
                clr     complete                    ; start new conv
                mov     w,#zero_offset              ; sub zero offset
                mov     w,v0-w
                call    send_hex                    ; write out
                mov     w,#zero_offset
                mov     w,v1-w
                call    send_hex
                mov     w,#13                       ;send cr
                call    send_byte
                jmp     top
```

do this. One is to load -50 into the counter at the start of your interrupt routine. The other is to use a special instruction to return from the interrupt. This instruction — RETIW — adds the W register to the real-time clock and performs a return from interrupt.

So if you loaded W with -50 and executed RETIW, you'll return and the counter will be poised to interrupt again in a microsecond. Because the number is added to the current counter contents, it doesn't matter how long the interrupt code takes to process (as long as it is less than a microsecond).

A Software ADC?

It is easy to understand how you can implement a UART in software. But how can you make an analog-to-digital converter? The trick relies on some clever software and the SX's CMOS input threshold (you can select TTL or CMOS input thresholds in software).

When you select the CMOS input threshold on an input pin, that pin will respond to a 2.5V or higher level as a logic 1. Notice in Figure 1 that each analog input connects through a resistor to a capacitor. The capacitor also connects to an SX input and, through another resistor, to an SX output.

The ADC virtual peripheral sets up a periodic timer interrupt. On each interrupt, the VP reads the logic level at the capacitor, inverts the bit, and writes it to the output. If the output is 0, the VP increments an accumulator. After repeating this 255 times, the VP stores the accumulator, which will be proportional to the voltage on the input.

The effect of all this is to generate a PWM voltage that will keep the capacitor's voltage hovering above and below 2.5V. The amount of time the SX is not pumping current into the capacitor is proportional to the amount of time the input is supplying current, and this must also be proportional to the input voltage.

This method is simple and allows you to calculate as many bits as you want. By cycling 256 times, for example, you can perform an eight-bit conversion. Of course, the least-significant bit will vary because of noise and other factors, but this is common in many types of ADCs.

With the 50MHz clock and an interrupt time of -163, the ADC can work with signals at about 600Hz and below. Above this frequency, accuracy will suffer.

Another consideration is that the input impedance of the ADC is relatively low (10K with the components used here). That means you must either account for the 10K resistor, or you'll need to use an op-amp to isolate the input. The op amp's high input impedance will minimize loading on the circuit while the low output impedance will prevent the ADC's resistance from affecting measurements much.

Making it Work

You can find the entire system schematically in Figure 1. This configuration is compatible with the Parallax SX demo board so you can use it instead of building the hardware yourself.

You can see the SX development environment in Figure 2. This is a simple text editor with few frills. The real treat is when you want to troubleshoot your program. You can run the SX program directly from the development environment. The software programs the SX through a four-pin connector that connects to the SX clock pins. After programming, the SX hardware generates a clock at your choice of frequencies.

In addition to running the program directly, you can also initiate a debugging session (see Figure 3). From here you can set a breakpoint, and examine or change registers. You can also single step code line-by-line.

Other Ideas

Although Scenix has a plethora of VPs available on their web site, there is nothing to stop you from writing your own. Scenix even has a program where independent companies can sell their own VPs.

Having a 50 or 100 MIPs microprocessor opens up a lot of new territory for designers. DSP-style software becomes possible at these speeds, and the SX is much less expensive than the typical DSP chip.

Of course, you can simply use the SX as a replacement for the PIC, and that's good, too. However, extra computing power is like extra cash; you can always find something to do with it! **NV**

Resources

Scenix — www.scenix.com (makers of the SX chip)

Parallax — www.parallaxinc.com (makers of the SX-Key system)

AWC — www.al-williams.com/awce.htm (macros that allow Microchip-like instructions with the SX key)

Scenix Net Resources — http://www.svtehs.com/scenix.htm (Alexy Vladimirov's page of links to Scenix material including free programmer designs)

SXPoint — http://www.sxpoint.com another page of links)

Parts List

C1, C2 - .1uF 25V capacitor
C3, C4, C5, C6 - 1uF 25V electrolytic capacitor
C7 - 100uF 25V electrolytic capacitor
C8 - .01uF 50V ceramic capacitor
IC1 - 28 pin Scenix SX (Could use 18 pin with minor software changes)
IC2 - Maxim MAX232
IC3 - 7805 or 78L05
J1 - 4 pin header (for SX Key programmer)
J2 - DB9 connector
R1, R3, R4, R5, R6 - 10K 1/4W resistor
R2 - 33K 1/4W resistor
Y1 - 50MHz ceramic resonator with capacitors (Murata CST50.00MX040)

OUT OF SIGHT HIGH-FREQUENCY ANTENNAS

by Gordon West

In a few more months, the Federal Communications Commission will take action on their proposed Docket 98-143 to restructure the amateur radio service and allow worldwide high-frequency General class privileges at a slower Morse Code test speed.

PHOTO A. 6' STEPLADDER.

The General class code test will probably be 5 wpm, and any Technician-Plus ham operator may be instantly grandfathered to the new worldwide high-frequency General class band privileges. Technician no-code operators would simply learn the code at 5 wpm and, they too, would fall into those new worldwide General class privileges.

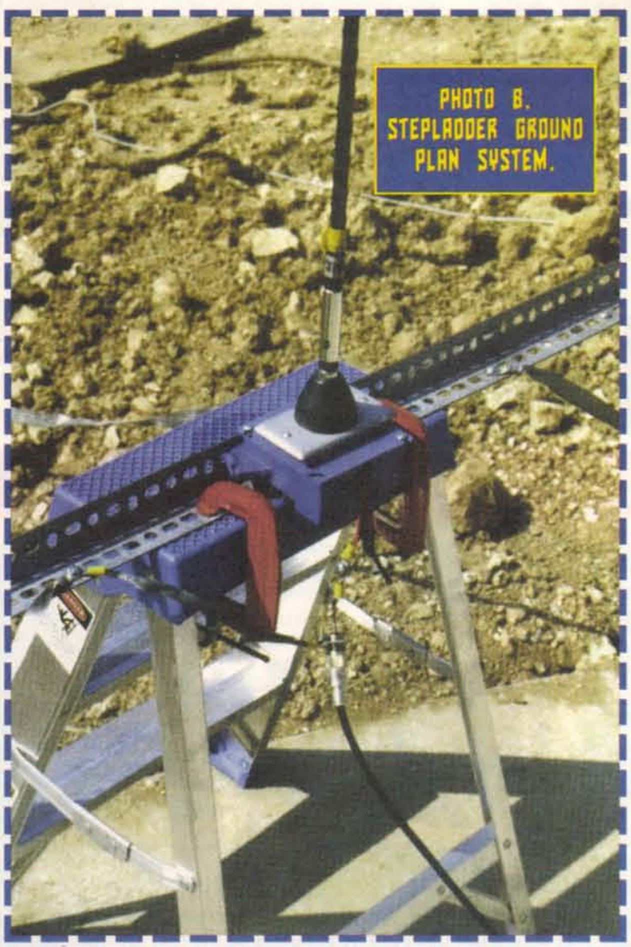


PHOTO B. STEPLADDER GROUND PLAN SYSTEM.

Or maybe there might be one additional General class theory test involved — Element 3B. This is a relatively easy multiple-choice test to pass, so everyone in the industry is anticipating a major influx of Technician class operators to worldwide high-frequency band privileges.

High-frequency equipment manufacturers like Yaesu with their new FT100, ICOM with their new IC-706G, Kenwood with their 50, and Alinco with their 70 are ready with equipment for immediate dealer sales. In fact, most manufacturers agree that high-frequency radio sales are up to Technician class operators anticipating their new General class privileges.

THOSE ANTENNAS

Getting onto the high-frequency bands requires big antennas. The simple dipole is easy to construct and, for 10 meters, the end-to-end length is 16 feet. But for 40 meters, the unloaded dipole is now 64 feet tip-to-tip, and you can double that for the popular nighttime 75-meter band.

The simple dipole is an inexpensive way to get onto all worldwide General class bands with a terrific signal, but they do require a sizeable amount of open space for big attic runs and, because of their length, they put RF everywhere in the household.

The long dipole will also pick up household noises, too. This would include the FAX machine, "smart" telephone systems, the computer, electronic thermostat, florescent lights, and a variety of other household appliances that may now incorporate a micro-computer chip on the inside. There is no easy way to minimize this noise pick-up, other than to isolate your antenna away from the attic area.

WORKS BEST

If you live in a house and there are no city restrictions on big ham antennas, go ahead and put up a compact three- or four-element beam. This could give you 10 through


SGC tuner and model 303 whip antenna for a completely automatic tune-up.

40 meters, and your 75- and 160-meter dipole would give you the two additional lower bands. The big beams from leading manufacturers are not difficult to construct, just as long as you follow the assembly instructions. We recently put together a Cushcraft A4 with the 40-meter add-on dipole kit, and we had everything up in the air and playing by late afternoon with an 8:00 a.m. morning start. Three of us were working on the project, so if you do it by yourself, it's going to take you a couple of days to get the big beam operational on high frequency.


PHOTO C.

MAGNIFICENT MOBILE ANTENNAS

Amateur radio operators love to experiment with mobile high-frequency antennas operated in the attic or their backyard. Mobile antennas are traditionally helical or center-loaded to minimize their length; and when configured end-to-end as a dipole, they work well for single-band operation. You can also take that mobile whip, counterpoise it off of a metal ladder, tripod, or iron railing, and achieve fantastic transmission and reception, especially if you are near water or in an area with good ground conductivity.

Amateur radio operator Don Wilson N9ZGE (2908 Dartmoor Court, Springfield, IL 62704-6469), has achieved fabulous results from mobile antennas in his backyard; some of the photos appeared in this publication about a year ago. We received so many letters about "How well did it work?" I thought we would take some of his best experiments and review the potential results.

LADDER ELEVATED DIPOLE (PHOTO A)

"Here's how I use a six-foot stepladder to mount a variety of mobile antennas, fed end to end as a dipole, in a temporary backyard set-up. Note that the ladder is chained down to a screw anchor," comments Wilson. Since the ladder is used just for support, a wooden ladder would work fine, and this arrangement will lead to good single-band operation on 10, 12, 15, and 20 meters. For 40 and 75 meters, I would think that the dipole would need to be raised a lot higher.

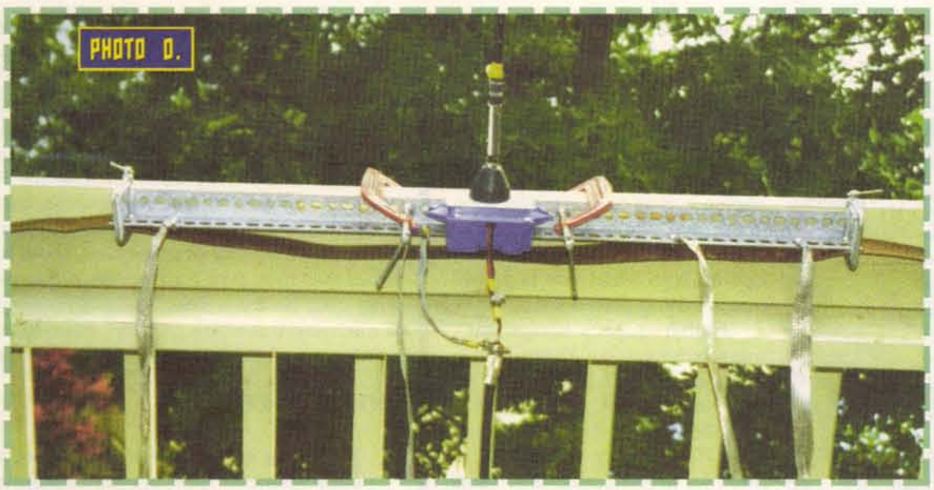


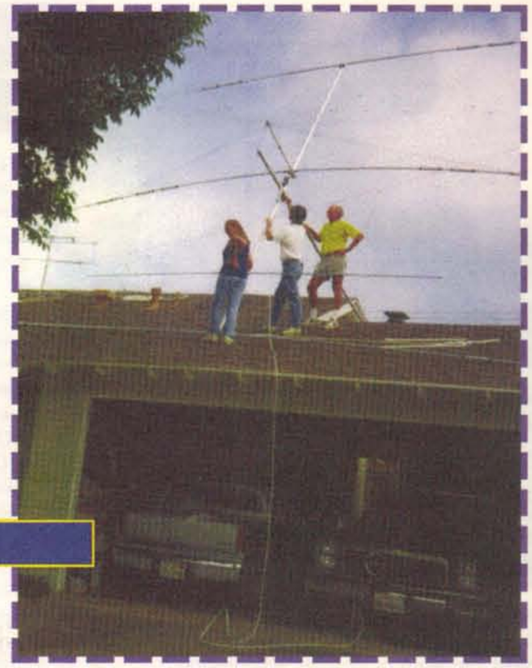
PHOTO D.

VERTICAL WITH GROUND COUNTERPOISE (PHOTO B)

Here is a classic stealth antenna set-up that will drive a shortened HF quarterwave whip into a perfect 50-ohm match against one-quarter wavelength, or greater, counterpoise. Here we see an aluminum ladder with two quarter wavelength metal ribbons for each band of desired operation. The natural downslope of the aluminum ladder helps improve that 50-ohm match. The whip could also be mounted on a metal bar across a picnic table (Photo C) or even on a railing (Photo D) with terrific results.

"I use the RADIO WORKS line isolator to keep RF from coming back into the shack on the outside of the coax shield," comments Don Wilson. "In the stepladder set-up, I use a Kenwood TS50S, a Kenwood AT50 tuner, and an 80-meter ham stick that I retune for different bands," adds Wilson. Although automatic antenna tuners, as well as manual antenna tuners, can do wonders for fooling a radio

Author West and friends putting up the Cushcraft A4 beam.



into full output, I always recommend using the right whip for the specific band of operation.

Alpha Delta Communications (Manchester, KY; 606-598-2029) produces an excellent metal tripod specifically for mounting their Outbacker antenna where the tripod acts as the active ground plane counterpoise. The tripod can quickly be deployed, and Don Wilson indicates it is a good solid performer.

FOLD-DOWN

Alpha Delta Communications also has a unique fold-down antenna system specifically designed for permanent installation of an all-band, high-frequency vertical.

It will raise and lower a vertical, up to 29 feet and 25 pounds in weight, and includes a hydraulic dampener to prevent the antenna from coming down too fast. But keep in mind that this is a permanent installation, and you won't be able to easily move it from one home to another without digging another big hole! (See Photo D.)

AUTO-TUNED WHIP

SGC produces an automatic antenna tuner that covers 160 meters through six meters, and allows their Model 303 whip to be automatically tuned from a ground-mounted counterpoised installation. Don Wilson sends along several photos showing how this set-up works in his backyard, and

Alpha Delta fold-down antenna system.

The ladder elevated HF loop system.

the beauty of the SGC installation is instant band changes without needing to go out and re-adjust the whip or change resonators.

"My home base station consists of a Kenwood TS870S, Henry 2K classic amplifier, MFJ 960 tuner feeding a MPD-2-105 dipole from W9INN Antennas, with ladder line," comments Wilson.

"As you might guess, we have antenna restrictions in our subdivision, but with all of these great antennas in my backyard, no antennas are visible," adds Wilson.

Wilson has also experimented with high-frequency loop antennas, and these he mounts on that fiberglass stepladder, and concedes that the higher up the loop is off the ground, the better it performs.

"The W9INN multi-band dipoles are another good way to go for a stealth antenna, maybe placed in an attic," comments Bill Alber WA6CAX. Bill recommends that all radio experimenters send a couple of bucks for postage to W9INN, P.O. Box 393, Mount Prospect, IL 60056 (708-394-3414) for his many informative sheets on multi-band dipoles. Bill also indicates that www.radioworks.com/nbgnd.html#counterpoise is another great source of information from Radio Works, Inc. I have ordered a lot of products from Radio Works, and they really know their antenna business from the importance of a ground on up.

Some of the most popular whips are those you see at the hamfest that are helical center-loaded, with a stainless steel stinger. Valor, Ham Sticks, and Hustler traditional white center-loaded mobile antennas are popular choices among backyard experimenters. I like the Outbacker from Alpha Delta because all bands are on a single whip, and you simply re-adjust the fly-lead for a specific band of operation.

More good hints for portable mobile-whip operation in the backyard is to keep dipoles as high off the ground as possible, and as far away from the side of your dwelling as possible.

For single whips off of a ground counterpoise, dry soil usually won't do the trick — you must have metal, or quarter wavelength wire strips. If you have aluminum or wrought iron railings, your ground plane is all set, and you can angle your mobile antenna off of the ground plane almost any way you want.

The bigger the antenna, the better the performance. The Alpha Delta Australian Outreach puts in about an S-unit better signal to a distant station than its smaller brother, the Alpha Delta Outbacker. And when you compare all of these expensive mobile antennas to a simple dipole you can make yourself with just #16 stranded wire, the dipole will usually do the best job of them all.

So have fun in the backyard, always wear protective glasses when working around antennas, and caution everyone to stay well away from the antenna when you are transmitting.

Think safety, and have fun on the high-frequency bands. **NV**

Continued from page 46

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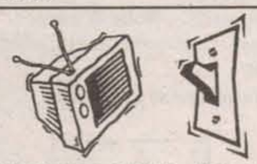

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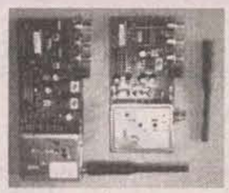

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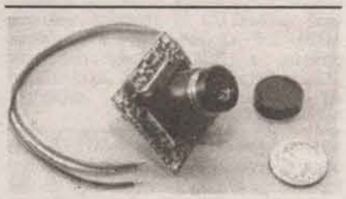

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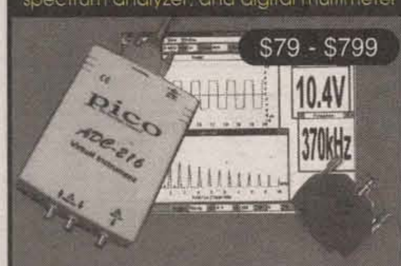

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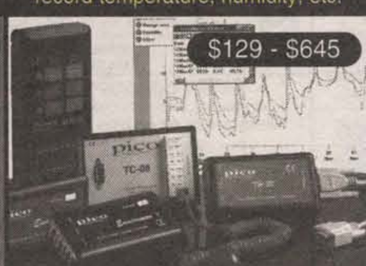

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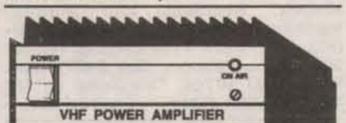

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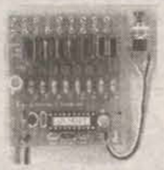

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No drift, microprocessor synthesized! Excellent audio quality, connect to CD player, tape deck or mike mixer and you're on-the-air. Strapable for high or low power! Runs on 12 VDC or 120 VAC. Kit includes case, whip antenna, 120 VAC power adapter - easy one evening assembly.

FM-25, Synthesized FM Stereo Transmitter Kit.....$129.95

Lower cost alternative to our high performance transmitters. Great value, tunable over FM band, plenty of power and manual goes into great detail about antennas, range and FCC rules. Handy kit for sending music thru house and yard, ideal for school projects too - you'll be amazed at the exceptional audio quality! Runs on 9V battery or power from 5 to 15 VDC. Add our matching case and whip antenna set for a nice 'pro' look.

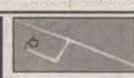
FM-10A, Tunable FM Stereo Transmitter Kit........$34.95
CFM, Matching Case and Antenna Set............$14.95
FMAC, 12 Volt DC Wall Plug Adapter..............$9.95

RF Power Booster

Add muscle to your signal, boost power up to 1 watt over a freq range of 100 KHz to over 1000 MHz! Use as a lab amp for signal generators, plus many foreign users employ the LPA-1 to boost the power of their FM transmitters, providing radio service through an entire town. Runs on 12 VDC. For a neat finished look, add the nice matching case set.

LPA-1, Power Booster Amplifier Kit...............$39.95
CLPA, Matching Case Set for LPA-1 Kit...........$14.95
LPA-1WT, Fully Wired LPA-1 with Case...........$99.95

FM Station Broadcast Antenna



For maximum performance, a good antenna is needed. Properly tuned and matched antenna is fully PVC enclosed for weather protection and rugged use. Vertical or horizontal mounting, 'F' style connector, 5' long.

TM-100, Tru-Match FM Station Antenna Kit..........$39.95

AM Radio Transmitter

Operates in standard AM broadcast band, set to clear channel in your area. AM-25 'pro' version is synthesized for stable, no-drift frequency and is setable for high power output where regulations allow, typical range of 1-2 miles. Entry-level AM-1 has tunable transmit oscillator, runs FCC maximum 100 mw power, expected range 1/4 mile. Both accept line-level inputs from tape decks, CD players or mike mixers, run on 12 volts DC. Pro AM-25 includes AC power adapter, matching case and bottom loaded wire antenna. Entry-level AM-1 has an available matching case and knob set for a finished, professional look. High level modulation for low distortion.

AM-25, Professional AM Transmitter Kit..........$129.95
AM-1, Entry level AM Radio Transmitter Kit.......$29.95
CAM, Matching Case Set for AM-1................$14.95

RAMSEY

Binocular Special

Wow, did we nab a deal on these first rate binoculars! Absolutely identical to a famous big name brand here in Rochester, NY - but without 'their' name. Well made with fully coated optics, super nice rubber armored housing over hi-alloy aluminum, includes lens cleaner cloth, neck lanyard and carry case. 4 styles: roof prism 10x25 (10 power, 25 mm), 10x25 high performance roof prism ruby coated objective lens model for demanding use in bright sun, 10x25 high-end BAK-4 lens porro prism ruby coat with Tac-Grip housing, and Ultra-View 10x50 porro prism ruby coats. First quality, yet at a close-out price on the exact same units as the 'Trademarked' units - but at half price!

BNO-M, 8x21 Mini Monocular......................$14.95
BNO-1, 10x25 Roof Prism Binoculars..............$24.95
BNO-1EX, 10x25 Ruby Coated Porro Prism.........$29.95
BNO-2, 10x25 TacGrip Ruby Coat Porro Prism......$59.95
BNO-6, 10x50 Ultra-View Ruby Coat Porro Prism...$69.95

World's Smallest FM Radios

Everyone who sees one of these babies says they just gotta have one! Super cute tiny FM radios have automatic scan/search tuning, comfortable ear bud earphones and we even include the battery. The pager style unit looks like a shrunken pager and even has an LCD clock built-in. You will be amazed at the crystal clear amazing sound! That's a quarter in the picture for size comparison - pretty tiny, huh?

