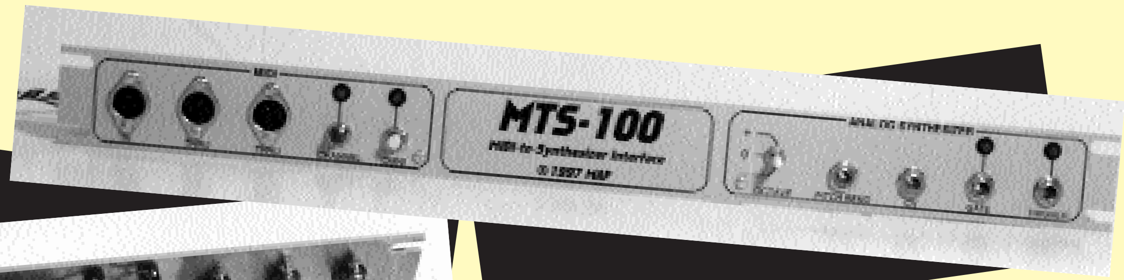
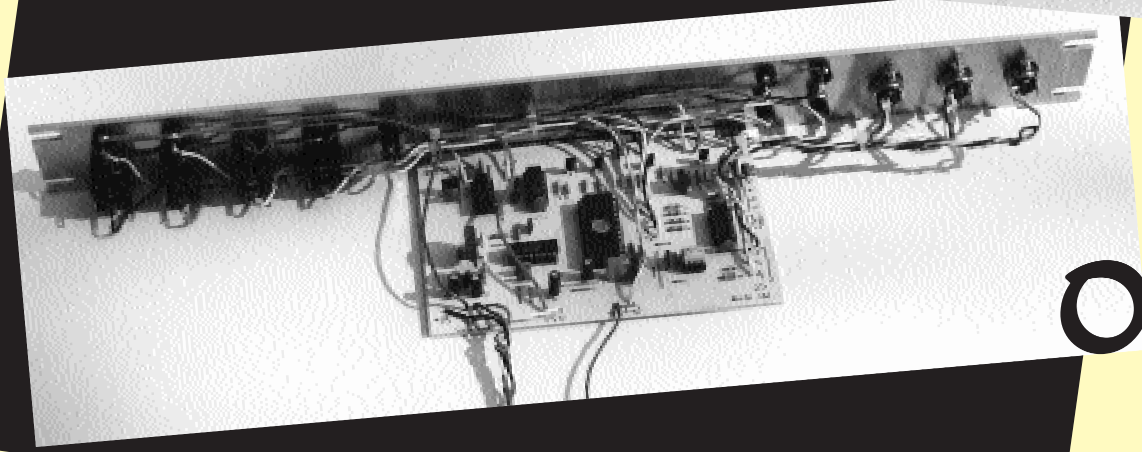
by Thomas Henry





Build Your Own MIDI-to-Synthesizer Interface

Flip through any music or recording magazine and you'll find constant reference to the fact that we're in the midst of an analog synthesizer revival. Indeed, more and more musicians are dusting off their favorite instruments of yesteryear and hauling them into the studio or onto the stage again.

The claim is that these old analog synthesizers have a richer and warmer sound than their modern digital counterparts. The only trouble, though, is that analog units are voltage-controlled, whereas virtually all modern recording and performing equipment is MIDI based.

MIDI is a standard protocol that permits the interconnection of a broad range of musical devices, and then lets them communicate with each other via a digital bit stream.

Well, don't give up on your analog synthesizer just yet, for here's the MTS-100! The MTS-100 is an inexpensive monophonic MIDI-to-Synthesizer interface which lets you add digital control. With it, it's a snap to connect a modern music keyboard or a personal computer running sequencer software to your dinosaur.

The MIDI messages coming down the pike are converted to standard control voltage, gate and trigger formats, perfect for taming most older equipment. And just check out these features:

- MIDI IN and THRU jacks
- 1V/octave control voltage output
- Pitch bend (pitch wheel) control voltage output
- Independent gate and trigger outputs for full retriggerability
- Omni on or off switch and indicator
- Channel switch and indicator
- Recognizes a variety of MIDI Channel Mode messages
- Octave transpose switch extends response with short keyboards
- Fits behind an industry standard 1U rack panel (1-3/4" by 19")

But if you really want to know what the MTS-100 can do, then check out its Implementation Chart in Figure 1. By custom, each piece of MIDI gear is supposed to be provided with just such a chart. It's really nothing more than a standardized way to explain what MIDI features are available, what messages are recognized, etc. Take a moment to review it. After you get a feel for what to expect, then read on to see how the MTS-100 works.