MFMT-1, World's Smallest FM Radio..............$11.95
PFMR-1, Pager Style LCD Clock & FM Radio.......$12.95

Speech Descrambler

Decode all that gibberish! This is the popular descrambler / scrambler that you've read about in all the Scanner and Electronic magazines. Speech inversion technology is used, which is compatible with most cordless phones and many police department systems, hook it up to your scanner speaker terminals and you're in business. Easily configured for any use: mike, line level and speaker output/inputs are provided. Also communicate in total privacy over telephone or radio, full duplex operation - scramble and unscramble at the same time. Easy to build, all complex circuitry contained in new custom ASIC chip for clear, clean audio. Runs on 9 to 15VDC. Our matching case set adds a professional look to your kit.

SS-70A, Speech Descrambler/Scrambler Kit.......$39.95
CSS, Custom Matching Case and Knob Set.........$14.95
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HARD-TO-find parts; big screen tubes $135; 13", 19", 25" $25; electronic tuners $20; RF modulators $5; modules, knobs, flybacks. Call 912-272-6561. Scarborough TV, 1422 Old River Rd., East Dublin, GA 31027.

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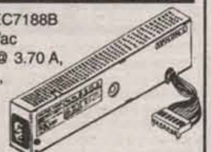
MINI-RIGHT ANGLE GEARHEAD MOTOR WITH CIRCUIT CONTROL

Omron # R2DG-41
Built-in control circuits allow this motor to be used in a continuous or a pulsed mode. In continuous mode the final drive gear turns at 22-45 RPM (3-6 Vdc). In the pulsed mode the final drive gear turns one revolution each time the controller is momentarily pulsed. The motor assembly is 1.75" x 1.25" x 0.5" overall. The nylon final gear is 0.62 diameter and has a little nipple slightly off-center to which a small push-rod could be attached. Motors are in good condition, removed from equipment. Hook-up instructions included.

CAT# DCM-110 $7.50 each

10 for $60.00

ENCLOSED SWITCHING POWER SUPPLY



Voltek Corp # SPEC7188B
Input: 100 - 240 Vac
Outputs: + 5 Vdc @ 3.70 A, +12 Vdc @ 0.60 A, -5 Vdc @ 0.05 A, +5 Vdc Trickle @ 0.1 A. Metal encased switching supply. Standard three-prong IEC socket power input. 7 conductor, Molex-type connector output. 9" x 2.1" x 1.36". UL recognized. Removed from new equipment.

CAT # PS-27 $3.50 each

3000 MCD ULTRA-BRIGHT RED LED

Everlight # 383URC-2/TR1-C(R)
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CAT# LED-50

2 for $1.00

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1000 for $250.00

30 Minute Timer Board

Timer circuit board will operate 120 or 240 Vac devices. Originally designed to run a vibrating motor in a massage chair, the circuit automatically shuts-off a motor, lamp or other device after approximately 30 minutes. Shut-off time can be varied by replacing one of the resistors on the board with a pot or resistor of different value. Hook-up instructions included with the board explain how to make this modification.
1.9" x 2.5". **CAT# TMR-5** $3.50 each

45 Amp Solid State Relay

Crouzet/Gordos # G240D45
Control Voltage: 3-32 Vdc
Load: 45 Amps, 24-280 Vac
Back-to-back (dual) SCR output for severe induction loads. False turn-on immunity and positive turn-off at high dv/dt. Standard "hockey-puck" 2.25" X 1.75" X 0.90". UL/CSA

CAT# SSRLY-45 $19.50 each

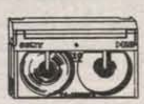
Surface Mount Momentary Pushbutton Switch

Panasonic # EQV PHV03T
S.P.S.T., normally open, surface mount pushbutton. 0.25" square x 0.13" high. Leads on 0.15" centers.

CAT # PB-85 3 for $1.00

100 for $25.00 • 2000 per reel $200.00

"HI-8" Video Cassette



SONY Hi-8 Top quality, metal particle 120 minute video cassettes. *Used for a short time, then bulk-erased.* Each cassette has its own plastic storage box.

CAT # VCU-8 $3.00 each

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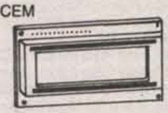
20 Character X 4 Line LCD



Optrex # DMC 20434-CEM
(PWB 20434-CEM)
5 x 8 dot format.
3" x 1" viewing area.
3.88" x 2.38" module.
Removed from new equipment. May have felt padding on metal bezel. 14 pin single row header is pre-attached. Spec/hook-up sheet included.

CAT# LCD-46 $7.00 each

10 for $60.00

Microphone For Fish

Consists of a dart-shaped underwater transducer on a 21' wire and a small amplifier. According to the manufacturer, it enables you to hear the fish striking your bait, thus allowing you to catch more fish. We don't have the instructions, and you will need some headphones with a 3.5 mm phone plug. Also requires 4 AAA batteries (not included). Transducer is 3.3" long. Amplifier assembly is 3.5" x 2.4" x 1".

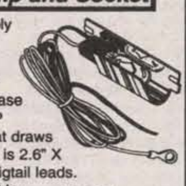
CAT # AQS-1 $5.00 each

NEODYMIUM MAGNET

0.25" DIAM.0.25" LONG
Small cylindrical magnet with metallic coating. **CAT # MAG-45**

2 for 80¢ • 10 for $ 3.50 • 100 for $ 25.00

12 Volt Lamp and Socket



A great lamp assembly for display or special effects lighting. Consists of a removable 12 volt wedge base bulb # 921, 12C21CP wedge base lamp that draws 1.2 Amps. Assembly is 2.6" X 0.95" X 0.75". 19"" pigtail leads. Large quantity available.

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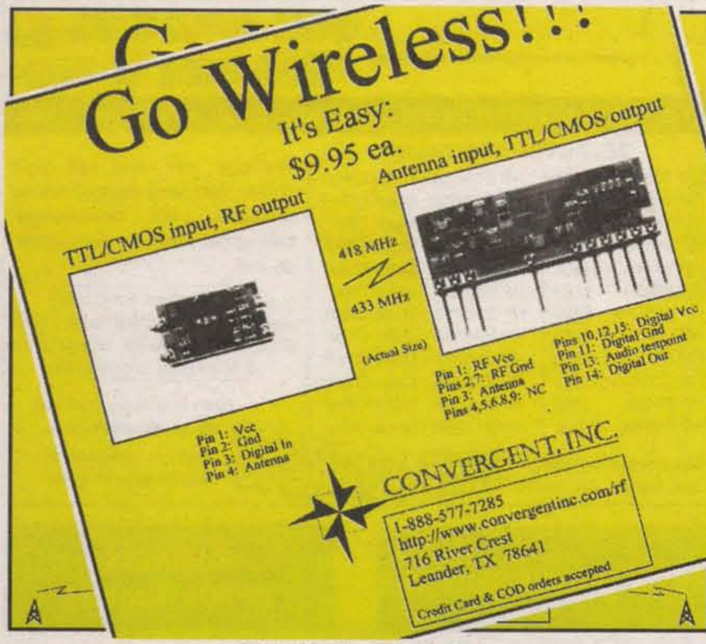

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7 individual output pins are controlled with buttons 1-7 on your touch-tone phone. Automatically answers telephone and waits for commands. Monitor room noises with built in mic. "Dial-Out" pin instructs unit to pick up phone and dial user entered number(s). Password protected. **$49**

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475, 200MHz Oscilloscope	$650
475A, 250MHz Oscilloscope	$800
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7L12, Spectrum Analyzer, 100KHz-1.8GHz	$1500

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MISCELLANEOUS

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Datron 1062, 6.5 Digit Autocal Multimeter, DC/AC/Ohms	$900
EIP 545A, Microwave Frequency Counter	$800
EIP 548A, Frequency Counter, 10Hz-26.5GHz	$2000
EIP 548B, Frequency Counter, 10Hz-26.5GHz	$3250
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LeCroy 9424, 350MHz Oscilloscope	$3500
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Polarad 1105E-FT, Signal Generator, 0.8-2.4GHz	$400
Sorensen DCS40-25, DC Power Supply, 40V/25A	$750
Trans. Devices DLR400 15 3500A, Dynamic Load	$1500
Trans. Devices DLP 50-60-1000A, Electronic Load	$800
Trans. Devices DLVP 130-110-1000 Electronic Load	$950
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Closing Date For Next Issue — June 5th

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Events CALENDAR

Continued from page 19

MI - TAWAS - Hamfest. Iosco County AR Enthusiasts, John Hanley KA8AIP, 517-756-2845. E-Mail: ka8aip@centuryinter.net Web: http://www.oscoda.net/icare/

MO - SPRINGFIELD - Hamfest. Southwest Missouri ARC, Karen Thorpe N0TDW, 417-889-6775. E-Mail: n0tdw@juno.com

NY - PLATTSBURGH - Hamfest. Champlain Valley ARC, Bernard Jakobetz KC2ALG, 518-643-9657

NY - WEEDSPORT - Hamfest. Auburn ARA, Joe Kahler WA2NGX, 315-364-5135. E-Mail: htx@usa.net

OH - COLUMBUS - Hamfest. Voice of Aladdin ARC, Jim Morton KB8KPJ, 614-846-7790

PA - MATAMORAS - Hamfest. Tri-State ARA, Dave W2DRH, 914-856-2529; Ray WY2D, 914-856-1733; Rich K3BBC, 570-559-7401

AUGUST 7-8

WA - SPOKANE - ARRL Eastern WA Section Convention. University High School, 10212 E. 9th Ave. Sat: 9am-5pm, Sun: 8am-12pm. VE Exams. Neil Gallup N7LVO, 509-928-7442. E-Mail: n7lvo@cet.com Betsy Ashleman N7WRQ, 509-448-5821. E-Mail: n7wrq@aol.com Web: http://www.iea.com/~n7utg

AUGUST 8

IA - AMANA - Hamfest. Cedar Valley ARC, Wayne Kolosik KI0FE, 319-393-4224. E-Mail: ki0fe@usa.net

IL - PEOTONE - Hamfesters Hamfest. Will County Fairgrounds. Tom Davis KB9NUQ, 708-210-9548; David Brașel NF9N, 708-448-0580. E-Mail: nf9n@aol.com or tdavis@internetplus.net

OH - LISBON - Hamfest. Triangle ARC, Mike Mays KB8JNM, 330-386-6021. E-Mail: mike.mays@usa.net Web: http://www.qsl.net/tarc

OH - MARTINS FERRY - Hamfest. Triple States RAC, Ralph McDonough K8AN, 740-546-3930. E-Mail: k8an@aol.com Web: http://www.qsl.net/tsrac

AUGUST 14

CA - FONTANA - Inland Empire ARC Amateur Radio & Electronics Swapmeet. A B Miller High School. Bill 909-822-4138 eves

NY - WESTMORELAND - Hamfest. Rome RC, Jack Roux KB2TXR, 315-336-1391

OH - NELSONVILLE - Hamfest. Sunday Creek AR Federation, Russell Ellis N8MWK, 740-767-2226. E-Mail: scarf@hocking.edu

WV - HUNTINGTON - Hamfest. Tri-State ARA, Dwight Smith WB8JPJ, 304-522-7865 eves; 304-523-6675 days. E-Mail: wb8jpj@arrl.net E-Mail: tara.amateur.radio@juno.com

AUGUST 15

CO - GOLDEN - ARRL Colorado State Convention. Denver Radio Club, Bob Lindell N0YIX, 303-422-0610. E-Mail: Bob Lindell@compuserve.com

KY - LEXINGTON - Hamfest. National Guard Armory. 8am-4pm. VE Exams. Talk-in: 146.760-. John Barnes KS4GL, 606-253-1178. E-Mail: KS4GL@juno.com Web: http://www.qsl.net/k4kjq/

MA - CAMBRIDGE - Flea at MIT. Albany and Main Sts. 9am-2pm. Talk-in: 146.52 & 449.725/444.725 W1XM/R PL 114.8 (2A). Nick Altenbernd KA1MQX, 617-253-3776 (9-5). Web: http://web.mit.edu/w1mx/www/swapfest.html

MI - JACKSON - Hamfest. Cascades ARS, Dennis Byrne KC8IJZ, 517-522-4058. E-Mail: byrneda@voyager.net Web: http://www.qsl.net/cars-jxn/

NJ - BAYVILLE - Hamfest. Jersey Shore ARS, Bob Murdock WX2NJ, 732-269-6379. E-Mail: JARSFEST@aol.com. Web: http://members.aol.com/jarsfest/jarsfest.html

NY - DEPEW - Hamfest. Lancaster ARC, Luke Calianno N2GDU, 716-634-4667. E-Mail: lcalianno@freewwweb.com. Web: http://hamgatel.sunyerie.edu/~larc/GreaterBuffalo Hamfest.ht

PA - YORK - Swapfest and Auction. York VO Tech School, Pauline Dr. (1 blk S of I-83 Exit 6, Rt 74S). 7am. Talk-in: 146.865. Swap Fest, John Salony (Ph) 717-741-1780; Greg Towson (fax) 717-741-0874. Gene Warner (E-Mail) ad3e@arrl.net

Questions & Answers
TECH FORUM

This is a READER TO READER Column. All questions AND answers will be provided by *Nuts & Volts readers* and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and *NO GUARANTEES WHATSOEVER* are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

QUESTIONS

Send all material to **Nuts & Volts Magazine**, 430 Princeland Court, Corona, CA 91719, OR fax to (909) 371-3052, OR E-Mail to **forum@nutsvolts.com**

Editor's Note - Please check our web site at www.nutsvolts.com for more questions that were not printed due to lack of space.

I have three motion security lights on the outside of the house. When I try to use my ham transmitter in the late evening, it puts all the lights on.

Any ideas to keep them from coming on?

6991 **via Internet**

I have a "big dish" satellite system which uses a feed horn polarization motor that rotates the antenna for proper polarization. The motor has three leads. Black for ground, red for +5 volts, and white for pulses which cause the motor to rotate.

I do not understand how the pulses can rotate the motor in both directions, and also how the receiver determines just what the angle is. When the receiver sets the polarization for maximum signal, it causes the motor to rotate in one direction, and then in the reverse direction, and then back to where the signal is maximum.

The angle of rotation is shown on the TV display in the range from -90° to +90°.

I would like to be able to bench test the motor. It would help to know how the receiver determines the angle of rotation, since there doesn't seem to be any feedback from the motor shaft location to the receiver.

6992 **Robert Fankhauser**
Yelm, WA

Recently, I subscribed to your magazine and admit to being a beginner with a strong interest in electronics. I committed to creating a buzzer and contestant identification light set-up for my high school debate club to use during competitions. I need help with the circuit design for this purpose. The requirements are:

1. A single buzzer to sound for two seconds when the first contestant to press their button wants to answer the question. The first press should prevent any other contestant from tripping the buzzer.

2. A light should turn on in front of the contestant that was able to turn on the buzzer and stay lit for the time that contestant is answering the question.

3. There needs to be a total of eight press/release buttons with lights arranged for two teams of four.

4. Some way to reset the system for the next round of questioning is important.

5. If you can specify RadioShack parts that would be great.

6993 **Lloyd Harris**
via Internet

When replacing the 6JS6C final tubes in the Model 101FT, Yaseu says they should be replaced with matched pairs. Does anyone know how to use unmatched pairs? Years ago, Yaseu came out with a modification to do this, but I am unable to obtain the information.

6994 **Philip Petrus**
White Plains, NY

I need a computer program that enables me to make a polar map (a great circle map) with any QTH being the center.

6995 **J. P. Dawson**
Edmond, OK

I need an inexpensive device to register the frequency of a PTO driven generator, so I can adjust the engine speed for 60N. It should read from 50 CPM to 65 CPM.

6996 **John W. Coble, Jr.**
Jacksonville, AR

ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed.
- In most cases, only one answer per question will be printed.
- Your name, city, state, and E-Mail address, (if submitted by E-Mail), will be printed in the magazine, unless you notify us otherwise with your submission.
- Due to space limitations, we can not reprint the original questions with the answer. The question number and the issue it appeared in are printed above the answer.
- Unanswered questions from a past issue may still be responded to.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO

TO BE CONSIDERED FOR PUBLICATION

All questions should relate to one or more of the following:

1) Circuit Design 3) Problem Solving
2) Electronic Theory 4) Other Similar Topics

INFORMATION/RESTRICTIONS

- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions may be subject to editing.

HELPFUL HINTS

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address and Phone Number. Only your name will be published with the question, but we may need to contact you.

ANSWERS

ANSWER TO #49917 - APR. 1999

I hope to construct a series of 61 selective band-pass filters to be used with outputs of music synthesizers.

The only practical way to do this is with a DSP (Digital Signal Processor). It won't take much horsepower, so even the least expensive of the evaluation boards from Analog Devices or TI would do.

You will have to program the DSP, however, even if you need to learn how to do this it will take less time than designing, fabricating, and tuning 61 filters. Also, unlike the bank of analog filters, the DSP won't drift over time and you can change the bandwidth and center frequency or even the number of filters by simply changing the software.

Finally, the DSP should be cheaper than all of the parts needed for that filter bank. It will certainly take less space.

The essence of tone detection is the FFT (Fast Fourier Transform). Your input is a voltage whose amplitude varies over time. The DSP will digitize that signal, then compute its FFT. The result of that computation is a histogram or plot of amplitude vs. frequency.

Since the computation is done on a digitized signal, the computation results in amplitudes at discrete frequencies or bins. By proper selection of program parameters, these bins can be made to correspond to the center frequencies and bandwidths of the filters you desire. Now all you need to do is check each bin for an output greater than a certain threshold to know if that particular frequency component was present.

Digital signal processing can get extremely complicated, however, Analog Devices and probably some others publish basic textbooks with program code that make DSP easy even for a relative beginner.

An evaluation board can be had for less than $100.00, and a complete set-up with documentation and software for less than $200.

This is comparable to many microprocessor development systems and is less than the cost of the parts for 61 analog filters. If you're motivated and are at all familiar with rudiments of computer programming, then DSP should not be an impossible hurdle.

Dave Sarraf
via Internet

ANSWER TO #4995 - APR. 1999

Needs visual phone ring indicator for office cubicle.

Here is what I would try for a remote telephone ring indicator: Purchase a microphone (RadioShack #33-3019), amplifier (277-1008), an output phone plug (274-287), an LED (276-086), and a current limiting resistor (271-1315).

Connect the resistor in series with the LED to the phone plug, with enough wire to reach the top of the cubicle. Plug the phone plug into the earphone jack of the amplifier and adjust the volume to light the LED when the phone rings.

You will want an AC adapter (273-1455) rather than using batteries. If the LED is not bright enough, parallel two resistors. To get 360° visibility, point the LED straight up and put a spherical reflector above it.

Russell Kincaid
Milford, NH

ANSWER TO #4994 - APR. 1999

I would like to read Caller ID information from my modem with Visual Basic 4.0 or 5.0.

I have used my Caller ID compatible modem for that purpose. I have a U.S. Robotics 56K winmodem. You use the Caller ID command "AT#CID=" <argument>. The arguments are either 0, 1, or 2. Zero disables CID, "1" returns formatted CID info, and "2" returns the unformatted CID info.

You send this command to the modem and then monitor the serial port where the modem is installed.

After the first ring, the modem will return the Caller ID info as if it were coming from the serial port, all Basic has to do is read the com port input.

You can get an explanation of this command at http://ae.pcd.usr.com/techref/commands/voice/CID.htm

Van Dubansky
Terryville, CT

ANSWER TO #49911 - APR. 1999

The military has been using a "cigarette pack size" electronic device to remove sulfation from car batteries. I am looking for the circuit.

This sounds a good deal like a battery charge controller/pulser.

For items such as these (with applications both in the car collecting field and the home power field — photovoltaic cells charging batteries to run your house), I recommend reading: **Home Power** (ISSN:1050-2416), P.O. Box 520, Ashland, OR 97520. **http://www.homepower.com**

Also full of ads, and great articles. They too may have run an article in the past with a schematic. I can't find my master reference at the moment. However, one ad that comes immediately to mind is: **Abraham Solar Equipment**, 124 Creekside Pl., Pagosa Springs, CO 81147; **1-800-222-7242**, **970-731-4675**.

They advertise a "PowerPulse" battery maintenance system, the pictures in the ad show before and after the use of their device, with the sulfates that covered the plates in photo one, and gone in photo two. Sounds like just the device he is looking for.

Continued on page 82

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AMATEUR ROBOTICS NOTEBOOK

by Robert Nansel

In April, I attended the Sixth Annual Fire Fighting Home Robot Contest at Trinity College in Hartford, CT. This was my third year at what has become the premiere Amateur Robotics event in this country – three days of hanging with fellow gearheads, attending topnotch seminars, and watching seriously cool robots do their thing. It draws from all over the US and Canada, and places like Thailand, Switzerland, and Israel.

The contest involves an autonomous robot finding and extinguishing a lit candle in a model house in the shortest possible time. All this must be done without the robot touching any walls, getting lost, or knocking the candle over. The model house is an eight-foot-square maze with four "rooms."

The contestants know the floor plan ahead of time, so maze-solving is not needed, but efficient navigation is. All walls are 13 inches high and are painted flat white, while the floor is painted flat black. Each room in the floor plan is equally likely to be selected as the room where the candle will be placed.

As for the robots, the only restrictions are: 1) Robots must operate autonomously (though tethers to stationary computers are allowed); 2) Robots must never exceed 12.25" in any dimension during operation; 3) Robots must operate in a safe manner as determined by the judges; 4) Robots are not allowed to peer over the tops of the walls. There are no weight or materials limits, and no limits on the kinds of sensors that can be employed.

Kids Are Welcome

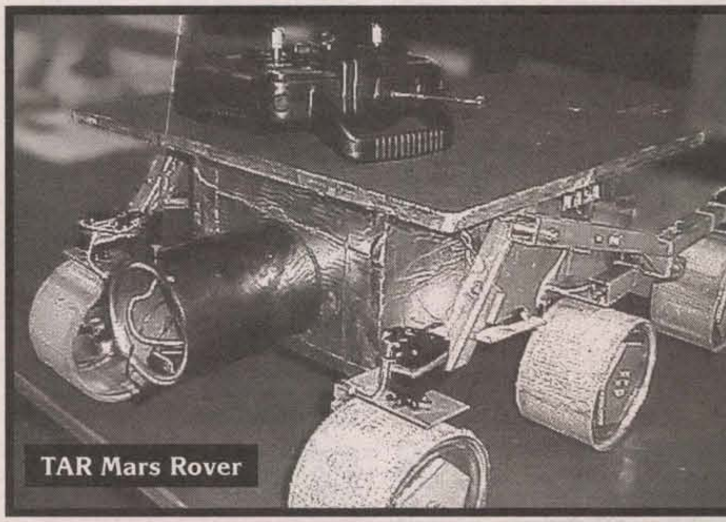
A key part in this contest has always been that there are separate Junior and Senior classes, with equal cash prizes awarded to both: \$1,000.00 for 1st place, \$500.00 for 2nd, \$250.00 for 3rd, \$125.00 for 4th, \$75.00 for 5th, and \$50.00 for 6th. The Junior class is open to all kids up through high schoolers, and even fifth graders have entered competitive robots. The Senior division is for everyone else, from college students to retirees.

A great thing about this contest is the number of robots entered – a number that grows each year.

This year, 73 robots were entered, up from 60 in '98. In the Senior division, there were 41 robots this year, up from 36 robots in '98. Moreover, there were 32 Junior division robots, up a full third from last year's 24 robots.

To achieve a more accurate and just ranking system, the contest organizers have tinkered with the rules over the years. This year, they made a few changes – such as running three mazes at once to make the contest run faster – but they also altered the scoring formula. The scores are still based on the adjusted times for the best two out of three runs, but some score adjustment factors are different this year, so I can't directly compare last year's scores with this year's.

However, at this year's contest, I did get the impression that the caliber of robots competing was higher. Not only were there more robots, they were faster and more reliable in both divisions. The 1st place Junior robot was still slower than the sixth place Senior robot – but not by as much as last year. After pouring over the scores of the last two years, some interesting patterns emerged.



TAR Mars Rover

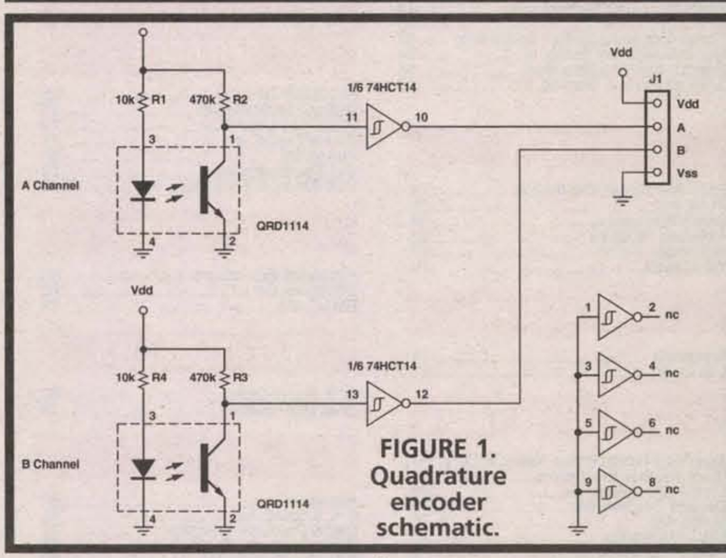


FIGURE 1. Quadrature encoder schematic.

Junior Robots Rock

The time ratio between 1st and 6th place has narrowed in both divisions. In '98, the Senior 1st place entry was 3.1 times faster than the Senior 6th place. This year, the ratio was 3.0, a small change, but clearly there's still room for improvement in the top. In the Junior division, the ratio was 7.8:1 in '98, but this year it had plummeted to 1.9, meaning the Juniors have proportionally improved much more than the Seniors.

Junior robots are also doing much better relative to the Seniors this year. Last year, the Senior division champ, "Phoenix," was six times faster than the Junior divisions 1st place "Loser's Revenge." This year, the Senior 1st place, "Alexi," was only 4.4 times faster than the Junior 1st place, "Fluffy."

I added up and compared the scores for the top six Senior and Junior division robots for 1998 and 1999. In '98, this aggregate time ratio was 8.9, meaning that the Senior division times were about nine times faster than the Junior; this year, the ratio had dropped to 3.5. Are the kids closing the gap? You bet they are, and in a big way.

Experience Counts

One thing that jumped out was how important experience was in both divisions. Three of the top six teams had placed in the top six in their divisions in '98. In the Senior division, "Tornado '98" – the product of a team from the Swiss Federal Institute of Technology – placed 2nd both years, while "L.C." by Gary Teachout of the Seattle Robotics Society climbed from 6th last year to 3rd this year. The Trinity College team – always tough competitors – placed 5th this year instead of first as they did last year.

The Junior division had a similar story, but with a twist. In both '98 and '99, three of the top six robots came from one school: Grand River Collegiate in Kichener, Ontario. The Kichener crowd has shown up at Trinity year after year and their work is paying off. Both years, they've taken 2nd and 4th. Last year, they took five out of the top nine places. This year, they fielded six teams and took four of the top 10 places. I might speculate about the beginning of a dynasty here, but many of them will no doubt soon graduate from high school and compete at the Senior level.

TAR Rover, Come Over

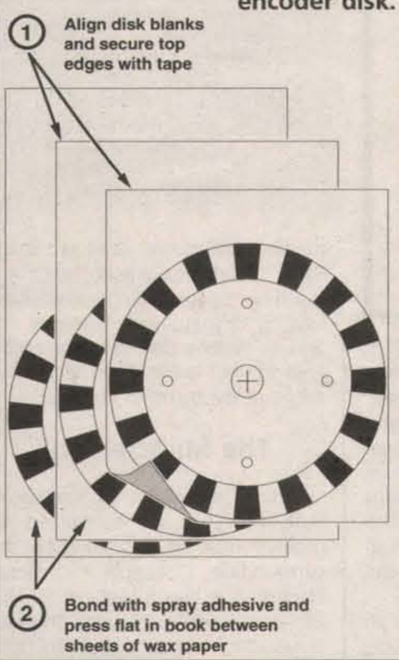
Some of the coolest machines were there only for show. Check out the photo of the TAR Mars Rover, for instance. This is a full-size mockup of Mars Sojourner built by Ken Boone of the Triangle Area Robotics club in Raleigh, NC. The TAR Rover features six-wheel drive and independent four-wheel steering, just like the real thing.

Although it's a radio-controlled machine, it does use a couple microprocessors onboard to translate the radio control signals into separate pulse commands for each of the 10 hobby servos used. Ken has been crafting robots for 35 years and it shows. Be sure to check out his website at http://users.aol.com/kensrobots/kensrobots.html.

Another big crowd pleaser was "Stampy," a bipedal robot built by Mark Whitney from Cary, NC. Stampy walked with a slow, deliberate gait into the maze, found the candle, and put it out, not once but several times. Mark got a special award for this achievement even though Stampy wasn't there to compete. Stampy is not a fast walker and so can't go head-to-head with the other bots. Some folks complained about a lack of innovation in this year's event, but Stampy is ample proof 'taint so.

Then, too, there was Gary Teachout's other robot, T-Cubed, the Table Top Terror. T-Cubed is a 2" by 3" Bot Board with a couple motors and sensors strapped on. It skittered across the table avoiding obstacles and edges. T-Cubed only fell off the table once the whole time of the competition, and only minor damage was done (one of the bumper whiskers got bent).

FIGURE 2. Making the encoder disk.



Back to Breadbot

Change gears. Last month, I got started on a long-promised project – upgrading Breadbot with shaft encoders for its drive wheels to provide speed and odometry information. I talked a bit about the theory of optical shaft encoders and showed how to make low-cost encoder wheels of various resolutions that work with either Breadbot or the Parallax GrowBot. This month, I'll continue with the project and show how to build the electronics to go along with those encoder disks.

But first, I need to correct an embarrassing error I made last month.

Egg on My Encoder

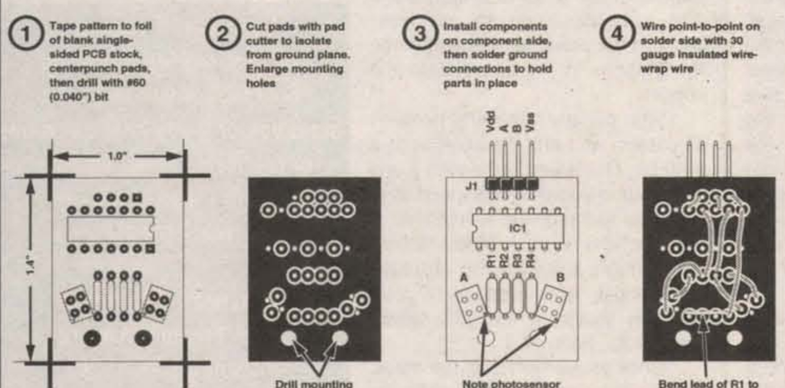
The 32-segment encoder disk shown in Figure 2 last month will not give you 128 counts per revolution with quadrature decoding as I stated; the correct number is 64 counts per revolution. That encoder disk has 16 black and 16 white segments, which give an equal number of positive and negative transitions – 32 altogether. Combine this with 32 transitions from a second sensor channel in quadrature, and you get 64 transitions per disk revolution. Not 128.

This error also throws off the maximum frequency the encoder disk will produce when used with a servo. The example servo I used – the Futaba S148 – is rated to slew 60 degrees in 0.22 seconds (0.76 rev/sec). With a 32-segment encoder wheel, the individual sensor channels would produce a maximum raw squarewave frequency of just over 12 Hz; though, in continuous rotation, most Futabas I've tried run closer to 14 Hz. The frequency of transitions is double the squarewave frequency, or about 24 Hz. With a quadrature channel thrown in, a 32-segment wheel then gives an output frequency of double that, or about 48-49 Hz – not 97 as I said. Sorry for the confusion. Really, I can count, folks. Honest.

Encode This

Warm up your soldering irons. Figure 1 shows the schematic for a simple circuit that does quadrature decoding for last month's encoder disks. The QRD1114 is an inexpensive, compact reflective IR emitter/sensor pair. It's available from Mouser Electronics and Digi-Key, so you shouldn't have any trouble finding it. IC1 is just a plain old 74HCT14 hex Schmitt Trigger. An 'HC14 might work, too, but I haven't tried it. You may have to experiment with the resistor val-

FIGURE 3. Encoder board fabrication.



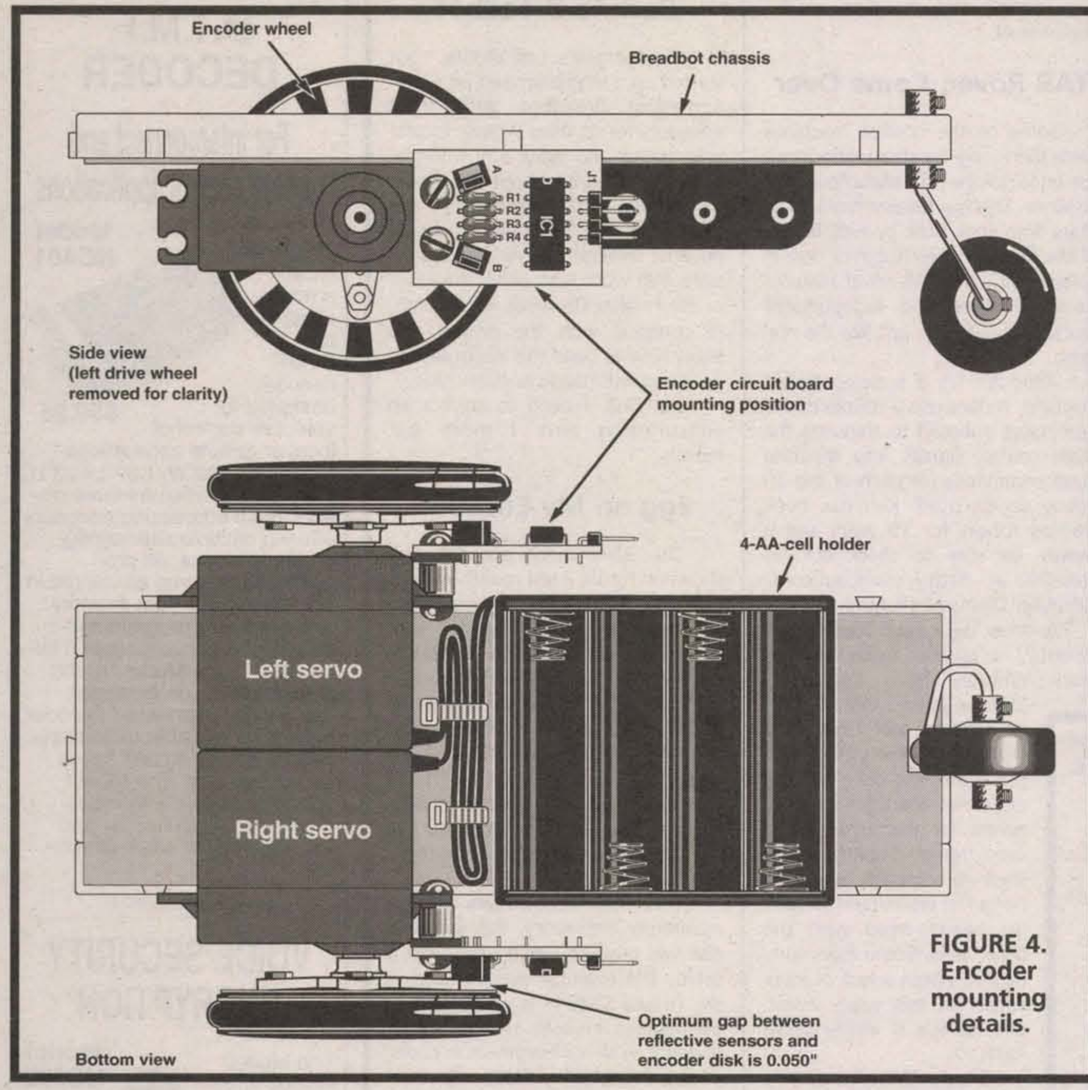


FIGURE 4. Encoder mounting details.

ues anyway, depending on the paper and toner used to reproduce the disks.

Mobile Robotics by Jones & Flynn suggests using blank disks of paper behind your encoder pattern to ensure that enough IR is reflected from the white segments back to your sensor. With my disks, though, I ran into the opposite problem: too much IR reflected from the black segments.

I tried increasing the values of R1 and R4 in order to cut the intensity of the IR emitters, but then the signal was too weak. Increasing the size of R2 and R3 increased the sensitivity of the sensors, but now the circuit became squirrely and far too sensitive to ambient light conditions – a fatal flaw in an unenclosed encoder.

I was finally forced to resort to the technique of gluing together a stack of identical copies of the encoder pattern (see Figure 2). If I make the IR emitters strong enough to drown out ambient room lighting, the toner from my laser printer isn't dense enough to prevent some of that IR from reflecting from the paper behind the first disk. Stacking black on black and white on white solved the problem. I used 3M Super 77 spray adhesive.

A Prototype for All Seasons

Figure 3 shows a circuit board with sensor geometry intended for use with the 32-segment encoder disk. I intend to make a reasonably-priced printed circuit board available for this decoder circuit if there is enough interest but, for prototype purposes, it was easier to use the hybrid point-to-point technique shown.

Normally, I prototype with perfboard but, in this case, I needed to control the precise angular separation and orientation of the sensors. For a 32-segment encoder disk, the sensors must have an angular separation of 39.4 degrees. Also, the sensors must be oriented so that the encoder segments cut across the optical axis of the sensors at right angles. I could have drilled special holes in perfboard for the sensors, but getting the extra holes drilled to the accuracy required would have been quite tricky.

Instead, I used bare copper-clad stock so I could drill holes with any spacing and pattern I wished and a paper pattern to show me where the holes should go. I drew the pattern with a CAD program and printed it out on my laser printer – one pattern for each board I wanted to make. You can do the same thing, or you can photocopy the pattern in Figure 3. If you do photocopies, be sure your copies match the dimensions shown in Step 1 of the figure. The Step 1 pattern gives the locations of the hole locations as seen from the copper side of the circuit board.

Securely tape the patterns to an oversized piece of copper-clad stock, then use a prick punch to precisely locate and lightly punch the location of each hole. When you are done punching, use a metal straight edge and a hobby knife to cut right through the paper pattern and scribe the outlines of the board onto the copper.

Strip off any remaining portions of pattern and drill the holes with a # 60 bit. This is best done with a drill press but, if you use high-speed steel bits, you can manage it freehand if you are very careful. With carbide bits, though, a drill press is absolutely essential, and even then you'll probably shatter a few bits before you get the hang of it.

Once you've drilled all the holes, enlarge the two mounting holes by step drilling with one or two intermediate drillbit sizes until you reach 9/64", the clearance hole size for # 6 machine screws. Cut each board roughly to shape with a Dremel drill and an abrasive disk using the scribe lines as your guide. Sand or file the edges of the board to final size.

The Miracle Tool

Next, the nodes of the circuit that aren't to be connected to ground must be isolated from the surrounding copper. Vector Electronics makes a tool just for this job – the P138A pad cutter. This tool is available for about $20.00 US from Digi-Key, Mouser, and others, and no robot builder should be without one.

With this hand tool, you make

Fire Fighting Home Robot Contest
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As always, if you have suggestions for improving Breadbot, if you've built a Breadbot, or if you have questions or comments about amateur robotics topics, you can reach me at:

Robert Nansel
69 S. Fremont Ave. #2
Pittsburgh, PA 15202
E-Mail: bnansel@nauticom.net

your own isolated circuit board pads. Just insert the pilot pin in a hole where you want a pad, press in until the teeth of the shank bite into the copper, and give the tool a couple turns until you've created an insulating mote between the pad and the rest of the board. For holes spaced on 0.1" centers, the cutter will take a tiny bite out of the adjacent pads, but don't worry about it. There will still be plenty of pad to solder to.

Step three is to install the components. Bend the leads of the resistors so they won't fall out as you handle the board, then bend the lead of R1 nearest the mounting hole so it lays flush with the board and touches the leads of R2 through R4; solder these leads and clip close to the solder joints.

Pay special attention to the orientation of the reflective sensors: pin 1 is marked by a dot on the top side of the plastic case. You can hold these and other components in place with masking tape on the component side until they are securely soldered in at least two places.

Start with the ground connections. You'll need a fairly hot soldering iron because the copper ground plane will soak up a lot of heat before it will take solder. I recommend using rosin paste flux to make the job easier. Just dab a little flux around the pin to be soldered; you'll be amazed how much easier the joint is to make then. Don't use too much solder for these ground plane connections, though, because it's easy to make inadvertent solder bridges to adjacent pads.

The fourth step is to wire up the remaining nodes of the circuit. This is done with 30 gauge insulated wire-wrap wire. Do the shorter wires first. Strip an eighth inch of insulation off one end, then lay the wire out between the two points to be connected following the wiring diagram. Snip off the other end an eighth inch beyond the second pin, then strip that end. Crimp the bare wire end around the pin and solder. Wait to solder pins that have more than one wire to be connected until all needed wires have been crimped to that pin.

It's best to do continuity checks with a meter as you make each connection. Check that the two pins being connected actually have continuity, check that you haven't accidentally bridged to ground, and also check that you haven't shorted to adjacent pins. A good way to keep track of your checks is to highlight them on the schematic as you make each check.

Once you are satisfied that all of the connections are correct, do a continuity test between ground and the pins of the connector. Only the ground pin should show low resistance. If the circuit has passed all these tests, it's safe to apply five volts to the Vdd and ground to the Vss pins. Use an oscilloscope or a logic probe to check the output levels of the "A" and "B" pins as you bring a few sheets' thickness of plain white paper near each sensor in turn. You should see a crisp 0 to 1 logic transition when you bring the paper close, and an equally crisp 1 to 0 transition when you remove the paper. Under fluorescent lights, you may see a 120 Hz pulse train coming from the sensors, but these pulses should disappear when you shield the board from direct fluorescent light.

Mount the boards to the servos as shown in Figure 4. The boards mount on 0.25" aluminum standoffs with 1/16" thick fiber washers to shim the boards out to get 0.050" gaps between sensors and encoder disks. If you don't have calipers to measure the gaps, you can use an ordinary automotive feeler gauge to set the distance.

It Works, Right?

When everything is aligned you should be able to see two (hopefully) squarewave signals on your scope. They should be 90 degrees out of phase. A fair amount of asymmetry can be tolerated, but if they are so asymmetrical that a positive and negative transition of one channel can occur without an intervening transition from the other channel, then you have trouble. You'll need to fiddle with the resistance values to set the IR emitter power and the receiver sensitivity.

Temporarily wire in a couple linear taper 1 meg, 15-turn potentiometers in place of R2 and R3, and two 20K potentiometers in place of R1 and R4. The best way to do this is to clip the original resistors out of the circuit from the component side and solder some lengths of wire to the remaining pin stubs. Form twisted pairs from these wires for each resistor and solder each pair to the first pin and wiper of the corresponding potentiometer. As a starting point, adjust the resistance of each pot until they match the original values in the circuit.

With the servos running, tweak the pots of one channel at a time until you achieve two symmetrical waveforms with 90 degree phase difference between them. Once that's accomplished, disconnect power and measure the resistances of each pot and replace them with the nearest standard value fixed resistor.

I know, this is not the easiest procedure. I'm working on a more elegant solution, but that will have to wait for another column because I am out of space this month. Anyway, next time I'll finish up with the encoder project with the software needed for the PIC to make sense of all these quadrature squarewaves. **NV**

SWITCHING VOLTAGE REGULATOR BASICS — PART 2

by TJ Byers

Weighing The Options

Last month, we looked at buck and boost switching regulators — those that typically change +12 volts into +5 volts (buck converter), and +5 volts into +12 volts (boost converter). Neither are isolated from the source and have a limited convert up/down ratio. In this article, I'll show you how the industry deals with converting 110 VAC into 5 volts, 12 volts into 1000 volts, and +5 volts into -5 volts. As before, I'll provide design rules and typical applications.

In case you missed Part 1, or need your memory refreshed, here are the switching topologies that are discussed in this series.

- **Buck:** Reduces a high DC voltage to a lower DC voltage.
- **Boost:** Increases a low DC voltage to a higher DC voltage.
- **Flyback:** Generates an output voltage that is lesser or greater than the input, including multiple output voltages.
- **Invert:** Generates a DC voltage which is opposite in polarity to the input voltage.

The buck and boost were reviewed in the May '99 issue. This month's article deals with the flyback and invert configurations.