CIRCUIT DESCRIPTION

Since the MTS-100 is really little else than a glorified digital-to-analog converter (DAC), it's convenient to split the schematic into two main parts. In broad terms, Figure 2 depicts the digital side of things, while Figure 3 shows the analog portion.

Refer to Figure 2 now. If you're getting a sense of deja vu, there's a reason! You might recall my ADV-MIDI project which appeared in the Oct. '97 issue of *Nuts & Volts Magazine*.

The purpose of that circuit was to convert incoming MIDI messages to triggers suitable for firing analog drum sets. As it turns out, quite a bit of the input circuitry can be copied over directly. So, we can really buzz through the explanation now. The basics will be described here, but if you need more details or want to refresh your knowledge of MIDI, refer back to the article just mentioned.

A source of MIDI messages (coming from a music keyboard, sequencer, personal computer, etc.) is applied to jack J5. Optocoupler IC1 isolates and translates the electrical signal as required by the MIDI specification. A suitable replica of the bit stream is generated at output pin 6 of IC1.

One path conducts this bit stream directly to input port line PA7 of the MC68705P3 microprocessor. (For brevity, this chip will be referred to as the 68705 from now on.) The bits roll in to the microprocessor one at a time and are properly reassembled into a complete byte under control of the firmware residing within the chip.

Function		Transmitted	Recognized	Remarks
Basic	Default	***	1	
Channel	Channel	***	1-16	note 1
	Default	***	Mode 4	
Mode	Messages	X	Modes 2 or 4	note 2
	Altered	***	Modes 2 or 4	note 3
Note		X	O	
Number	True Voice	***	0-127	note 4
Velocity	Note ON	X	X	
	Note OFF	X	X	
Aftertouch	Key	X	X	
	Channel	X	X	
Pitch Bend		X	O	
Controllers		X	O	note 5
Program		X	X	
Change	True #	***	***	
System Exclusive		X	X	
System	SPP	X	X	
Common	Song Select	X	X	
	Tune Request	X	X	
System	Clock	X	X	
Realtime	Commands	X	X	
Aux	Local ON/OFF	X	***	
	All Notes Off	X	O	note 6
	Active Sensing	X	X	
	Reset	X	O	note 7

Notes:
1. At power-up or during reset, switch S2 can set the MTS-100 to receive on any channel (1-16).
2. The MTS-100 can be set to Omni Off or Omni On either by front panel switch S1, or by an appropriate Channel Mode Message.
3. The MTS-100 is a monophonic device, but is compatible with any MIDI keyboard even if polyphonic. In this case, it simply responds to the most recent Note On message.
4. The MTS-100 can convert all 128 MIDI notes. If using a short keyboard, switch S3 can transpose notes up or down by one octave to extend the output range.
5. The following Channel Mode messages are recognized: Reset All Controllers, All Notes Off, Omni Off, and Omni On. Reset All Controllers sets the pitch bend output to its midposition value.
6. Sending the Omni Off or Omni On commands also turns all notes off, as required by the MIDI 1.0 spec.
7. The current channel can be changed during the Reset sequence, if desired.

Mode 1: Omni On, Poly	Mode 2: Omni On, Mono	O: Yes
Mode 3: Omni Off, Poly	Mode 4: Omni Off, Mono	X: No