Flyback Converter

The granddaddy of all switching converters is the flyback circuit, better known to us ol'-timers as a flyback transformer. This circuit has roots that go back to the very beginning of modern electronics — back to the invention of the television, to be exact. At the heart of every TV set is a cathode ray tube (CRT) which requires a very high DC voltage — something on the order of 25 kV. Using a standard 60 Hz power transformer to generate this voltage is a bulky, heavy, and expensive proposition. To make the TV a viable consumer product, a cheaper, lighter-weight power supply was needed. Enter the flyback transformer.

The flyback converter is the most versatile of all the topologies, permitting step-up, step-down, and multiple voltage outputs. Unlike the buck and boost circuits, the flyback topology uses a real transformer, not a simple inductor. The configuration can also provide load isolation with mixed positive and negative voltage sources.

Yes, this is identical to the way a RadioShack transformer converts 110 VAC into 12 VAC and other voltages. The difference is the frequency of operation. Instead of driving the primary at 60 Hz, the switching flyback converter runs at 100 kHz and higher. The net benefits are:

- Smaller physical size
- Lighter weight
- Reduced ripple
- Tight voltage regulation
- Cheaper construction costs

The basic flyback converter is shown in Figure 1.

Essentially, this circuit works like the ignition coil under the hood of your car. When the switch is closed, current flows through the primary of the transformer and builds up a magnetic field. When the switch is opened, the field collapses and transfers its energy to the secondary winding, inducing a voltage in that winding.

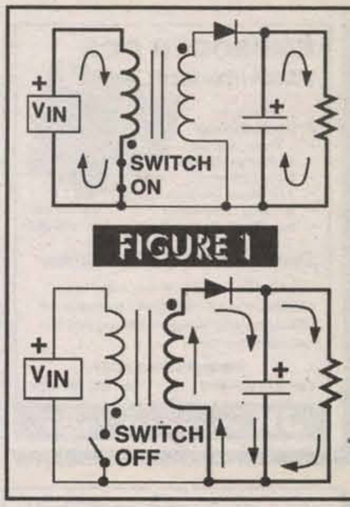


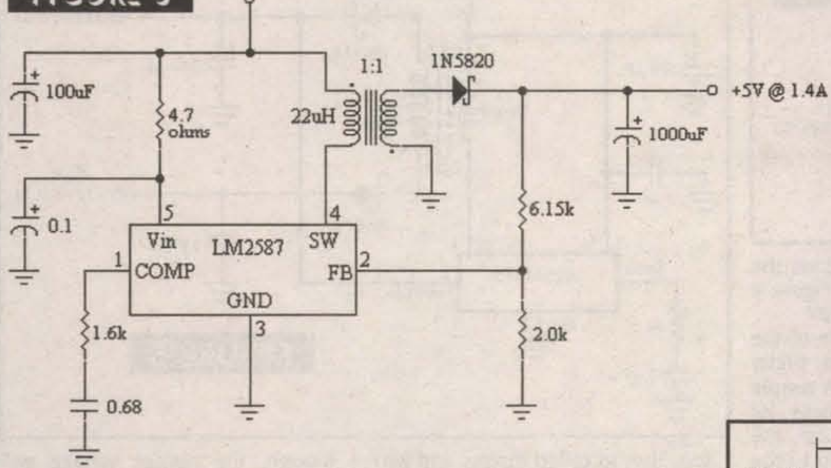
FIGURE 1

An important difference between an AC-line transformer — like a 12-volt RadioShack power transformer — and a flyback transformer is the phase relationship between the primary and secondary windings. In a power transformer, the output leaders are interchangeable. In a flyback transformer, a proper phase relationship between the primary and secondary windings (as indicated by the dots in Figure 1) is imperative for proper operation.

Note that the dotted lead of the primary winding connects to the negative terminal of the source, while the undotted lead goes to the positive terminal. This phasing is just the opposite for the secondary winding, which returns its undotted lead to the negative terminal of the source.

When the switch is turned on, a voltage of opposite polarity appears across the secondary winding — a voltage that's blocked

FIGURE 3



Transformers	T1	T1	T1	T2	T3	T4
V_{in}	4V–6V	4V–6V	8V–16V	4V–5V	18V–36V	18V–36V
V_{OUT1}	3.3V	5V	12V	12V	12V	5V
I_{OUT1} (Max)	1.8A	1.4A	1.2A	0.3A	1A	2.5A
N_1	1	1	1	2.5	0.8	0.35
V_{OUT2}				–12V	–12V	12V
I_{OUT2} (Max)				0.3A	1A	0.5A
N_2				2.5	0.8	0.8
V_{OUT3}						–12V
I_{OUT3} (Max)						0.5A
N_3						0.8

FIGURE 4

LM2587
Transformer Selection Table

Transformer Type	Manufacturers' Part Numbers				
	Coilcraft (Note 15)	Coilcraft (Note 15) Surface Mount	Pulse (Note 16) Surface Mount	Renco (Note 17)	Schott (Note 18)
T1	Q4434-B	Q4435-B	PE-68411	RL-5530	67141450
T2	Q4337-B	Q4436-B	PE-68412	RL-5531	67140860
T3	Q4343-B	—	PE-68421	RL-5534	67140920
T4	Q4344-B	—	PE-68422	RL-5535	67140930

Note 15: Coilcraft (800-322-2645; http://www.coilcraft.com)
Note 16: Pulse Engineering (619-674-8100; http://www.pulseeng.com)
Note 17: Renco Electronics (800-645-5828; http://www.rencousa.com)
Note 18: Schott Corp. (612-475-1173; http://www.schottcorp.com)

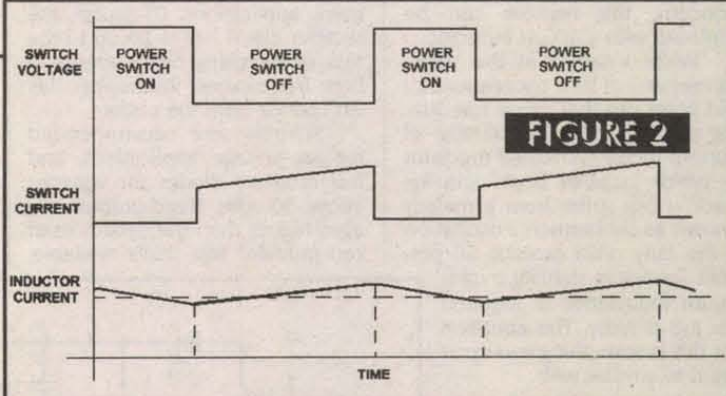


FIGURE 2

from charging the capacitor by the diode. When the switch is opened, the primary field collapses and the dotted secondary lead swings positive, which now lets current pass through the diode into the capacitor and the load.

During the next cycle, the polarity reverses again, and the capacitor provides power to the load while the magnetic field builds up. And so it goes. Figure 2 shows the idealized waveforms for a flyback converter.

Flyback Output Voltage

The secondary voltage is proportional to the number-of-turns between the primary and secondary windings. For a line-operated power transformer, the output voltage is equal to

$$\text{Vout} = \text{Vin} \times \text{N(turns ratio)}$$

A RadioShack 12.6 volt transformer, for example, has a turns ratio of 10:1, whereas a 25.5 volt transformer has a 4.5:1 ratio. In both cases, there's a fixed relationship between output voltage, turns ratio, and the 110 VAC line.

Most switching flyback transformers, on the other hand, determine the output voltage by varying the amount of time current flows through the primary of the transformer. The ratio between the time the current is on and the time it's off is called the duty cycle, which is mathematically defined as:

$$d = \frac{t_{on}}{t_{on} + t_{off}}$$

In a feedback converter, the duty cycle and output voltage are determined by the following equations:

$$d = \frac{\text{Vout}}{\text{N(Vin)} + \text{Vout}} = \text{Vout} = \text{N} \times \text{Vin} \times \text{d}/(1\text{-d})$$

where N equals the turns ratio between the primary and secondary windings.

Theoretically, the output voltage can be as large as desired — just keep increasing the turns ratio of the transformer. However, there are physical limitations that prevent the output voltage from increasing to infinity.

They include losses in the switching circuit, magnetic losses, and breakdown voltage of the insulators. Moreover, the flyback converter has the same limits of a power transformer; that is, you can't take out more power than you put in.

For example, if the input to the transformer is 5 volts and the switching current is 5 amps, the best you can hope for is 25 watts of power out (assuming no losses, of course). If the output voltage is 100 volts, the output current is just 250 mA — a far cry from the 5 amps you may have been expecting.

At some point, the ratio between higher voltage and lower current becomes unusable; infinite voltage out equals zero current out. Typically, PC-based flyback transformers have a turns ratio that ranges from 1:1 to 1:2.5.

Typical Flyback Converter Application

Flyback circuits are the most forgiving because there's no critical magnetic component as in the previous buck and boost topologies. However, the closer you can match the flyback transformer to the switching frequency and output load, the more efficient it becomes. For this exercise, I've selected the LM2587.

As always, a bypass capacitor should be placed between the input pin and ground. It should consist of a low ESR aluminum electrolytic (100 uF) paralleled

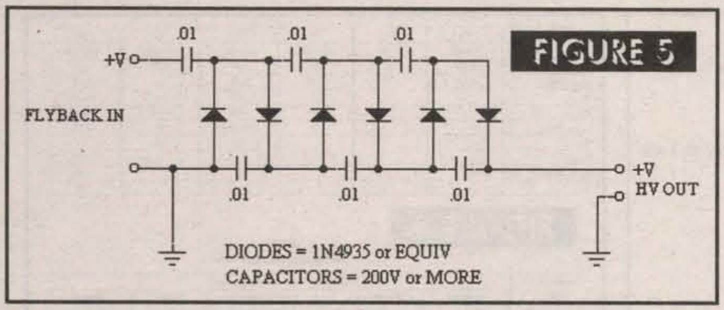


FIGURE 5

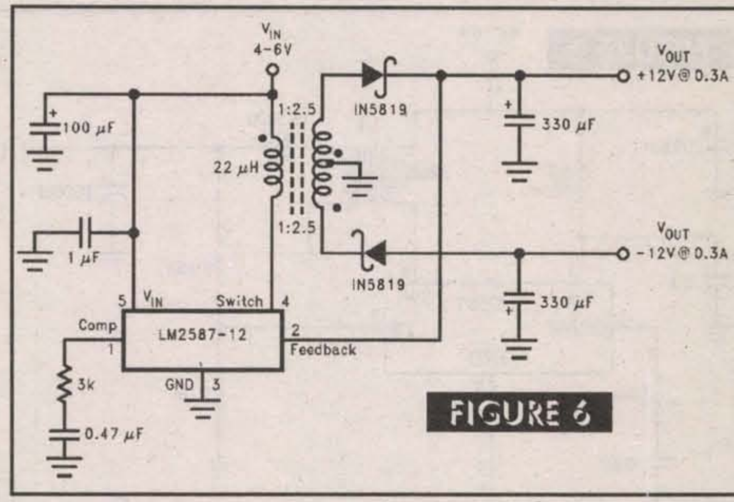


FIGURE 6

with a tantalum (1 uF). For serious applications, a small RC low-pass filter between the input pin and ground is recommended. Typically, it consists of a 4.7 ohm resistor and a 0.1 uF capacitor, as shown in Figure 3. If efficiency is a major concern, the resistor can be replaced with a 10 uH inductor.

While I said that the transformer was of little consequence, I did point out that some fine tuning was desirable. Specifically, all current-mode controlled regulator – which includes boost and flyback – can suffer from a malady known as subharmonic oscillation if the duty cycle exceeds 50 percent. To ensure stability, a minimum inductance is required for the primary. The equation for this is something you don't want to wrestle with.

$$L = \frac{2.92(Vin \times (2d-1))}{1-d}$$

where L is in uH and d is the duty cycle. To ensure stability over the full range of operation, set Vin to Vin (min) – the lowest expected input voltage – and d to d (max) (the maximum expected duty cycle). Personally I find this a lot of trouble, and so do a lot of other designers. That's why most switching regulator datasheets come with a nomograph that does the calculations for you. See Figure 4 for the table for the LM2587.

On the secondary side of the transformer, you can do pretty much what pleases you. A simple diode and capacitor suffices for many applications. Of course, the rectifier diode has to be up to the task of switching high currents at high frequencies. Remember this isn't 60 Hz from the outlet.

Schottky are recommended for low-voltage applications, and fast recovery diodes for voltages above 50 volts. Need output voltages higher than the flyback itself can provide? Yep, that's available, too. They're called triplers and you can find a bushel of them at your local TV/VCR repair shop, or you can build your own using the schematic in Figure 5.

As stated earlier, the output voltage is determined by the duty cycle of the current flowing through the primary of the transformer. Left to its own devices, though, the output voltage will vary up or down, depending on the load. As the load increases, the output voltage decreases, and visa versa. To hold the output voltage constant, a technique called pulse-width modulation (PMW) is applied to the switcher.

Basically what PWM does is adjust the duty cycle of the input pulse to control the input power, and therefore the output voltage. When peak output is required, the width of the input pulse is very wide to pack a heavier charge into the transformer. When the load is light, the input pulses are narrow, like a picket fence.

To control the PWM, a part of the output voltage is fed back to the switching controller (pin 2 of the LM2587) using a resistor divider. What the controller does is adjust the width of the switching pulse so that the voltage on this pin is always 1.23 volts – a voltage that's typical of most adjustable switching regulators, including buck, boost, and flyback.

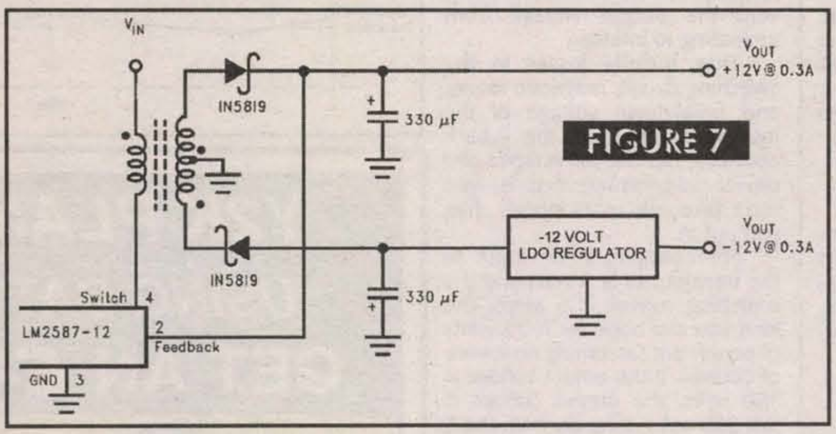


FIGURE 7

Where To Buy

SEMICONDUCTORS

Analog Devices
One Technology Way
Norwood, MA 02062-9106
(800) 262-5643
http://www.analog.com

Linear Technology Corp.
1630 McCarthy Blvd.
Milpitas, CA 95035
(800) 454-6327
http://www.linear-tech.com

Maxim Intergated Products
120 San Gabriel Dr.
Sunnyvale, CA 94086
(800) 835-8769
http://www.maxim-ic.com

National Semiconductor
2900 Semiconductor Dr.
P.O. Box 58090
Santa Clara, CA 95052
(408) 721-5000
http://www.national.com

INDUCTORS

Coilcraft, Inc.
1102 Silver Lake Rd.
Cary, IL 60013
(847) 639-6400
http://www.coilcraft.com

Pulse Engineering
12220 World Trade Dr.
San Diego, CA 92128
(619) 674-8100
http://www.pulseeng.com

Renco Electronics, Inc.
60 Jefryn Blvd., East
Deer Park, NY 11729
(800) 645-5828
http://www.rencousa.com

Schott Corp.
1000 Parkers Lk. Rd.
Wayzata, MN 55391
(612) 475-1173
http://ww.schottcorp.com

Note 15: **Coilcraft** (800-322-2645; http://www.coilcraft.com)
Note 16: **Pulse Engineering** (619-674-8100; http://www.pulseeng.com)
Note 17: **Renco Electronics** (800-645-5828; http://www.rencousa.com)
Note 18: **Schott Corp.** (612-475-1173; http://www.schottcorp.com)

CAPACITORS

AVX Corporation
3900 Electronics Dr.
Raleigh, NC 27604
(919) 878-6357
http://www.avxcorp.com

Mallory
North American Capacitor Company
7545 Rockville Rd.
Indianapolis, IN 46214
(317) 273-0090
http://www.nacc-mallory.com

Murata Electronics North America, Inc.
2200 Lake Park Dr.
Smyrna, GA 30080
(770) 436-1300
http://www.murata.com

Nichicon (America) Corp.
927 East State Pkwy.
Schaumburg, IL 60173
(847) 843-7500
http://www.nichicon-us.com

Sanyo
(619) 661-6835

Sprague
(603) 224-1430

TOKIN America, Inc.
155 Nicholson Ln.
San Jose, CA 95134
(408) 432-8020
http://www.tokin.com

(In a fixed-voltage regulator, like the LM2587-5.0, the divider resistors are placed on the chip inside the IC.)

If the voltage falls below 1.23 volts, it means the output voltage is sagging, which prompts the controller to increase the width of the pulse. Rising voltages on the feedback pin force a reduction in pulse width. In a well-designed converter circuit, it's not unusual to find the output voltage held to within 20 mV of nominal. Here are typical resistance divider values for popular voltages.

OUTPUT VOLTAGE	R1	R2
3.3V	3.4k	2k
5.0V	6.15k	2k
12V	8.73k	1k
15V	11.2k	1k

Generating Multiple Outputs

But we've only scratched the surface of the merits of flyback conversion. Not only can it provide a buck or a boost voltage, it can provide as many output voltages as you want using just one flyback transformer. Let's take a simple, dual-output power supply, like the kind needed for op amps (Figure 6).

Very often, op-amp circuits need a positive and negative power source. In fact, until just a few years ago, it was a requirement. Back in the days of old, these voltages were generated using a bipolar, tracking power supply, which were bulky and inefficient. While op-amp restrictions have relaxed since then, bipolar-powered circuits still have advantages over single-ended designs.

Our example starts off quite meekly as a simple flyback transformer voltage converter. In fact, the only change is in the secondary winding of the transformer, which is now center-tapped. Center-tapped transformers have been around for many years for different purposes.

Look at the power transformer options in any RadioShack catalog, and you'll see that nearly all sport a center tap. For our particular application, we're going to use that center-tap to generate a positive and a negative output voltage.

It's simple enough. We simply ground the center-tap so that the voltage is split in half, with 12 volts on the top and 12 volts on the bottom. Each half of the winding can now be treated as a separate transformer winding. On the top side, the output is run through a diode that has its anode lead connected to the transformer to produce a positive voltage. On the bottom side, the output is run through the cathode lead of a rectifying diode to generate a negative voltage. Ground is common.

The rectified outputs are typical enough, but not the PWM feedback. By design, PWM can only sense one output voltage, not multiple outputs. In our example, the feedback pin is connected to the +12 volt output. That means that this line alone will be held within about 20 mV of 12 volts. The negative output, on the other hand, is unregulated. It depends on the pulse width of the positive line.

Let's say the +12V output demands more current. This prompts a larger duty cycle to satisfy the request. Let's also say that the current demands of the -12V output remains the same. Well, I guess you can guess the results. The negative output voltage goes up — by how much is determined by the change in the duty cycle.

Fortunately, there's a simple solution which has recently appeared on the scene. It's called a low-dropout voltage regulator, or LDO. It's inserted into the circuit like this (Figure 7). Need three outputs? Here's a block diagram of how it's done (Figure 8).

As before, only one output can be regulated. If you want regulation on the other outputs, you need additional regulators. Linear LDOs are preferred over introducing another switching regulator.

Don't forget, however, that you can't get more power out than you put in, which is why PC switching power supply specs often paint a tainted picture. Let's take a common 250-watt PC power supply, for example. Typically, it lists the outputs as:

- +5V @ 30A
- +12V @ 10A
- -5V @ 1A
- -12V @ 0.5A

Added up, that comes to 281 watts, yet the power supply is only rated at 250 watts. How come? Well, it's because the outputs weren't meant to be working full-time all the time. They share.

For example, if the +5V load is drawing just 15 amps, the unused energy can be transferred to the +12V source to boost its output to about 16 amps, wiring and rectifier permitting. Just remember, altogether, they cannot exceed 250 watts.

FIGURE 8

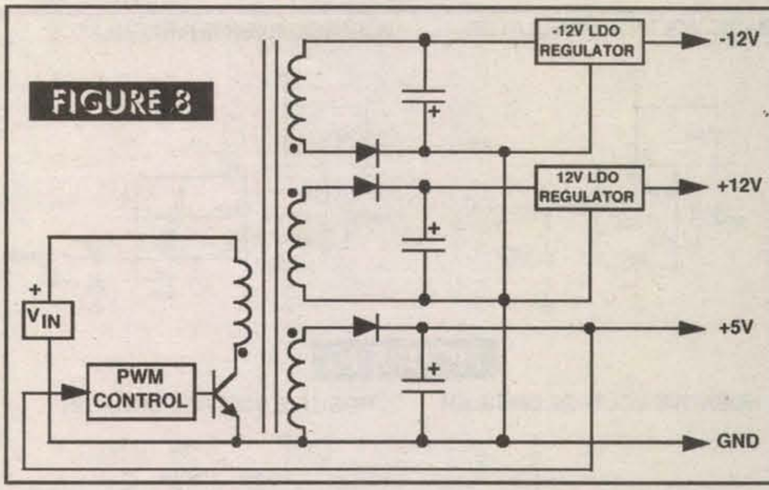
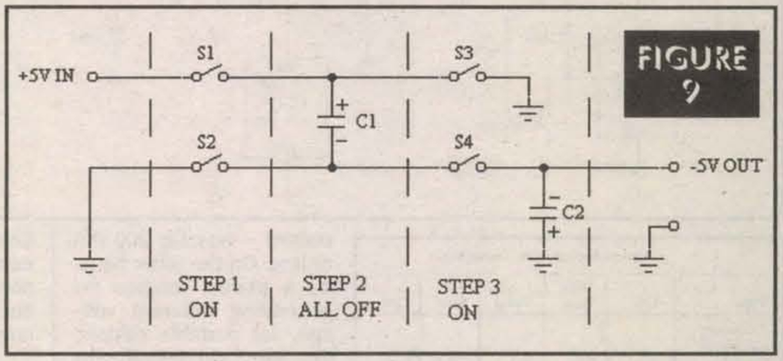


FIGURE 9



Weighing The Options

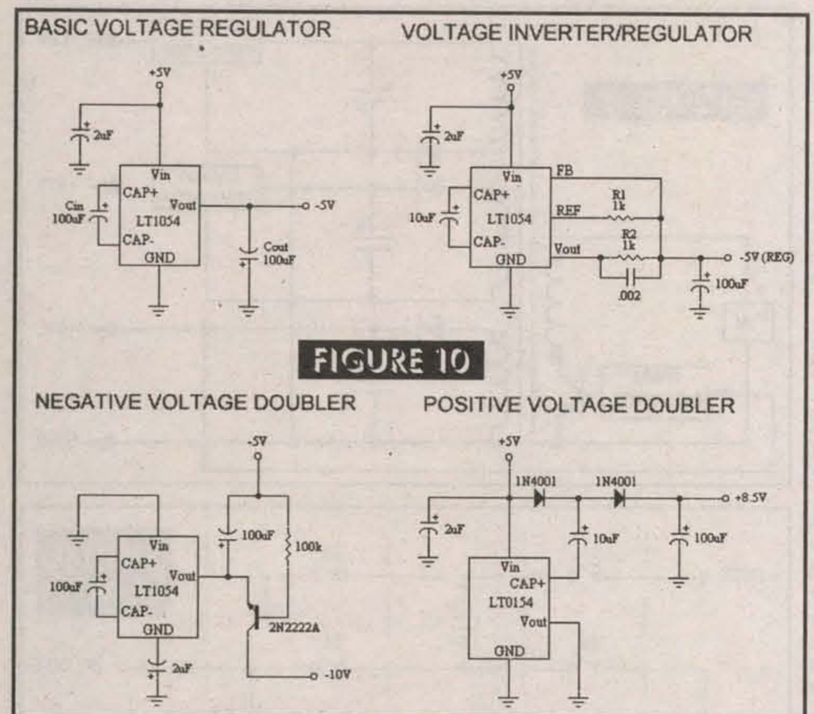


FIGURE 10

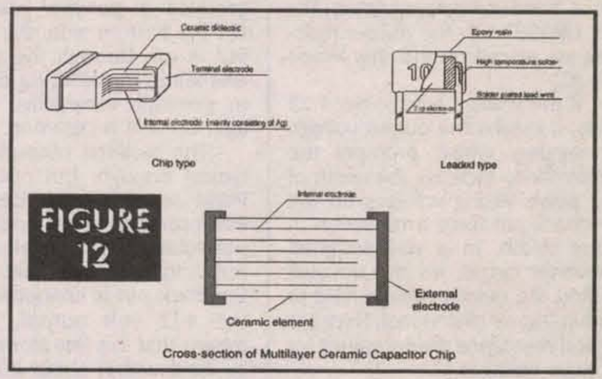


FIGURE 12

Alternative Capacitor Technologies					
Type	Life	High Freq	Temp	Size	Cost
Aluminum Electrolytic Capacitor	Fair	Fair	Fair	Small	Low
Multilayer Ceramic Capacitor	Long	Good	Poor	Fair[1]	High
Solid Tantalum Capacitor	Above Avg	Avg	Avg	Avg	Avg
OS-CON Capacitor	Above Avg	Good	Good	Good	Avg

NOTE
[1]Refer to capacitor manufacturer's data sheet for operation below 0°C.

Recommended Capacitor Manufacturers		
Manufacturer	Capacitor	Capacitor Type
Sprague	672D, 673D, 674D, 678D	Aluminum Electrolytic
Sprague	675D, 173D, 199D	Tantalum
Nichicon	PF and PL	Aluminum Electrolytic
Mallory	TDC and TDL	Tantalum
TOKIN	MLCC	Multilayer Ceramic
MuRata	GRM	Multilayer Ceramic

FIGURE 11

Inverting Regulator

Sometimes called a buck-boost converter, the inverting regulator takes a DC voltage and changes it to a voltage of opposite polarity. Furthermore, the voltage can be higher or lower than the input. More often than not, though, the output is a mirror image of the input.

Unlike the converters described above – all of which rely on magnetics – inverting regulators normally use switched capacitors to accomplish their goal. The correct term is called charge-pump, but switched-capacitor is the most popular term used. While the weight and expense of magnetics is gone, the tradeoff is lower output current – typically 200 mA or less. On the other hand, it's a perfect solution for generating different voltages for portable devices, like handheld instruments and cell phones.

How an inverting switched-capacitor circuit works is a lesson in design simplicity (Figure 9). There are three steps to the inverter's operation. In Step 1, S1 and S2 are closed, which charges capacitor C1. Step 2, S1 and S2 are opened. This is done to prevent overlapping as switches S3 and S4 are closed, and the charge of C1 is transferred to C2. Watch the polarity as the transfer takes place. What used to be ground is now the negative output and the positive is grounded. S3 and S4 are then opened and the cycle repeats. Generally, the output voltage is not regulated, just simply inverted.

By arranging the switches and capacitors in other configurations, voltages can be doubled in either polarity. Several switched-capacitor converters provide voltage regulation by using a PWM to control the switches time on and time off – just like their inductive counterparts.

Typical Switched-Capacitor Applications

Switched-capacitor converters are typically simpler than their inductive counterparts. Very often they're used to create bipolar power supplies for battery-operated equipment. Figure 10 shows a few examples of switched-capacitor applications taken from Linear Technology's LT1054 data sheet; just one of the devices we'll look at for this exercise.

As usual, a small bypass capacitor is recommended on the input pin, typically a 2 uF tantalum. For unregulated circuits, the value of Cin and Cout should be equal. While the exact values of Cin and Cout are noncritical, the quality of the capacitor is; they must be low ESR capacitors to reduce ripple.

Since ESR is a function of the operating frequency, you need to make sure the capacitor's value is rated at the circuit's operating frequency. In general, the capacitor's ESR is inversely proportional to its physical size, so capacitors with larger capacitance values and higher operating voltage tend to reduce ESR.

However, not all manufacturers guarantee capacitor ESR in the range required by the circuit, which is why many vendors publish charts listing recommended capacitor types and manufacturers. See Figure 11 for a chart from Analog Devices' ADP3605 data sheet.

What's an OS-CON capacitor, you ask? I, too, was confused until I looked it up. Invented by Sanyo in 1982, the OS-CON is an aluminum electrolytic type capacitor with an organic semiconductive electrolyte. Some of its features are:

- Very low ESR
- Totally temperature independent
- Wide frequency range
- High ripple current capability
- Long life

Just the prescription for a switched-capacitor converter. And because of these properties, a much smaller capacitance value can be used as compared to a normal aluminum electrolytic capacitor. Moreover, bypass capacitors can often be eliminated in less demanding applications because the noise will be reduced by the OS-CON capacitor.

Multilayer capacitors are also frequently used in switched-capacitor applications. Multilayer capacitors are high-dielectric capacitors made by sintering ceramic materials at a low temperature. Its advantages are high capacitance in a small size and layered construction that makes it especially well-suited for surface mount fabrication (Figure 12).

Increasing Switched-Capacitor Output

In many cases, you can increase the output of a switched-capacitor converter by linking two or more devices. This is especially helpful when working with low-voltage, low-current converters, like the MAX829 from Maxim, which has a maximum rating of 5.5 volts in and 25 mA out. For higher output voltage, two devices can be cascaded, as shown in Figure 13. The unloaded output voltage is normally

$$-Vout = +Vin \times 2$$

but this value is reduced by the output resistance of the first device multiplied by the quiescent current of the second. When cascading more than two devices, the output resistance increases dramatically. As a rule, the larger the value of the charge-pump capacitor (Cp), the lower the output resistance – at least up to a point. Above a certain point, increasing the value of this capacitor has negligible effect on output resistance.

Paralleling switched-capacitor converters also reduces the output resistance – and increases the output current. The resultant output resistance is calculated using the formula

$$Rout = \frac{\text{Rout of a single device}}{\text{number of devices}}$$

Each device must have its own pump capacitor (Cp), but only one output capacitor (Cout) is needed for the parallel devices (Figure 13). The value of this

Weighing The Options

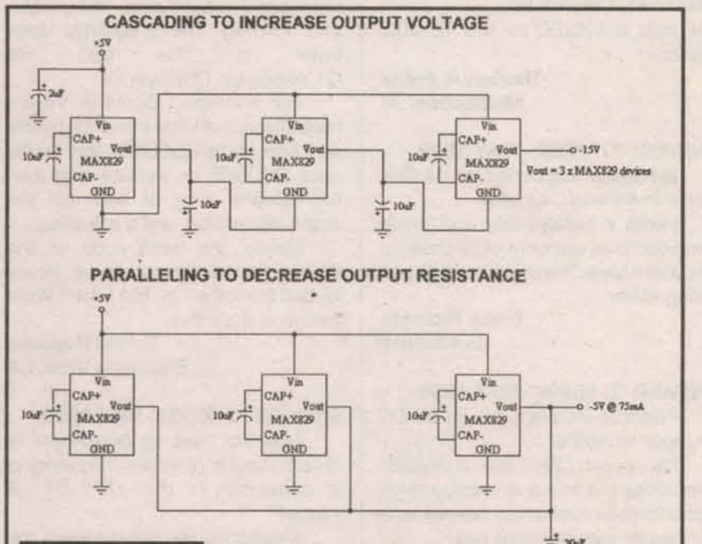


FIGURE 13

capacitor is directly proportional to the number of devices paralleled. For two chips, it's twice the original capacitance, three times for three chips, and so forth.

Just Touchin' The Basics

There's a lot more that I can say about switching converters, but space doesn't permit. You can obtain more information on switching regulators from the data sheets cited from http://www.questlink.com and the answers you'll find in this month's Electronics Q & A column. Want even more? Download the f5.pdf file, a whitesheet on switching regulator technology written by National Semiconductor, that's posted on our web site (http://www.nutsvolts.com). **NV**

TECH FORUM

Continued from page 67

The cost is $70.00 for the 12 VDC model.

Thomas A. Frank
Middletown, RI

ANSWER TO #5992 - MAY 1999

Whatever happened to McGee Radio in Kansas City, MO?

I work in Kansas City, and I have been told they went out of business a few years back. There is no telephone listing either.

Breck Ricketts
via Internet

ANSWER TO #5996 - MAY 1999

I want to interface my music CD changer to my PC.

Do music CDs have a header containing the title and catalog number and does each track have a similar header with the song title?

No, music CDs do not have ASCII title or track information. Programs that play CDs on a computer use the number of tracks and their track times to compute a hash code that will uniquely identify most CDs.

The program asks the user to supply the artist, title, and track information for that CD, and then the program saves the information in a file. When a CD is inserted, the program computes the hash code and checks the file. If the hash code is in the file, then the program assumes it is the same CD and displays the previously entered information.

A hash code has a good chance of being unique. A simple hash would use the last digit of each track duration. The last digit is essentially random, so the odds that two seven-track CDs have the same hash code is 10 million to 1.

Microsoft's Media Control Interface (MCI) apparently computes a 24-bit hash code where the odds of a collision are 16 million to 1. You can access this code with the MCI "info cdaudio identity" command. See the Multimedia Programmer's Reference help file for details about the MCI calls.

The Microsoft CD Player application uses this hash code (in hexadecimal format). The program's database is the text file C:\Windows\CDPlayer.ini.

For example, Suzanne Vega's Nine Objects of Desire has 12 tracks and hashes to D80665. The .ini file uses D80665 as the key, and then has several lines of data for the artist, album title, and track titles.

Ideally, the hash code to the album information could be downloaded from the net, but I don't know if anyone does that.

Gerald Roylance
Mountain View, CA

ANSWER TO #5993 - MAY 1999

How do I set up equipment to determine the resonant frequency of a capacitor in the .001-.01 uF range?

Measuring the self-resonant frequency of a capacitor requires a good test setup. The resonance is due to the capacitance and a series inductance.

For conventional capacitors, the wire leads supply most of the series inductance, and a good guess at this inductance is 20nH. 0.01uF capacitor will resonate at about 11 MHz. Any extra lead length in the test jig adds to the series inductance and affects the measurement.

The measurement is made by plotting the reactance of the capacitor versus frequency. At low frequencies, the capacitance determines the reactance.

The capacitive reactance decreases as frequency increases. At high frequencies, the inductance takes over. Inductive reactance increases with frequency. At resonance, the capacitive and inductive reactances cancel, and the measured reactance is a minimum (essentially zero).

In the test setup, a 50 ohm RF generator drives a series combination of a 50 ohm resistor and the capacitor under test. One end of the capacitor is grounded. A high-impedance scope measures the voltage across the capacitor.

TECH FORUM

As long as the amplitude across the capacitor is small compared to the amplitude of the generator, then the generator is properly terminated and the voltage across the capacitor is proportional to its impedance.

If the generator is 5V and the voltage across the capacitor is 0.1V, then the reactance is 50 ohms (0.1V/5V) = 1 ohm.

If you plot the impedance versus frequency on log-log paper, then you can get a good estimate for the resonant frequency. You can also just look for a minimum, but low signal levels and harmonic distortion make locating the minimum difficult unless you have a sensitive tuned detector.

I measured a 0.047uF 200V mylar to have a self-resonant frequency of about 6 MHz. At 5.4 MHz, the reactance was 0.34 ohms.

Gerald Roylance
Mountain View, CA

ANSWER TO #5998 - MAY 1999

I have an old Plectron alert tone receiver made in 1970. Inside, I found only one crystal, but not the receive frequency of 154.43 MHz.

How can I change the frequency to receive the NOAA severe weather alert tones.

The crystal is for the local oscillator which differs from the receive frequency by the intermediate (IF) frequency. You will need to replace the crystal with one that has the same difference from the frequency you want to receive.

The RF front end may be broad enough to cover the new receive frequency, but retuning won't hurt if you know what you are doing.

Russell Kincaid
Milford, NH

ANSWER TO #5995 - MAY 1999

I have a Masco three-channel amp. (Circa 1947.) Each mike input uses a 7B4 tube with 15 megohm grid resistor to GRND.

Can I use a 500Ω impedance mike on the input?

If you connect a 500 ohm microphone to the grid circuit on your tube amp, you will likely find that the audio level is too low. Also, the grid circuit is unbalanced in relation to ground (just one signal wire), which makes the input susceptible to hum and noise pickup.

The microphone circuits on tube amps generally fell into one of two categories. Either they had a high impedance input, for direct connection to a high-impedance mic, or they had an audio transformer in the input circuit, for connection to a low-impedance mic.

The transformer served to step up the voltage from the low imped-

TECH FORUM

ance mic, providing a better signal-to-noise ratio. (Most professional mics were 125 to 150 ohms, although some were in the 50-ohm range.) Most low-Z inputs were balanced, which greatly reduced hum and noise problems.

Of course, a transformer won't increase the power output from the mic, but it will increase the voltage. The transformer's voltage ratio (secondary/primary) is equal to the square root of the impedance ratio (secondary/primary). So a transformer with a 500 ohm primary and a 10K ohm secondary will have a voltage step-up of roughly 4.47, that's roughly a 13 dB increase in voltage, which will provide a corresponding improvement in S/N ratio.

Because of the very low levels and high-gain involved in a microphone input, the input transformer will almost surely need to have magnetic shielding to prevent pickup of hum or other unwanted signals. Keep the input transformer away from the power and audio output transformers.

You may need to adjust the physical orientation of the transformer, too, for lowest noise.

Good, broadcast-quality mic transformers, with flat frequency response and low distortion, are quite expensive. I found a few low-cost alternatives that you could try.

RadioShack sells an in-line mic matching transformer, with a standard XLR connector on the Low-Z primary, and a standard 1/4" phone plug on the Hi-Z secondary. Part #274-016; price around $15.00.

TechAmerica sells a miniature transformer with solder terminals. They list it as 100K ohm primary and 600 ohm secondary; just connect it in reverse for your application. Part #900-5844; price around $15.00.

Mouser Electronics sells a range of suitable transformers made by MagneTek. For example, stock #553-SP4 is listed as 200K ohm primary and 1K ohm secondary (again, connect it in reverse); price around $21.00.

Greg Miller
State College, PA
gemiller@commedge.com

ANSWERS TO #59915 - MAY 1999

I am a high school student interested in working with infrared video.

Does anyone know of a source for infrared video cameras?

You should check the Advertisers Index, under Cameras. **Resources Un-Ltd.** is the best bet at **1-800-810-4070**, as they have a lot of military surplus.

John M. Hoyt
Easley, SC

ANSWERS TO #59915 - MAY 1999

If you are talking about infrared light, then most of the $40.00 small black and white board cameras are sensitive to infrared light.

Just illuminate the area with light from a bunch of infrared LEDs or get an illuminator already built. However, if you are wanting to pick up infrared HEAT images, that's a very different story, they start around $1,000.00 and up, way up.

Breck Ricketts
via Internet

ANSWERS TO #59915 - MAY 1999

Depending on what you mean by infrared, you can purchase numerous cameras from the suppliers in *Nuts & Volts* and they are called "CCD Black and White" cameras.

Any solid-state B&W camera covers a part of the infrared spectrum and can be used with IR lasers or LEDs as a lighting source.

These cameras start at a very reasonable price of around $60.00 and some even come complete with both the lens and a casing for a little more.

The frequency response of these cameras run into the low side of the infrared spectrum however, and if you seek a higher frequency of infrared, say above the 1100 nm range, then expect to pay thousands of dollars for a complete camera or IR viewer.

However, you can build an "IR Viewer" for less than a couple of hundred bucks and add a B&W camera to its output viewer screen to achieve the higher "IR spectrum" past the 1100 nm range.

Chris
Bieber, CA

ANSWER TO #5997 - MAY 1999

I have a DPDT switch that forward and reverses a 12 VDC, 3 amp motor with limit switches that control in and out positions. I want to replace the switch with an RF transmitter and receiver.

I need additional circuitry to make it work the same as the DPDT switch. A garage door opener does what I want except it controls an AC motor.

Actually, the garage door opener relay will work in the AC or the DC mode. The relay itself will operate from AC or DC as long as the voltage is high enough to pull down the windings. The switch part of the relay will carry either AC or DC as long as the current doesn't exceed its ratings.

Smaller DC and solid-state relays can also be found that will operate from as low as 3 volts DC with 5- and 12-volt models being the most common.

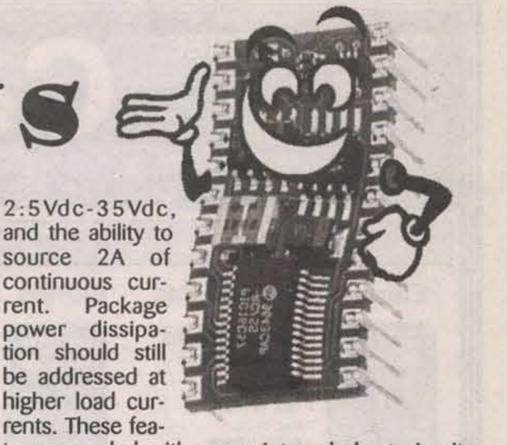
To simplify matters, you can purchase a DPDT relay that will directly replace your switch and they also come in the popular voltage and current ratings that you seek. **Digi-Key** at **1-800-344-4539** has 19 pages of relays to choose from.

Chris
Bieber, CA

Write in 60 on Reader Service Card.

STAMP APPLICATIONS

by Lon Glazner



Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Dual Digital Power Supply – Part 2

Overview

For those of you who were tuned into last month's episode of "Engineers With Brain Spasms," you would have seen me go through the process of defining a user interface for a digitally-controlled power supply. The user interface went together pretty quickly and with relatively little pain. I wish I could say the same about this month's power supply design. I went to great lengths to keep the design as simple as possible, and was thus hampered by my own design constraints. That being said, I feel that there are quite a few useful bits and pieces that can be filtered out of the final product.

So even though I came close to scrapping this implementation of a digitally-controlled dual power supply at least five times over the last month, in the end I felt that it provided enough useful information to push it through to completion.

In electronic design, there are a few fields that are clearly viewed as arcane arts by engineers not employed in those fields. A sampling of these disciplines would include radio frequency design, high-speed digital design, antenna theory and, of course, switching power supply design. I don't pretend to be an expert in any of those fields. So, when it came time to design a power supply circuit for this article, I made sure to make use of circuits that were relatively simple. The power supply circuit that I used is inexpensive, requires few parts, and is extremely useful. I have found this circuit to be quite useful in previous designs, although its effectiveness in this particular design was somewhat limited.

I also felt that this article should focus on implementing a digital control technique in conjunction with a user interface. I was wary of introducing too many new electronic components, and thus making the article too difficult for beginners to understand. Given the amount of space I have available, it's very difficult to provide an accurate overview of a design if I have to describe in detail a large number of electronic parts. What's the point of my diatribe you ask? Well, in order to keep things simple, I resorted to using the DS1267-010 Dallas Semiconductor digital potentiometer, and the ADC0831 National Semiconductor eight-bit A/D. Both of these parts were used in the April '99 Stamp Applications article. So, if you are a regular reader, you should be familiar with those parts. But by selecting these parts, I placed some serious limitations on the power supply's capabilities.

Defining the Design

In my initial design, I was shooting for a digitally-controlled dual power supply with on output range of 3-20V and about 2A current source capability. A linear regulator, such as the National Semiconductor LM317, could be used. But if I used a linear regulator, cooling and heatsinking would be mandatory. For example, an 8Vdc output linear regulator, providing 500mA of current, with an input voltage of 24Vdc would have to dissipate (24Vdc-8Vdc)*0.5A = 8 watts. Even with external pass elements, I would have to account for considerable power dissipation.

On the other hand, a switching power supply would provide me with the efficiency necessary to minimize power dissipation concerns. It was primarily due to power dissipation considerations that I selected the MAX726 (Maxim Integrated Products: 1-800-998-8800 for samples) step-down, PWM, switch-mode DC-DC regulator, as a power supply. You can approximate the power dissipation requirements for the MAX726 by multiplying the load current by 1.1Vdc. This is described in the MAX726 data sheet. Therefore, by using a MAX726 instead of a linear regulator, your 8Vdc supply would only have to dissipate 1.1Vdc*0.5A = 0.55 watts; which is a significant improvement over the linear regulator.

Furthermore, the MAX726 has an output voltage range of 2:5Vdc-35Vdc, and the ability to source 2A of continuous current. Package power dissipation should still be addressed at higher load currents. These features coupled with some internal short circuit protection make the MAX726 ideal for this design.

But how do you adjust the output voltage with this regulator? Take a glance at Figure 1. From the MAX726 data sheet, I know that the output voltage is selected by R7 and the value of the potentiometer. I also know from the equation for a voltage divider that the feedback voltage at pin 1 of the MAX726 can be described by …

Vfb = Vout*(Rpot/(Rpot+R7)

But unlike your average voltage divider, the feedback voltage, Vfb, is pre-set to 2.21Vdc internally by the MAX726. This has two important effects on our design. The first effect is that with Vfb set to 2.21V, the current through our digital pot will not exceed its maximum rating (5mA). Additionally, the voltage on our digital pot is kept within its specifications (7Vdc maximum). All in all, it means that a digital pot is an effective means of adjusting the output voltage generated by the MAX726.

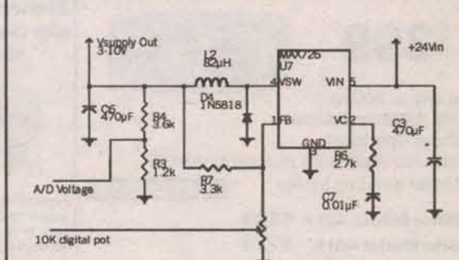


Figure 1: Power Supply Circuit

There are a few points that must be stated here. The digital potentiometer (DS1267-010) was very effective in controlling the output voltage of the MAX726 over a short range of voltages. Specifically, I had luck controlling the MAX726 between 3Vdc-10Vdc. Over 10Vdc, there was not enough resolution available in the DS1267-010 to allow accurate voltage control. So at this point, I reduced the power supply output to 10Vdc maximum, and modified the user interface code to reflect this change. I also realized that whenever I reduced the output voltage below 4Vdc, I was violating a recommendation in the MAX726 data sheet. The data sheet specifically states that the resistor between the FB pin and ground should not exceed 4K ohms (this is where the DS1267-010 is located). In this system, any voltage output between 3Vdc and 4Vdc is generated by a DS1267-010 setting of greater

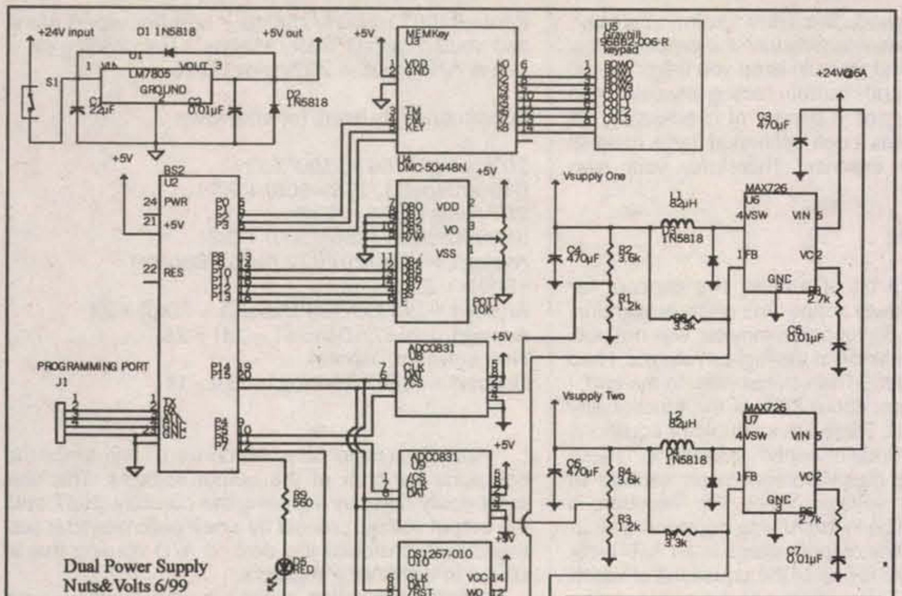


Figure 2: User Interface and Power Supply Together

than 4K ohms. I tested the voltages under load and didn't find any serious degradation in performance. So I left the minimum output voltage limit set to 3Vdc.

The limitations forced onto this design really did revolve around the capabilities of the DS1267-010. If, for example, the digital pot had 10 bits of resolution, then I think many of these shortcomings would disappear. But for simplicity and, due to a nearing publication deadline, I decided to press on with the design.

As part of a feedback system, I included two eight-bit A/D converters (ADC0831). So the way the system worked could be described in five steps.

1) The user enters the desired voltage output.
2) The BASIC Stamp2 (BS2) converts the desired output to a desired A/D reading.
3) The BS2 calculates an approximate setting for the digital potentiometer.
4) The BS2 measures the actual output voltage and trims the DS1267-010 until the desired A/D matches the actual A/D.
5) If the actual output voltage never matches the desired output voltage, then the user is notified, otherwise the system waits for the next user update.

The A/D inputs were originally read through a voltage divider circuit that divides down the actual output voltage by four. This was done in order to measure 20Vdc maximums with 5Vdc A/Ds. When I changed the output voltage range of the supply from 3Vdc-20Vdc to 3Vdc-10Vdc, I could have changed the voltage divider from a divide by four configuration to a divide by two configuration. Making this change would give greater resolution in the A/D measurement results. While this would be good, it doesn't change the fact that output voltage resolution is limited at higher output voltages due to the characteristics of the DS1267-010.

So, after all of the give and take, what is left over is a dual supply with 3Vdc-10Vdc regulated output and a 1A source capability. The current handling capability of this circuit was limited to 1A by the inductor selected.

Connecting the Parts

The two ADC0831s and the DS1267-010 were all connected to the same clock and data lines. Each chip had a separate chip select control line. Using the LCD in four-bit mode – as well as the MEMKey for serial keypad encoding – freed up enough I/O lines to allow this design to get done. The MEMKey could be used in single wire communication mode by connecting the TM and FM pins together to one BS2 I/O pin. This would free up another I/O line. Also, if the out of regulation indicator LED was omitted from the design, then three I/O lines could be available for other use.

Program memory is pretty much used up at this point, although moving the design to a BS2SX would eliminate that problem. A complete system schematic is detailed in Figure 2.

Power Supply Limitations

The major limitations of this power supply were imposed by using the DS1267-010. If I had this design to do over again, I would probably remove the digital potentiometer and add two 5K ohm mechanical potentiometers for voltage setting. Then you could change the eight-bit A/Ds to 10-bit A/Ds. You might even add a couple more A/Ds and some current measurement capability. The keypad could also be removed in lieu of a couple of buttons for selecting voltage or current displays.

If you wanted to get really tricky, you could design an active load by biasing a BJT in its active region through adjustments to its base resistance. This could potentially replace the DS1267-010.

An important thing to consider when using the MAX726 is which inductor to use. The inductor is in the high current path. So your inductor must have a continuous current rating equal to, or greater than, the maximum load current that your supply will provide. An inexpensive, relatively high current inductor is the Toko 8RHB type which can be found at Digi-Key. I had some 82uH inductors laying around which were rated for 1.1A, and they seemed to do the trick. There are higher current rated inductors that are available, but I really like the packaging of the Toko parts. They take up less room than some electrolytic capacitors.

Lastly, I didn't heatsink my MAX726 regulators. They handled about a watt of power (900mA load) without overheating. I used the three second test for my thermal modeling. The three second test consists of licking your finger and placing it on a potentially hot device. If you hear a sizzle (that sounds like saliva turning to steam), then it would be prudent to withdraw the exposed digit. If no sizzle occurs, and you can keep you finger on the device for three seconds without feeling any pain, then the part is probably not in danger of overheating. Of course, my finger has been calibrated by a national laboratory at great expense. Therefore, your own results may vary.

Writing the Code

The code was a bit of a bear. The concept for implementing this power supply was pretty straightforward. But since the digital potentiometer was not able to give me good resolution at the higher voltages, I had to throw in a slew of If…Then statements. In the end, I think I was able to get about 80% of the functionality that I was looking for. There are a couple of equations that I use in the "UpdateSupply" subroutine. These equations relate the digital potentiometer settings to the desired output voltage. When the equation is implemented, the value in the Analog register is a binary value that relates the output voltage to an A/D measurement result. Here is one of the equations of which I speak:

$$DSpots1 = (2376/(Analog1 - 28)) - 14$$

And here is how it is arrived at. From the MAX726 data sheet, we know that the output voltage can be related to the digital potentiometer with the following equation:

$$Vout = (R7 + Rpot)^*(2.21V/Rpot)$$

where
$R7 = 3300$ ohms
$Rpot= 9000^*Dspots1/256bits + 500$ (for wiper) ohms and $Vout= Analog1^*5Vdc/256bits^*4$ (for dividing circuit at A/D input) $= 20^*Analog1/256$

Substituting this result for Vout gives …

$$20^*Analog1/256 = 3300^*2.21/((9000Dspots1/256)+500) + 2.21$$
$$20^*Analog1/256 = 7293/((9000Dspots1/256)+500) + 2.21$$
$$Analog1 = (256/20)^*((7293/(35^*Dspots1 + 500)) + 2.21)$$
$$Analog1 = (93359/(35^*Dspots1 + 500)) + 28$$
$$Analog1 = 2667/(Dspots1 + 14) + 28$$
Now solve for Dspots1…
$$Dspots1 = (2667/(Analog1 - 28)) - 14$$

After this relationship was derived, I fine-tuned the equations for both of the output voltages. This was most easily done by adjusting the constant 2667 until the output voltage created by a new potentiometer setting closely matched the desired A/D reading that is stored in the Analog registers.

A little explanation of the how the registers were used in this program may clarify the functionality of the software. The Analog registers store an eight-bit value that is boiled down from the desired output voltage as it is displayed on the LCD. This eight-bit value is then used to derive a value for setting the digital potentiometer, as described by the equations above. After the digital potentiometer has been updated, the program trims the output voltage by taking A/D readings (stored in AD_in registers), and comparing them to the desired value (again in the Analog registers). Any readings that do not meet the requirements set forth in the program cause the potentiometer setting to be

Code Listing 1: june99_4.bs2

```
'
' JUNE99.BS2 - Dual power supply and user interface code listing. This source code
' implements a user interface consisting of a 2x8 LCD screen operating in 4 bit mode,
' and a 4x4 keypad. The LCD is driven directly with a BASIC Stamp 2 while the keypad
' is encoded by a MEMKey serial keypad encoder. LCD display data is stored in the
' MEMKey's user accessible EEPROM.
' Further modifications to this code were included to implement a digitally
' controlled dual power supply. The supplies parameters were reduced from a
' maximum of 20.0V to 10.0V in order to maintain resolutions with eight-bit A/D
' and D/A (digital pot) devices.
'
'
' LCD constants
RS        CON    12        ' Register Select (1 = char)
E         CON    13        ' LCD Enable pin (1 = enabled)
'
'LCD control characters
ClrLCD    CON    $01       ' clear the LCD
CrsrHm    CON    $02       ' move cursor to home position
CrsrLf    CON    $10       ' move cursor left
CrsrRt    CON    $14       ' move cursor right
DispLf    CON    $18       ' shift displayed chars left
DispRt    CON    $1C       ' shift displayed chars right
DDRam     CON    $80       ' Display Data RAM control
'
' LCD Variables
Char      VAR    Byte      ' Character sent to LCD
'
' MEMKey pin assignments
TM        CON    0         ' To Master
FM        CON    1         ' From Master
KEY       CON    2         ' Key press notification pin
'
' MEMKey variables
Index     VAR    Byte      ' For next loop variable
KeyVal    VAR    Byte      ' Storage for key values
B_1       VAR    Byte      ' Variable storage byte
B_2       VAR    Byte      ' Variable storage byte
B_3       VAR    Byte      ' Variable storage byte
B_4       VAR    Byte      ' Variable storage byte
B_5       VAR    Byte      ' Variable storage byte
B_6       VAR    Byte      ' Variable storage byte
B_7       VAR    Byte      ' Variable storage byte
B_8       VAR    Byte      ' Variable storage byte
B_9       VAR    Byte      ' Variable storage byte
'
' MEMKey constants
Baud      CON    396       ' Baud rate = 2400
PConfig   CON    $0E       ' Program configuration command
Config    CON    $00       ' Disable typematic, disable auto
PDBounce  CON    $04       ' Program debounce command
DBounce   CON    $0A       ' Set debounce for 25ms
Peeprom   CON    $08       ' Program user EEPROM command
Reeprom   CON    $09       ' Read user EEPROM command
Pkeyval   CON    $0A       ' Program key value command
Rkeyval   CON    $0B       ' Read key value command
Default   CON    $11       ' Resets MEMKey to default values
Rbuffer   CON    $00       ' Read key in buffer
'
'Serial Device Pin Assignments
Clk       CON    14        ' Serial clock control pin
Dat       CON    15        ' Serial data control pin
CS_ad1    CON    4         ' Chip select for A/D one
CS_ad2    CON    5         ' Chip select for A/D two
CS_pot    CON    6         ' Chip select for digital pot.
'
'Serial Device Variables
DSpots    VAR    WORD              ' Storage word for pot values
DSpots1   VAR    DSpots.lowbyte    ' Voltage control pot for V1
DSpots2   VAR    DSpots.highbyte   ' Voltage control pot for V2
Analog1   VAR    WORD              ' Analog working register
Analog2   VAR    WORD              ' Analog working register
AD_in1    VAR    BYTE              ' Results from A/D read of V1
AD_in2    VAR    BYTE              ' Results from A/D read of V2
Working   VAR    WORD              ' Working register f
'
'LED pin assignment
LED_control CON  7         'Out of regulation LED indicator
'
'*****************************************************************************'
' This routine initializes the BASIC Stamp, LCD, DS1267-010, and MEMKey.

' Initialize the BS2
BS2_ini:
        DirH = %01111111            ' set pins 8-15 direction
        OutH = %00000000            ' clear the pins
        DirL = %11110010            ' set pins 0-7 direction
        OutL = %10110010
''Initialize digital potentiometers
        DSpots = $FFFF              ' Initialize V1 and V2 to 3V each
        GOSUB SetPotValue
'
' Initialize the LCD (Hitachi HD44780 controller)
LCD_ini:
        OutC = %0011                ' 8-bit mode
        PULSOUT E, 1
        PAUSE 5
        PULSOUT E, 1
        PULSOUT E, 1
        OutC = %0010                ' 4-bit mode
        PULSOUT E, 1
        Char = 40                   ' Set for 2 line operation
        GOSUB LCDcmd
        Char = 12                   ' Shift cursor right
        GOSUB LCDcmd
        Char = 6                    ' Increment DDRAM after write
        GOSUB LCDcmd
        Char = 1                    ' Clear LCD screen
        GOSUB LCDcmd

'
' Initialize the MEMKey
MEMKey_ini:
        HIGH        FM              ' Make sure FM is high
        PAUSE 2000                  ' Let the system power settle
        SEROUT      FM,Baud,[PConfig,Config]
                                    ' Configure MEMKey for Polled Mode
        PAUSE       15              ' Pause 10ms for EEPROM access
        SEROUT      FM,Baud,[PDBounce,DBounce]
                                    ' Program debounce value
        PAUSE       15              ' Pause 10ms for EEPROM access
'       GOSUB       Reset           ' Run this when using a new MEMKey
'
'
'Initialize output voltage and display
        GOSUB       DisplayLCD      ' Recall display
        GOSUB       UpdateSupply    ' Modify output voltages
'***************************************************************************MainProgram:
```

adjusted up or down until a closer match occurs.

If, after several adjustments, the desired value does not match the actual value, then the actual value is loaded into the display and the "out of regulation" LED is lit.

This implementation of a digitally-controlled dual power supply required most of the BS2's RAM and EEPROM program memory to implement. However, the code is far from fine-tuned and could be refined to a great degree.

In Closing

I'm probably going to have a second go at this power supply circuit. The keypad and digital potentiometer will likely be removed. Instead a four-line LCD, four separate 10 bit A/Ds, and a couple of manual potentiometers will be used. The extra A/Ds would be used for current measurement. Further testing is also required to determine regulation under load. I would also like to locate a higher current inductor to maximize the current source capability of the design. It may be feasible to parallel a couple of the Toko inductors that I'm currently using to reach the 2A capability that the MAX726 can provide.

For those of you in need of a higher current system, Maxim also has the MAX724. This part is identical in functionality to the MAX726, but can handle up to 5A of current.

This was one of those designs that seem to force limitations on me. Or maybe I should say that I forced them on myself by sticking with the DS1267-010 as a means of controlling the output voltage. But with those changes that I mentioned above, I think I can tweak this into a successful and useful electronic design.

Regardless, I learned a little, and didn't blow anything up. **NV**

RESOURCES

For more information on the BASIC Stamp, contact:

Parallax, Inc.
3805 Atherton Road, #102
Rocklin, CA 95765
phone **(916) 624-8333**
http://www.parallaxinc.com

Scott Edwards Electronics, Inc.
1939 S. Frontage Rd. Ste. F
Sierra Vista, AZ 85635
phone **520-459-4802**
fax **520-459-0623**
www.seetron.com info@seetron.com

Solutions Cubed
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3029 Esplanade Suite F
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E-Mail: **lon@solutions-cubed.com**
www.solutions-cubed.com
Phone: **530-891-8045**
Fax: **530-891-1643**

Lon Glazner is a partner and engineer at Solutions Cubed. Solutions Cubed is an innovative group of design engineers who specialize in embedded control design. They also produce a line of BASIC Stamp compatible products called Miniature Engineering Modules.


```
        If IN2 <> 1 Then MainProgram      ' Check the KEY pin for a logic high
        GOSUB       KeyFind               ' Poll for a key press
        GOSUB       ModeSelect            ' Start user interface interaction
        GOSUB       UpdateSupply
        GOTO        MainProgram
'
'
'***********************************************************************
'—[ Subroutines ]————————
'***********************************************************************
' LCD commands, such as address pointer, are sent via LCDcmd, characters are sent with the
' LCDwr routine. This routine and LCD initialization routines taken from a previous
' author's Stamp Applications code listing. I believe it was Jon Williams who wrote the original
' code.
'
LCDcmd:
        LOW RS                            ' Enter command mode
                                          ' then write the character
LCDwr:
        OutC = Char.HIGHNIB               ' Output high nibble
        PULSOUT E, 1                      ' Strobe the Enable line
        OutC = Char.LOWNIB                ' Output low nibble
        PULSOUT E, 1
        HIGH RS                           ' Return to character mode
        RETURN
'***********************************************************************
' All display data including voltage levels is stored in the MEMkey's EEPROM
' in locations $00-$0F. Whenever the display is updated each character is
' read from EEPROM and then sent to the LCD. The leading zeros for the voltage
' levels one both line one and line two are displayed as ASCII " "(space). This
' makes the display look a little nicer. If this display update routine is too
' slow for your design you can just update the voltage levels.
'
DisplayLCD:
Line1:
        Char      =     $80               ' Display line one
        GOSUB     LCDcmd
        For Index = $00 to $07
                  SEROUT FM,Baud,[Reeprom,Index]
                                          ' Read EEPROM command
                  SERIN   TM,Baud,[B_1]   ' Display value is read
                  If Index <> $04 then TestAn1A   ' Translate ASCII tens value into decimal
                  Analog1 = (B_1 - 48) * 100
TestAn1A:
                  If Index <> $05 then TestAn1B   ' Translate ASCII ones value into decimal
                  Analog1 = Analog1 + (B_1 -48 * 10)
TestAn1B:
                  If Index <> $07 then TestAn1C   ' Translate ASCII tenths value into decimal
                  Analog1 = Analog1 + (B_1 -48)
TestAn1C:
                  Char    = B_1
                  If Index <> $04 then Continue1  ' Test for leading zero
                  If Char <> $30 then Continue1   ' If ASCII zero then
                  Char = " "                      ' replace with blank space
Continue1:
                  GOSUB LCDwr
        Next
Line2:
        Char      =     $C0               ' Display line two
        GOSUB     LCDcmd
        For Index = $08 to $0F
                  SEROUT FM,Baud,[Reeprom,Index]  ' Read EEPROM command
                  SERIN   TM,Baud,[B_1]           ' Display value is read
                  Char    = B_1
                  If Index <> $0C then TestAn2A   ' Translate ASCII tens value into decimal
                  Analog2 = (B_1 - 48) * 100
TestAn2A:
                  If Index <> $0D then TestAn2B   ' Translate ASCII ones value into decimal
                  Analog2 = Analog2 + (B_1 -48 * 10)
TestAn2B:
                  If Index <> $0F then TestAn2C   ' Translate ASCII tenths value into decimal
                  Analog2 = Analog2 + (B_1 -48)
TestAn2C:
                  If Index <> $0C then Continue2  ' Test for leading zero
                  If Char <> $30 then Continue2   ' If ASCII zero then
                  Char = " "                      ' replace with blank space
Continue2:
                  GOSUB LCDwr
                  Next
        Analog1 = Analog1 * 256 / 200     ' Analog1 is the desired AD_in1 value
        Analog2 = Analog2 * 256 / 200     ' Analog2 is the desired AD_in2 value
        RETURN
'*********************************************************************' The Reset subroutine
returns the MEMKey to it's initial settings. It also
' resets the LCD display values. Upon initial power up of this design
' a "GOSUB Reset" should be placed prior to entering the MainProgram code space.
' After the EEPROM has been initialized the "GOSUB Reset" may be commented
' out or deleted. By doing this the last values displayed, prior to a power down,
' will be the values loaded on power up.
'
Reset:
        SEROUT FM,Baud,[Default]          ' Reset MEMKey to default settings
        PAUSE     200
        SEROUT FM,Baud,[PConfig,Config]   ' Configure MEMKey for Polled Mode
        PAUSE     15                      ' Pause 10ms for EEPROM access
        SEROUT FM,Baud,[PDBounce,DBounce] ' Program debounce value
        PAUSE     15                      ' Pause 10ms for EEPROM access

                                          ' Update key values and display values
        For Index = $00 to $0F
            LOOKUP Index,[$00,$01,$02,$03,$04,$05,$06,$07,$08,$09,$0A,$0B,$0C,$0D,$0E,$0F],B_1
            LOOKUP Index,["1","2","3","A","4","5","6","B","7","8","9","C","*","0","#","D"],B_2
            LOOKUP Index,["V","1",":"," ","0","5",".","0","V","2",":"," ","0","5",".","0"],B_3
            SEROUT FM,Baud,[Peeprom,B_1,B_3]
            PAUSE   15
            SEROUT FM,Baud,[Pkeyval,B_1,B_2]
            PAUSE   15
        Next
        RETURN
'***********************************************************************
' ModeSelect determines which voltage is being adjusted, or if a reset command has been
' implemented. The scroll-up and scroll-down modes have not yet been implemented. The scroll ' functions can be
defined once the voltage control method has been proved in the lab.a
'
ModeSelect:
        If KeyVal = "A" then AdjustV1     ' Adjust voltage one has been selected
        If KeyVal = "B" then AdjustV2     ' Adjust voltage two has been selected
        If KeyVal = "D" then ResetSupply  ' A reset command has been entered
        RETURN                            ' Any key other than A,B, or D was pressed and can be
ignored
AdjustV1:
        SEROUT FM,Baud,[Peeprom,$03,">"]  ' Load a ">" into EEPROM
        PAUSE     15
        GOSUB     DisplayLCD              ' Display the ">" next to voltage being adjusted
        B_2 = $04                         ' Start EEPROM address at voltage values
AdjV1Continue:
        GOSUB     KeyFind                 ' Wait for the next keypress
        If KeyVal = "C" then AdjV1Done    ' If a "C" was pressed then were done adjusting
        If KeyVal > "9" then AdjV1Over    ' Check to if A,,B,C,D key was pressed by accident
        If KeyVal = "#" then AdjV1Over    ' Check to see if pound key was preseed
        If KeyVal = "*" then AdjV1Over    ' Check to see if asterisk key was pressed
        SEROUT FM,Baud,[Peeprom,B_2,KeyVal] ' Store numeric 0-9 in current EEPROM address
```

continued on page 90

```
        PAUSE       15
        GOTO AdjV1Again
AdjV1Over:
        SEROUT FM,Baud,[Peeprom,B_2,"0"]            ' If keypress was "A","B", or "D" return a "0"
        PAUSE       15
AdjV1Again:
        GOSUB DisplayLCD                            ' Update display with the latest key press
        B_2 = B_2 + 1                               ' Increment EEPROM address pointer
        If B_2 = $06 then AdjV1Again                ' If EEPROM pointed at "." then increment again
        If B_2 = $08 then AdjustV1                  ' If line2 pointed at then reset EEPROM pointer
        GOTO        AdjV1Continue
AdjV1Done:
        GOSUB Limits                                ' Make sure values are within limits
        RETURN
AdjustV2:
        SEROUT FM,Baud,[Peeprom,$0B,">"]            ' Comments for second line are the same except all
        PAUSE       15                              ' EEPROM pointers are 8 greater than line 1
        GOSUB       DisplayLCD
        B_2 = $0C
AdjV2Continue:
        GOSUB       KeyFind
        If KeyVal = "C" then AdjV2Done
        If KeyVal > "9" then AdjV2Over
        If KeyVal = "#" then AdjV2Over
        If KeyVal = "*" then AdjV2Over
        SEROUT FM,Baud,[Peeprom,B_2,KeyVal]
        PAUSE       15
        GOTO AdjV2Again
AdjV2Over:
        SEROUT FM,Baud,[Peeprom,B_2,"0"]
        PAUSE       15
AdjV2Again:
        GOSUB DisplayLCD
        B_2 = B_2 + 1
        If B_2 = $0E then AdjV2Again
        If B_2 = $10 then AdjustV2
        GOTO        AdjV2Continue
AdjV2Done:
        GOSUB Limits
        RETURN
ResetSupply:
        GOSUB       Reset                           ' Implement reset command
        GOSUB DisplayLCD                            ' Update display
        RETURN
'*******************************************************************
' Keyfind looks for a logic high on the KEY pin (IN2). If one is present then the Read Key Buffer command
' for the MEMKey is implemented. There is enough RAM allotted in the SERIN command to read a maximum
' buffer size of 8 bytes. It is likely that only one key value will be returned since the typematic rate
' has been truned off in the MEMKey. The SERIN "escape clause" has been set to 50ms to ensure that
' the serial communication does not hang up the program. Once this subroutine is entered it will not
' exit until a key has been pressed. When it does exit the key value will be loaded into the KeyVal
' variable.
'
KeyFind:
                If IN2 <> 1 Then KeyFind            ' Check the KEY pin for a logic high
                SEROUT FM,Baud,[Rbuffer]            ' Read buffer command
                SERIN
TM,Baud,50,DoneBuffer,[KeyVal,B_3,B_4,B_5,B_6,B_7,B_8,B_9]
DoneBuffer:
                SEROUT FM,Baud,[Rbuffer]            ' If there is a fast key press don't accept it
                PAUSE   40
                If IN2 <> 0 then DoneBuffer         ' Wait for KEY pin to go to logic low
                RETURN
'*******************************************************************************
***********
' The Limits subroutine checks entered values for out of range or mis-keyed entries. If either
' voltage input is greater than 10.0 or less than 03.0 then the values are forced to either the
' minimum or maximum values accepted. Prior to this routine being exited the ">" character
' that was loaded next to the adjusted voltage is replaced with a space character.
'
Limits:
                SEROUT FM,Baud,[Reeprom,$04]        ' Read tens character of voltage on line 1
                SERIN TM,Baud,[B_1]
                If B_1 > "0" then ZeroOnesV1        ' Check to see if tens is greater than "1"
                If B_1 = "0" then TestOnesV1        ' Check to see if tens is a zero
                GOTO    NextLimit
ZeroOnesV1:
                SEROUT FM,Baud,[Peeprom,$04,"1"]    ' If tens is greater than "1" then force display
                PAUSE   15                          ' to "10.0". The "." is not adjusted
                SEROUT FM,Baud,[Peeprom,$05,"0"]
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$07,"0"]
                PAUSE   15
                GOTO NextLimit
TestOnesV1:
                SEROUT FM,Baud,[Reeprom,$05]        ' If tens is "0" the read ones character
                SERIN TM,Baud,[B_1]
                If B_1 > "2" then NextLimit         ' Check to see if ones is less than "3"
                SEROUT FM,Baud,[Peeprom,$05,"3"]    ' If so then force display to "03.0"
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$07,"0"]
                PAUSE   15
NextLimit:
                SEROUT FM,Baud,[Reeprom,$0C]        ' Test voltage on line 2 as line one was tested
                SERIN TM,Baud,[B_1]
                If B_1 > "0" then ZeroOnesV2
                If B_1 = "0" then TestOnesV2
                GOTO    DoneLimit
ZeroOnesV2:
                SEROUT FM,Baud,[Peeprom,$0C,"1"]
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$0D,"0"]
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$0F,"0"]
                PAUSE   15
                GOTO    DoneLimit
TestOnesV2:
                SEROUT FM,Baud,[Reeprom,$0D]
                SERIN TM,Baud,[B_1]
                If B_1 > "2" then DoneLimit
                SEROUT FM,Baud,[Peeprom,$0D,"3"]
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$0F,"0"]
                PAUSE   15
DoneLimit:
                SEROUT FM,Baud,[Peeprom,$03," "]    ' Replace either ">" with a " "(space)
                PAUSE   15
                SEROUT FM,Baud,[Peeprom,$0B," "]
                PAUSE   15
                GOSUB   DisplayLCD
                RETURN
'******************************************************************************' The
UpdateSupply routine uses the Analog1 and Analog2 values to approximate the
' appropriate digital potentiometer settings. Once the potentiometer is adjusted a For
' Next loop is used to trim the output voltages. If the desired A/D measurement
' stored in the Analog register matches the actual A/D reading in the AD_in
' register the no adjustments to the digital pot are made. Otherwise the
' potentiometer setting is incremented or decremented to trim the voltage until
' the A/D reading is in line with the desired value.
' Trimming is attempted 10 times, with 50ms allotted for settling time between
' adjustments. I found that this system lacked resolution at voltages above about
' 8.5V. For this reason if the digital pot setting is less than 20 I settle for
' a an A/D match within 2 bits of the desired value (± 160mV). If, after trimming
' is attempted, the desired A/D value is not reached then the program jumps to
' an out of regulation section. This portion of the code updates the display
' to the actual voltage output, and lights the "out of regulation" LED to
' inform the user that the output voltage has been adjusted.
'
UpdateSupply:
        LOW         LED_control
        DSpots1 = (2376/(Analog1 - 28)) -14         ' Equation to estimate the desired pot setting(V1)
        DSpots2 = (2304/(Analog2 - 28)) -14 '       Equation to estimate the desired pot setting(V2)
        GOSUB       SetPotValue                     ' Update pot settings
'
TrimV1:
        For Index = 1 to 10                         ' Trim voltage 10 times
                GOSUB       ReadAnalogs
                If AD_in1 = Analog1 then DoneV1     ' If on first 7 trims then adj. by 1s
                If Index < 8 then NoMinV1
                If DSpots1 > 20 then NoMinV1        ' If pot setting > 20 then adj. by 1s
                If AD_in1 = (Analog1+2) then DoneV1' Otherwise accept +/- 2 bits as accurate
                If AD_in1 = (Analog1-2) then DoneV1
NoMinV1:
                If AD_in1 > Analog1 then IncDSpots1 ' Reduce output voltage
                DSpots1 = DSpots1 - 1
                GOTO        DoneV1
IncDSpots1:
                DSpots1 = DSpots1 + 1               ' Increase output voltage

DoneV1:
                If AD_in2 = Analog2 then DoneV2     ' V2 follows same adjustment rules as V1
                If Index < 8 then NoMinV2
                If DSpots2 > 20 then NoMinV2
                If AD_in2 = (Analog2+2) then DoneV2
                If AD_in2 = (Analog2-2) then DoneV2
NoMinV2:
                If AD_in2 > Analog2 then IncDSpots2
                DSpots2 = DSpots2 - 1
                GOTO        DoneV2
IncDSpots2:
                DSpots2 = DSpots2 + 1

DoneV2:
                GOSUB       SetPotValue             ' Update pot settings after trimming
                Pause       50                      ' Allow 50ms for voltages to settle
        NEXT                                        ' Trim up to 10 times
'
        GOSUB       ReadAnalogs                     ' Read in analog voltages
        If AD_in1 = Analog1 then TestOutOfReg2      ' Find the differences between desired
        Working = Analog1 - AD_in1                  ' and actual A/D readings
        If Working < 3 then TestOutOfReg2           ' If < 3 then all OK
        Working = -Working                          ' If > 3 see if AD_in was > Analog by complimenting
        If Working < 3 then TestOutOfReg2           ' If compliment < 3 then all OK
        GOTO OutOfReg1                              ' Not OK so out of regulation
TestOutOfReg2:
        If AD_in2 = Analog2 then DoneOOR2           ' Test analog and AD_in 2 for settings
        Working = Analog2 - AD_in2
        If Working < 2 then DoneOOR2
        Working = -Working
        If Working < 2 then DoneOOR2
        GOTO OutOfReg2
DoneOOR2:
        GOSUB       DisplayLCD                      ' Update display values
        RETURN
'
OutOfReg1:
        HIGH        LED_control                     ' Light out of range LED
        If AD_in1 < 129 then NoChangeAD_in1         ' Make sure A/D is under 10V
        AD_in1 = 128
NoChangeAD_in1:
        Working = (AD_in1 * 200) / 256              ' Translate actual A/D value to ASCII
        B_1 = (Working / 100) + 48                  ' Calculate ASCII hundreds digit from AD meas.
        SEROUT FM,Baud,[Peeprom,$04,B_1]            ' Program MEMKey EEPROM with new value
        PAUSE       15
        B_2 = (Working / 10)                        ' Calculate ASCII tens digit from AD meas.
        If B_2 < 10 then SkipSub1
        B_2 = B_2 - 10
SkipSub1:
        B_2 = B_2 + 48
        SEROUT FM,Baud,[Peeprom,$05,B_2]            ' Program MEMKey EEPROM with new value
        PAUSE       15
        If Working < 100 then SkipSub2
        Working = Working - 100
SkipSub2:
'
        B_3 = (Working - ((Working/10)*10)) + 48    ' Calculate ASCII ones digit from AD meas.
        SEROUT FM,Baud,[Peeprom,$07,B_3]            ' Program MEMKey EEPROM with new value
        PAUSE       15
        GOTO TestOutOfReg2

OutOfReg2:
        If AD_in2 < 129 then NoChangeAD_in2         ' Update V2 as V1 was updated
        AD_in2 = 128
NoChangeAD_in2:
        Working = (AD_in2 * 200) / 256
        B_1 = (Working / 100) + 48
        SEROUT FM,Baud,[Peeprom,$0C,B_1]
        PAUSE       15
        B_2 = (Working / 10)
        If B_2 < 10 then SkipSub3
        B_2 = B_2 - 10
SkipSub3:
        B_2 = B_2 + 48
        SEROUT FM,Baud,[Peeprom,$0D,B_2]
        PAUSE       15
        If Working < 100 then SkipSub4
        Working = Working - 100
SkipSub4:

        B_3 = (Working - ((Working/10)*10)) + 48
        SEROUT FM,Baud,[Peeprom,$0F,B_3]
        PAUSE       15
        GOTO DoneOOR2
'
'******************************************************************************
' The SetPotValue shifts the pots settings out to the DS1267-010.
'
SetPotValue:
        HIGH CS_Pot
        PULSOUT Clk,10
        SHIFTOUT Dat,Clk,msbfirst,[DSpots\16]
        LOW CS_Pot
        PAUSE       10
        RETURN
'******************************************************************************
' The ReadAnalogs routine reads in the actual output voltages from the ADC0831 8 bit A/Ds.
'
ReadAnalogs:
        LOW CS_ad1
        SHIFTIN Dat,Clk,2,[AD_in1\9]
        HIGH        CS_ad1
'
        LOW CS_ad2
        SHIFTIN Dat,Clk,2,[AD_in2\9]
        HIGH        CS_ad2
        RETURN
'******************************************************************************
END:
```

Making RS-232 Interfaces Work

by Gerald Roylance

The RS-232 interface is one of the most common ways of getting information into and out of a computer. Although originally intended for connecting a modem to a computer, the interface has been widely used for connecting devices such as test equipment, weather stations, PROM programmers, and signal digitizers. Sadly, many of these devices disobey the RS-232 standard, and that causes headaches and hung computers. Misunderstandings about the RS-232 interface have buried us in a profusion of swapped pins, gender changers, breakout boxes, and hydra-headed cables.

RS-232 is a well thought out standard for interfacing computers (or terminals) to modems. Remembering that RS-232 is about connecting computers to modems is the first step in understanding RS-232. ***RS-232 was never intended to directly connect a computer to another computer. RS-232 connects a computer to a modem.***

Unfortunately, many of today's RS-232 applications do the unintended. We connect computer-to-computer, computer-to-terminal, computer-to-printer, and computer-to-digital voltmeter using RS-232 interfaces — all without apparent modems. RS-232 did not intend these applications, and it is not surprising that confusion reigns.

> ***RS-232 was never intended to directly connect a computer to another computer. RS-232 connects a computer to a modem.***

The secret to understanding RS-232 is recognizing the phantom modems, because the modems have to be there for RS-232 to work. The modems may be disguised as swapped pins, or a voltmeter may masquerade as a modem. Before delving into the details of RS-232, let's show what an RS-232 user should see in an ideal world.

The Rational RS-232 World

Many RS-232 products are irrational. My local computer store has an aisle full of RS-232 accessories. There are cables of different lengths, different connector combinations, and different wiring. There are gender changers, null modems, and break out boxes. Surprisingly, most of these products are incompatible with RS-232. Although the store sells five different models of null modems, each model violates the RS-232 specifications. If everybody followed the rules, the world would be much simpler.

The connectivity requirements of RS-232 are summarized in three rules, but first we must get two definitions out of the way. The standard refers to computers and terminals as Data Terminal Equipment (DTE), and it refers to modems as Data Communications Equipment (DCE). Here are the connectivity rules.

Rule 0. RS-232 connects Computers and Terminals (DTE) with Modems (DCE).

Rule 1. Computers and Terminals (DTE) must present male connectors.

Rule 2. Modems (DCE) must present female connectors.

For a practical introduction to these rules, look at the back of your computer, and you should see a male RS-232 connector. Figure 1 shows the back of my computer with its RS-232 connectors. If you have an external modem, then it should have a female connector.

These rules must be followed all the time. If you see a male RS-232 connector, then it better be a DTE interface. If the connector is female, then it better be a DCE interface. The rules still apply after you connect a cable. If you plug an ordinary cable into the male DTE connector on your computer, then the free end of that cable should still present a male (DTE) connector. RS-232 demands that the sex of the connector indicate its use. Figure 2 shows how RS-232 interfaces connect two computers. When you look at the figure, pay attention to the sex of the connectors.

These three rules show that many computer store products violate the RS-232 standard. Gender changers, for example, violate Rule 1 or Rule 2. Consider plugging a female-female gender changer into a DTE connector. The free end of the gender changer presents a female connector, but the internal wiring didn't change (it is still DTE), and that violates Rule 1. Similarly, using a male-male gender changer on a DCE interface violates Rule 2. Any cable whose pins are connected straight through and has the same sex connector on each end is just an extra-long gender changer, so such a cable also violates RS-232.

A null modem simulates the back-to-back connection of two modems (it should be called a null dual modem). Figure 2 shows how a null modem fits into the RS-232 framework. Both sides of the null modem are DCE, so a null modem (or null modem cable) must present two female connectors. A null modem with a male connector violates Rule 2, but my computer store sells several.

What should the computer store sell? If all equipment followed the RS-232 standard, then the only accessories you need are:

1. Null modems with female connectors on each end and the proper wiring (see null modem sidebar).

2. Various RS-232 cables with a male connector on one end and a female connector on the other end. The wiring should be straight through

Figure 1. The back of my computer and its DTE interface. The top bracket has two DTE ports — a male DB25 and a male DB9. The female DB25 is the printer port (which is not RS-232).

(i.e., no twists or "null modem" cables) and should include pins 1-8, 20, and 22. These cables are RS-232 extension cords.

These accessories guarantee correctly connecting RS-232 devices. You can use an extension cord to connect a computer and a modem, but you cannot connect a computer to a computer (or a modem to a modem) because the connectors won't mate. When you try to connect a computer to a computer with an extension cord, you run into the problem of trying to plug a male connector into another male connector. This mismatch tells you to use a null modem. If you can plug the devices together with the approved accessories, then the connection must be right. Unfortunately, this utopia is destroyed when someone introduces a gender changer or some other incompatible product.

Although a null modem cable with female connectors on both ends obeys the RS-232 rules, you don't need such a cable because it is just an extension cord with a null modem plugged into one end. Extension cords are more useful than null modem cables, so I always buy the extension cords. It's also easier to think about cables being wired straight through. The only time I use null modem cables is when the wiring runs in the walls of the building, and I want the walls to look like DCE.

In a perfect world, you would never use a gender changer. But the world is imperfect, and I use gender changers to fix RS-232 design errors. When an ignorant manufacturer uses the wrong sex connector, I use a gender changer to fix the device — and I'm tempted to epoxy the gender changer in place.

If you follow the rules, then your RS-232 connections should be painless. Now let's look at the details of the standard.

The RS-232 Standard

The standard includes a set of signals, which is described next. After that description, we show how a typical interface operates.

RS-232 Signals

Table 1 lists the RS-232 signals and pin assignments. Although there are many defined signals, only three pins (SG, TXD, and RXD) actually send data back and forth. Devices that use only these three pins should be called serial interfaces. An RS-232 interface requires the first seven signals in the table, and a practical RS-232 interface should include DTR and DCD. Many interfaces also include RI, and the other signals are rare.

There are four interface signal classes: grounds, data signals, control signals, and clock signals. Each signal has a standard signal designation (e.g., BA), a description (e.g., transmitted data), and a common signal designation based on the description (e.g., TXD). The CCITT uses numbers for its standard designation (e.g., EIA's BA is CCITT's 103), and some of those numbers are given. The RS-232 standard specifies a 25-pin connector, but it did not assign all the pin numbers. The IBM PC adopted a nine-pin connector, and its pin assignments are also in the table.

Signal Levels

The RS-232 standard uses bipolar signal levels. The signal characteristics are loose, but the pin voltage should be 5 to 25 volts for a positive voltage level and −5 to −25 volts for a negative voltage. These voltage levels are interpreted differently for data signals and control signals.

For data signals, the negative voltage represents a binary 1 (also called a mark or a marking level), and the positive voltage represents a binary 0 (also called a space). An idle line (no data being transferred) is held in the marking state (binary 1).

For control signals, a positive voltage represents ON, and a negative voltage represents OFF. The standard further requires that RTS, DTR, and DSR be fail-safe signals. These signals are interpreted as OFF even when half of the interface is powered down. This requirement has several benefits, such as turning off your computer turns DTR OFF, which tells your modem to hang up the phone, which saves long distance charges.

Grounds

Circuit AA. Protective Ground (FG). This circuit is the chassis ground (the green lead on the power supply connector).

Circuit AB. Signal Ground (SG). All the data and control lines share the signal ground wire.

Data

Circuit BA. Transmitted Data (TXD). The DTE should supply data only when CTS is ON.

Circuit BB. Received Data (RXD).

Control

Circuit CA. Request To Send (RTS). The DTE asserts RTS when it has something to transmit. When the DCE receives RTS, it should turn on its transmitter or modulator. In half-duplex operation, this signal determines whether the DCE is receiving or transmitting. In receive-only applications, RTS must be held OFF.

Circuit CB. Clear To Send (CTS). The DCE responds to RTS by asserting CTS when the communications channel is ready to transmit. When RTS goes OFF, CTS must also go OFF.

Circuit CC. Data Set Ready (DSR). DSR says the DCE is ready to operate. The signal is OFF when the data set is disabled or impaired. If the telephone is on hook, then DSR is OFF. DSR describes the local status of the DCE and does not imply connection to another modem.

Circuit CD. Data Terminal Ready (DTR). DTR ON tells the DCE to connect to the communications channel (go off hook). DTR OFF means disconnect the DCE from the communications channel (go on hook).

Circuit CE. Ring Indicator (RI). RI ON says the phone is ringing, and RI is asserted even if DTR is OFF.

Circuit CF. Data Carrier Detector (DCD). DCD indicates reception of a data carrier. OFF indicates the end of transmission or an error (e.g., a weak carrier signal).

Many control signals have been superseded by other methods. The speed controls, for example, worked fine for a two-speed modem, but modern multi-speed modems use the AT command set.

Clocks

The clock signals have disappeared from most RS-232 interfaces. All fast modems are synchronous, and early synchronous modems needed these clock signals. Most computer interfaces did not have these clock signals, so modem manufacturers got rid of the clock signal requirement by putting synchronous to asynchronous converters in their modems. Today RS-232 is almost synonymous with asynchronous signalling.

The clocks are 50% duty cycle. The falling edge of circuit DA marks the center of the data on BA (TXD). The rising edge of circuit DB coincides with changing data on circuit BA. The falling edge of DD is the center of the data on BB (RXD).

Typical Control Sequence

The DTE and DCE control signals perform a handshaking protocol. At each step, both sides must understand what can happen next, and the control lines provide that introduction. Here is a typical sequence, but many other variations are

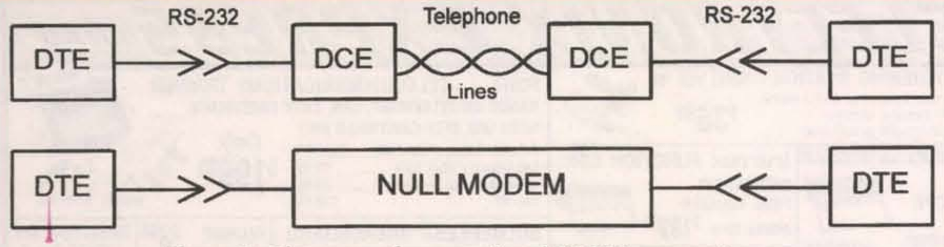


Figure 2. Diagrams of conventional RS-232 connections.

Table 1. RS-232 Signals

25 Pin	[9 Pin]	Circuit	Source	Common	Description
1†		AA 101	-	FG	Protective Ground
7†	5	AB 102	-	SG	Signal Ground
2†	3	BA 103	DTE	TXD	Transmitted Data
3†	2	BB 104	DCE	RXD	Received Data
4†	7	CA 105	DTE	RTS	Request To Send
5†	8	CB 106	DCE	CTS	Clear To Send
6†	6	CC 107	DCE	DSR	Data Set Ready
20	4	CD 108	DTE	DTR	Data Terminal Ready
22	9	CE 125	DCE	RI	Ring Indicator
8	1	CF 109	DCE	DCD	Data Carrier Detector
		CG	DCE		Data Modulation Detector
23*		CH	DTE		Speed Selector
12*		CI	DCE		Speed Selector
24		DA	DTE		Trans. Signal Element Timing
15		DB	DCE		Trans. Signal Element Timing
		DC	DTE		Rcvr. Signal Element Timing
17		DD	DCE		Rcvr. Signal Element Timing
21*		RL	DTE	RDL	Remote Digital Loopback
9*		+P	DCE		+12V through 1K resistor
10*		-P	DCE		-12V through 1K resistor

†RS-232 requires that this signal be present.
*These pin assignments are common, but are not specified in the standard.
RS-232 calls for a 25-pin connector, but many PCs use a DB9 connector.
RS-232 reserves pins 9 and 10 for DCE tests; they must be left open in DTE equipment.

possible.

The initial state is all control signals are off and both sides of the interface are asleep (i.e., not ready). The DTE usually starts things off by asserting data terminal ready (DTR), which tells the DCE to wake up. When the DCE is ready, it asserts DSR. At this point both sides are powered up and ready to exchange other control signals, but DSR doesn't imply contact with a remote modem. DTR and DSR will stay ON for the duration of the connection. When both sides are ready, then it is possible to transfer data.

If the DCE side has some data to give the computer (DTE), it first asserts data carrier detect (DCD), and then it sends the data over the received data line (RXD). A data carrier indicates a connection, and it is one reason that an answering modem spits out a carrier tone.

When the DCE has transferred its data, it may drop DCD (half-duplex communications) or it may leave DCD asserted for the duration of the connection (full duplex). Most connections can transmit and receive simultaneously (full duplex), but some connections (e.g., packet radio) are half-duplex.

If the DTE side has some data to send, it first asks the DCE for permission by asserting a request to send (RTS). The DCE grants permission by asserting clear to send (CTS), and then the DTE starts sending the data. In a half-duplex environment, the DTE drops RTS when it has no more data to send. In a full duplex environment, the DTE will leave RTS asserted for the duration of the connection. When the DTE is finished with the connection, it will drop DTR, essentially telling the DCE side to hang up the connection. The DCE responds by dropping DSR, and the connection is back to its initial state.

Implications for Hardware Designers

If your hardware is a modem, then following the standard is pretty clear. An RF modem, for example, would turn the transmitter on when RTS is asserted. If your hardware isn't a modem, then following the standard isn't so obvious. You can make your equipment look like DTE or DCE. Although a DTE interface seems more appropriate if the hardware includes a microcomputer, a DTE interface requires a null modem to connect it to a computer. If the hardware will be directly connected to a computer, the DCE interface is more convenient.

Once you have decided on the type of interface, then you must decide how to supply the RS-232 control signals. Adding the control signals – even if they are just tied high or jumped – makes your project more robust and reduces software problems. If you supply the control signals, then the computer won't hang because it doesn't see DSR or CTS. Furthermore, the computer can use the RS-232 control lines to determine if the device is connected – no DSR means the device isn't there. After all, that's what the RS-232 signals were intended to do.

If you make your hardware look like DTE, then you should supply two control signals, DTR and RTS. At a minimum, power on should assert DTR (the device is asking for a connection to the communications channel). If the device transmits data, then pull RTS high. If it doesn't transmit data, pull RTS low. If you can, obey the CTS signal from the DCE.

If your hardware looks like DCE, then you must supply DSR, DCD, and CTS. Either jumper DSR to DTR or have power on pull DSR high (better). A clever implementation can power down if DTR is OFF. If the device outputs data, then DCD can follow DSR; if no data is output, then pull DCD low. If the device doesn't take input, pull CTS low; if the device takes input, then at least connect CTS to RTS.

I favor the DCE wiring for devices that connect directly to a computer (such as a scale or voltmeter). Even quick and dirty projects can meet the RS-232 signaling convention with two jumpers. The first jumper connects DTR to DSR and DCD. The second jumper connects RTS to CTS.

Programming the Interface

Not only must the hardware be correct, but the software must also work. From a programming standpoint, you are much better off using standard library functions to talk to a serial port rather than programming the hardware directly. Library routines allow the programmer to set the baud rate, data format, and control lines without getting lost in details about specific I/O registers. Sadly, the library calls vary widely among operating systems and programming languages.

In general, the program should supply all the required RS-232 interface signals so an RS-232 device will wake up and respond correctly. If the program fails to assert DTR, then an RS-232 device may not wake up. If the program doesn't assert RTS, then the RS-232 device may ignore everything on TXD. The program must supply these signals to avoid a catatonic connection.

The program should also obey the DCE signals DSR, CTS, and DCD. These signals tell your program that a connection exists and prevent the hardware from being overwhelmed with data. It's easy to make your hardware RS-232 compatible (only two jumpers), so all of your projects can follow this convention.

When your program must talk to existing (non-RS-232) hardware, things get ugly. The best option is to use RS-232 control signals in your program and correct the hardware deficiency with an adapter that does the RS-232 control handshake (see sidebar about adapters). That way, your program can recognize a disconnected device rather than just blasting bits. Alternatively, the program can ignore DSR, CTS, and DCD – but it should still assert DTR and RTS. The penalty for ignoring these control lines is often more involved programming.

Programming in Basic

I looked for authoritative advice on programming the serial port with Basic, but the only relevant documents I found were some knowledge base articles (Q39342, Q39386, and Q94007) on the Microsoft Developer Network. You can find these articles at http://msdn.microsoft.com. The information is sketchy.

The open statement should look something like

```
OPEN "COM1:1200,N,8,1,BIN,CD0,CS0,
DS0,OP0,RS,TB2048,RB2048" AS #1
```

This statement opens the port COM1 at 1200 baud, no parity bit, eight data bits, and one stop bit. Other combinations of parity, data, and stop bits are possible, but make little sense because almost all links are (N,8,1). Trying to guarantee the eighth bit is zero by specifying (N,7,2) is a poor practice (it sets the eighth bit at the other end!); what you want is (S,7,1), but you are bet-

Helpful Adapters

Special adapters make debugging and fixing troubled RS-232 connections easier.

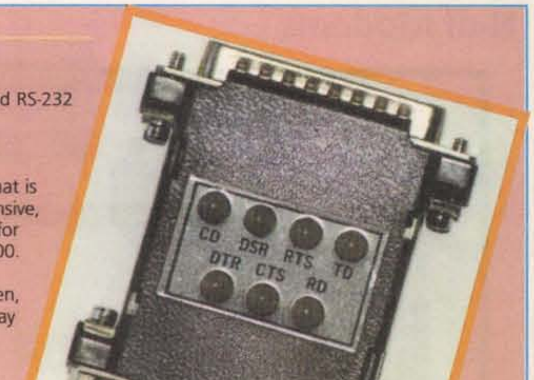


Figure 3. RS-232 Line Analyzer. Dual-color LEDs indicate signal values.

RS-232 Line Analyzer

An RS-232 analyzer is the quickest way to see what is going on. Many years ago, these adapters were expensive, but today RadioShack sells its 276-1401 line analyzer for $15.00, and I bought the analyzer in Figure 3 for $8.00. The analyzer's two color LEDs display the line state: green for ON and red for OFF. If the signal is not driven, then neither color lights. External modems often display this line status information, and some terminal programs do the same.

The analyzer displays the crucial control signals, and it quickly uncovers problems with the control handshaking. A flickering TXD or RXD indicates data transfer. If you are writing software, use an analyzer to confirm your code.

RS-232 violations are easy to spot, too. If a device presents a female connector (DCE) but lights the TXD LED, then the interface is wrong. Of course, this task would be easier if the LED layout in Figure 3 were better; the DTE-driven LEDs and the DCE-driven LEDs should be in separate groups. The signals DTR, RTS, and TXD should be next to the female connector (bottom connector in photo), and the LEDs for DSR, CTS, RXD, and DCD should adjoin the male connector (top connector).


Figure 6. Nine-Pin to 25-Pin Adapters.

Loopback Modem

A loopback adapter (Figure 4) quickly tests a COM port and instills confidence in a program. The loopback adapter echoes every character sent. It makes a terminal program behave as a typewriter, and some simple write and read statements will verify your programming ability. The loopback adapter manages all the modem control signals, and it is insensitive to baud rate. If you cannot make a COM port work with a loopback adapter, then something is seriously wrong.

The loopback adapter is a DCE device, so it has a female connector. DTR returns DSR, and transmitted data is copied to received data. RTS asserts both CTS and DCD.

Local Control Loopback Adapter

If you have a program that wants the control signals, but the hardware doesn't supply them, then you can use this adapter (Figure 5). It generates the DCE control signals locally but sends the data through. Asserting DTR responds with an immediate DSR and DCD. RTS produces a CTS so the transmit data doesn't hang.

9 to 25 pin adapters

RS-232 specifies 25 pin connectors, but IBM PC clones use nine pin connectors to save space. To handle these transitions, you need two adapters: a male nine-pin to a female 25-pin, and a female nine-pin to a male 25-pin connector (see Figure 6).

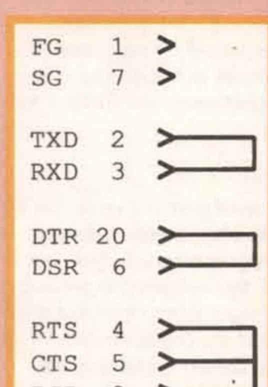
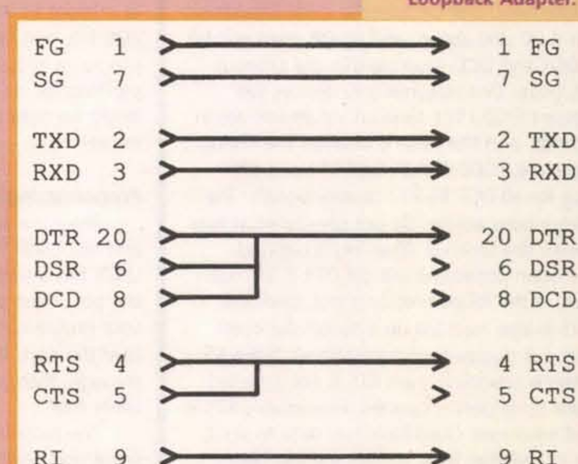


Figure 4. Loopback Adapter.

Figure 5. Local Control Loopback Adapter.



Null Modems

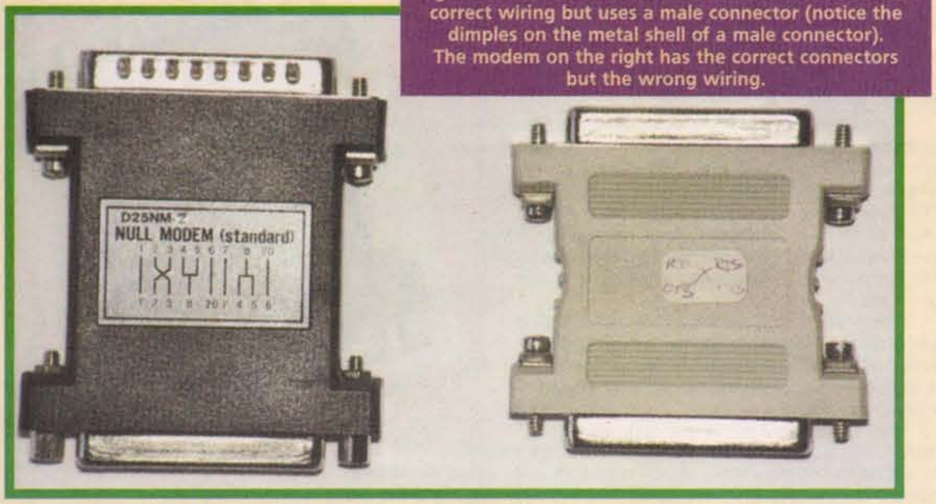


Figure 8. Null modems. The modem on the left has the correct wiring but uses a male connector (notice the dimples on the metal shell of a male connector). The modem on the right has the correct connectors but the wrong wiring.

A null modem must not only have female connectors on both ends, but it must also properly interact with the DTE interfaces, and that determines the internal wiring of the null modem. Commercial null modems offer many different internal wirings, and most are flawed. Some null modems even have asymmetrical wiring, but that defies reason.

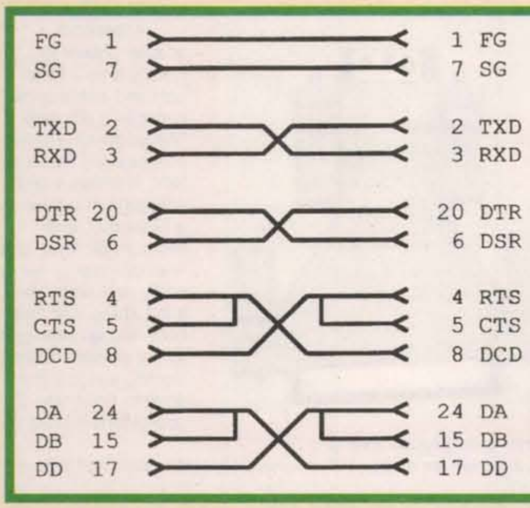


Figure 7. Standard Null Modem Wiring.

The reasonable wiring for a null modem is shown in Figure 7. The grounds are connected straight across, and the transmit and receive circuits are swapped. The control signals are more involved. Asserting DTR on one side asserts DSR on the other. To make half-duplex signals work, asserting RTS produces an immediate CTS on the same side and issues DCD on the far side. The null modem can also distribute the synchronous (but rarely used) clock signals by connecting the DTE's transmitter element timing signal (DA) to DB and DD.

My computer store does not sell a good null modem. Figure 8 shows a null modem with the proper internal wiring, but the adapter has male (DTE) connector that violates the RS-232 specification. Figure 8 also shows a null modem with two female connectors, but it has the wrong wiring. The wiring is called "Full Handshake," but it misinterprets the RTS control signal.

ter off with (N,8,1) and keeping your application eight-bit clean. To test for parity errors, you must add a "PE" option after the number of stop bits, but very few applications use parity. The BIN parameter is the default, but it makes it clear that you don't want ASC.

The CDm, CSm, DSm, and OPm parameters set the timeouts for DCD, CTS, DSR, and the open statement. The OP timeout is for QuickBasic versions 4.00 and above, and an OP open will fail unless DSR and DCD assert within the timeout interval. (Note that transmit-only devices will never assert DCD.) The timeout values (m) are in milliseconds, and the value 0 disables the check. Consequently, "CD0,CS0,DS0,OP0" turns off checking for all DCE RS-232 control signals. The knowledge base articles do not specify what happens when the timeout value (m) is omitted.

The open command will set DTR if the open succeeds. If the RS parameter is not specified, then RTS is also asserted on a successful open (assumes full duplex communications). If the RS parameter is specified, then RTS is not asserted when the serial port is opened. Presumably RTS is asserted whenever QuickBasic has data to send, but the knowledge base articles are not clear.

The TB and RB commands set the size of the transmit and receive buffers, but these commands are needed only for high-speed communications.

Microsoft describes the above OPEN statement as tolerant because it ignores handshaking. Your code will be better if you use non-zero timeouts for the control signals and check for errors.

To compound the problem of debugging RS-232 code, Microsoft has confirmed bugs in several versions of Basic for MS-DOS (Visual Basic 1.0, PDS 7.1, and QuickBasic 4.5). The bugs cause programs to hang unexpectedly — even after working for several minutes or hours. Your code might be right but still not work. See Q94007 for details.

Programming in C/C++

Programming the serial port in C under UNIX and Microsoft Windows offers some challenges. UNIX has a sensible programming interface, but the port must be correctly configured to prevent your program and the login demon from fighting over the port. If only half the characters get through, then the login demon is grabbing the other half.

The recommended way of programming the serial port under Windows depends on the version of Windows. If you use OpenComm(), then after opening the port you should call FlushComm() to clear the input and output queues, and then call GetCommError() to enable the hardware. There is a good chance that the hardware saw a framing, overrun, or some other fault, and was disabled. When the hardware is disabled, it doesn't issue any messages to your driver loop, so your program won't see any serial port activity. Procedures such as OpenComm(), SetCommState(), and SetCommMask() don't return errors if the port is disabled; your program must issue a GetCommError() at initialization.

More Complications — Flow Control

Ideally, a modem can take data as fast as the computer can dish it out, and vice versa. This is not true in practice. Initially, computers transferred a character at a time, and it was possible that the computer might be distracted long enough to lose a character. These problems got worse as the data rate went higher and the interrupt loads were heavier. FIFO buffers help, but they can never be deep enough. Modems are complicated, and the data rates on the RS-232 side don't match the data rates on the communication channel. Without flow control, one side or the other will run out of buffer space. To avoid overflowing its buffers, the modem must tell the computer when to stop sending data and when to resume. There are two common methods.

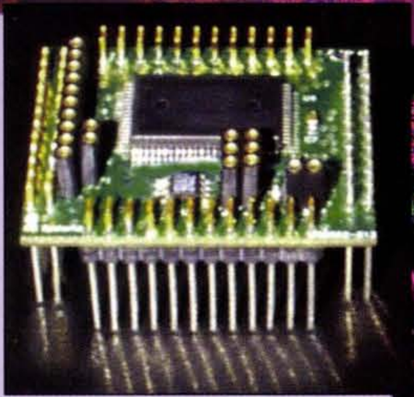
The first method uses control characters in the data stream. The common characters are Control-S and Control-Q. When the transmitter is running out of buffer space, it sends a Control-S to shut the computer up. When enough buffer space is free, a Control-Q tells the computer to resume. Although this method is popular, it has drawbacks. The main problem is Control-S and Control-Q are in-band characters (they could be part of a binary data stream). If data is being transmitted both directions at the same time, we must quote data characters that would be interpreted as flow control characters. Some applications, such as fax modems, can skirt this problem because binary data flows only one way at a time. Consequently, one direction is used for binary data, and the reverse direction is used for Control-S and Control-Q.

The second method is hardware flow control. This method uses out-of-band signaling, so binary data can flow both ways at the same time. Unfortunately, hardware flow control bends the RS-232 rules. A modem can tell the computer to stop sending characters by making CTS go away. Notice that CTS may go away in the middle of transmitting a character; something that RS-232 didn't expect. In fact, several more characters may get transmitted (e.g., the rest of the FIFO) before transmission stops. The receiving end must issue the flow control command well before it actually runs out of buffer (the same is true for software flow control). DSR can also be used for hardware flow control, but CTS is better.

Hardware flow control for data going to the DTE is a harder problem because RS-232 does not have a "Clear To Receive" signal. One method is to toggle DTR, but then the modem must realize that DTR OFF does not mean hang up the phone. Fortunately, a computer can use large buffers and take data faster than a modem can supply it, so flow control in this direction is avoidable. If flow control is required, software flow control (Control-S and Control-Q) will work. NV

New Product News

UNI-MICRO BOARD



OS Systems announces the availability of a new, compact 8051 compatible embedded controller module.

The Uni-Micro board features a combination of memory, digital, and analog I/O that is perfect for instrumentation, monitoring, and control applications.

The Uni-Micro has 128 Kbytes of flash memory, 32 Kbytes of boot/data flash, 256 bytes RAM, a 2-Kbyte battery back-up scratchpad SRAM, 3,000 gates programmable logic, and 54 programmable I/O pins.

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The Uni-Micro sells for $59.99.

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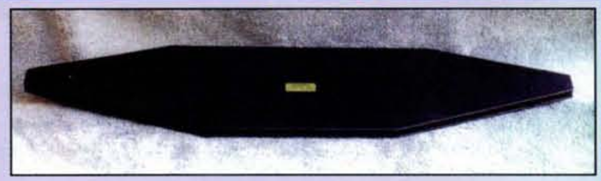

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Matco, Inc. introduces the VGA-801 PC monitor converter, an easy low-cost way of displaying B/W or standard NTSC/PAL color video directly on an existing VGA computer monitor.

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SPECTRUM FOR WINDOWS

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Spectrum for Windows sells for $49.00 and includes drivers for the O-Scope II and the Pico Technology ADC2xx products.

The Spectrum software also includes Spectrum for DOS which comes with drivers for both the ATC O-Scope I and O-Scope II.

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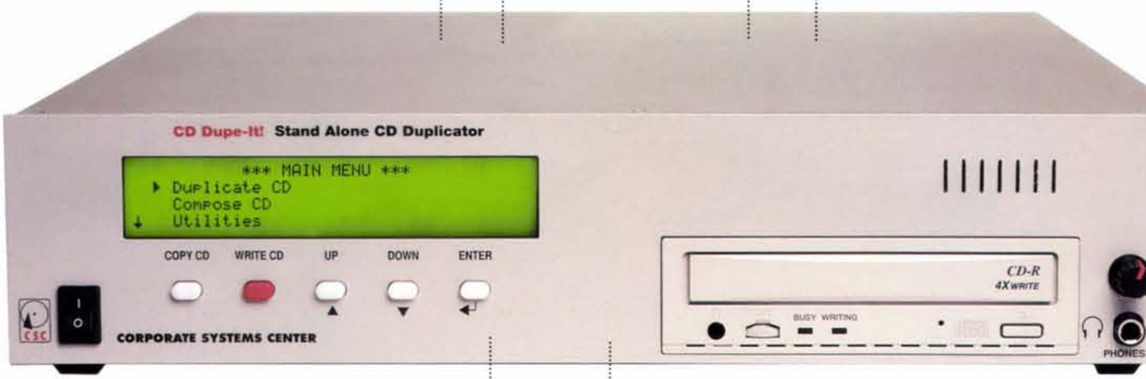

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