Figure 1 — The MTS-100 Implementation Chart

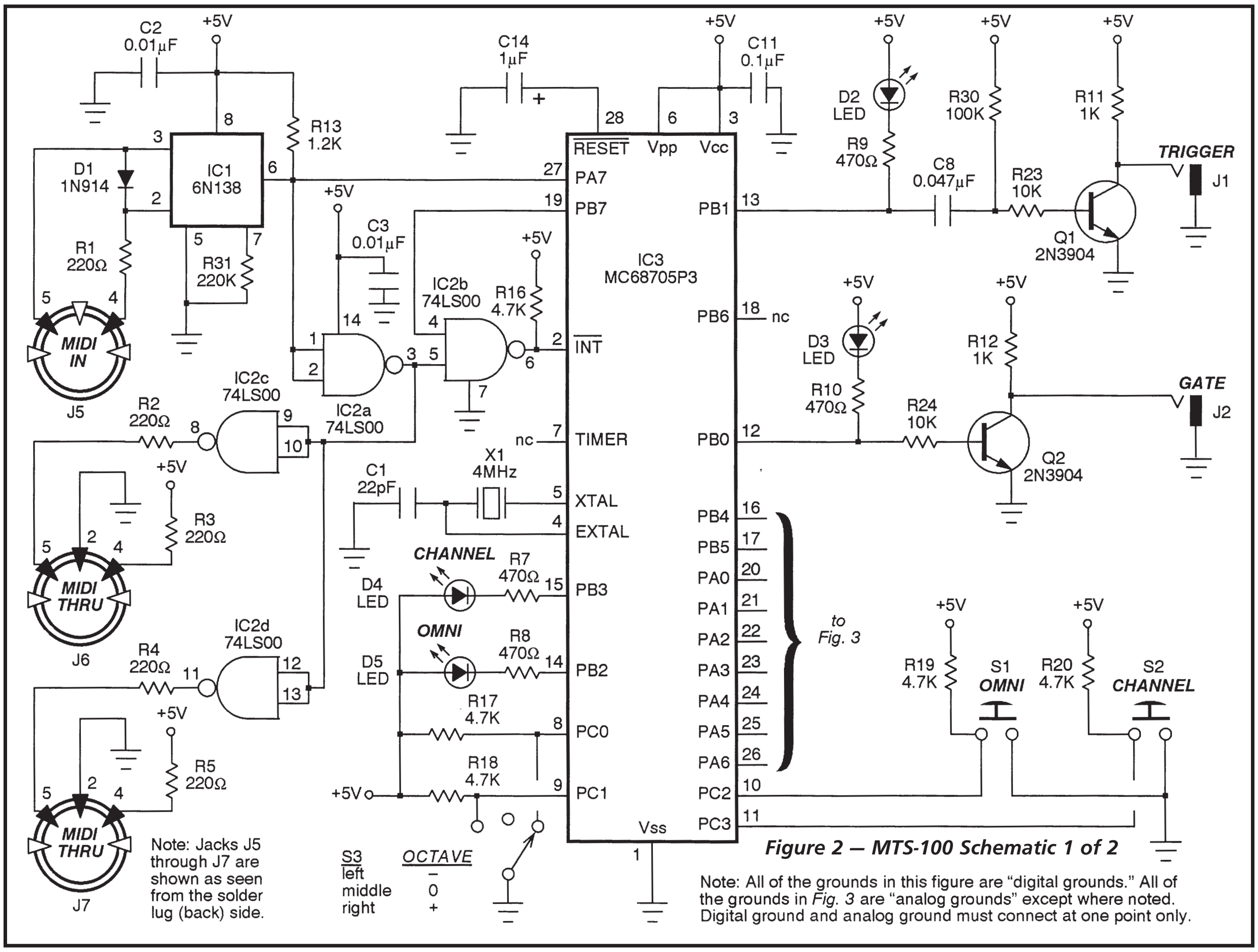


Figure 2 — MTS-100 Schematic 1 of 2

Pin 6 of IC1 also feeds MIDI THRU jacks J6 and J7 by means of the buffers configured around IC2c and IC2d. Again, this is a standard arrangement described in the MIDI specification. The MIDI THRU jacks can be used to daisy chain other equipment to the MTS-100.

Since the MIDI messages are asynchronous in nature (i.e., can occur at any time), microprocessor interrupts are used to dictate when data is to be read in. Once a message is rolling in, it is important that the 68705 not be further interrupted. Thus, IC2b is used to pass or block external interrupts to pin 2 of the 68705, as required.

Switch S1 and LED D5 work in tandem to let the user turn Omni mode on or off from the front panel. Port line PC2 of the 68705 is normally high. Tapping pushbutton S1 once causes this line to momentarily drop low. The microprocessor senses the change and toggles the condition of the Omni status, as well as LED D5. Obviously when the LED is shining, Omni mode is on, and when it is dark Omni mode is off. By the way, you can also turn Omni on or off by sending the standard MIDI Channel Mode message. The LED will still respond as just described.

S2 and D4 also work as a team, in this case to set or test the current channel. At power-up or during reset, the channel defaults to 1. But you can change it to any legal value (1-16) in the following way.

First, with power to the MTS-100 off, press and hold pushbutton S2. Now turn the power on. LED D4 will begin flashing, about once per second. Simply release the pushbutton after witnessing the desired number of blinks, representing the channel. For example, to set the MTS-100 to channel 5, hold S2 closed then turn the power on. After five blinks, release S2.

Once you're up and running, you can also use pushbutton S2 to check what the current channel is, in case you've forgotten it in the meanwhile. Simply tap the switch once. The LED will flash the number of times representing the current channel number. This is a very simple, yet effective method to set or test the channel. And best of all, it uses very little front panel real estate!

Switch S3, which connects to the 68705 port lines PC0 and PC1, can be used to transpose the currently played note up or down by one octave. This is handy if you are driving the MTS-100 with a smaller keyboard which spans less than the 128 notes of the standard MIDI scheme.

If the lowest note on your keyboard is number 36, for instance, then by flipping S3 to the minus position, the internal firmware automatically subtracts 12 (a one octave difference) and spits out the number 24 to the

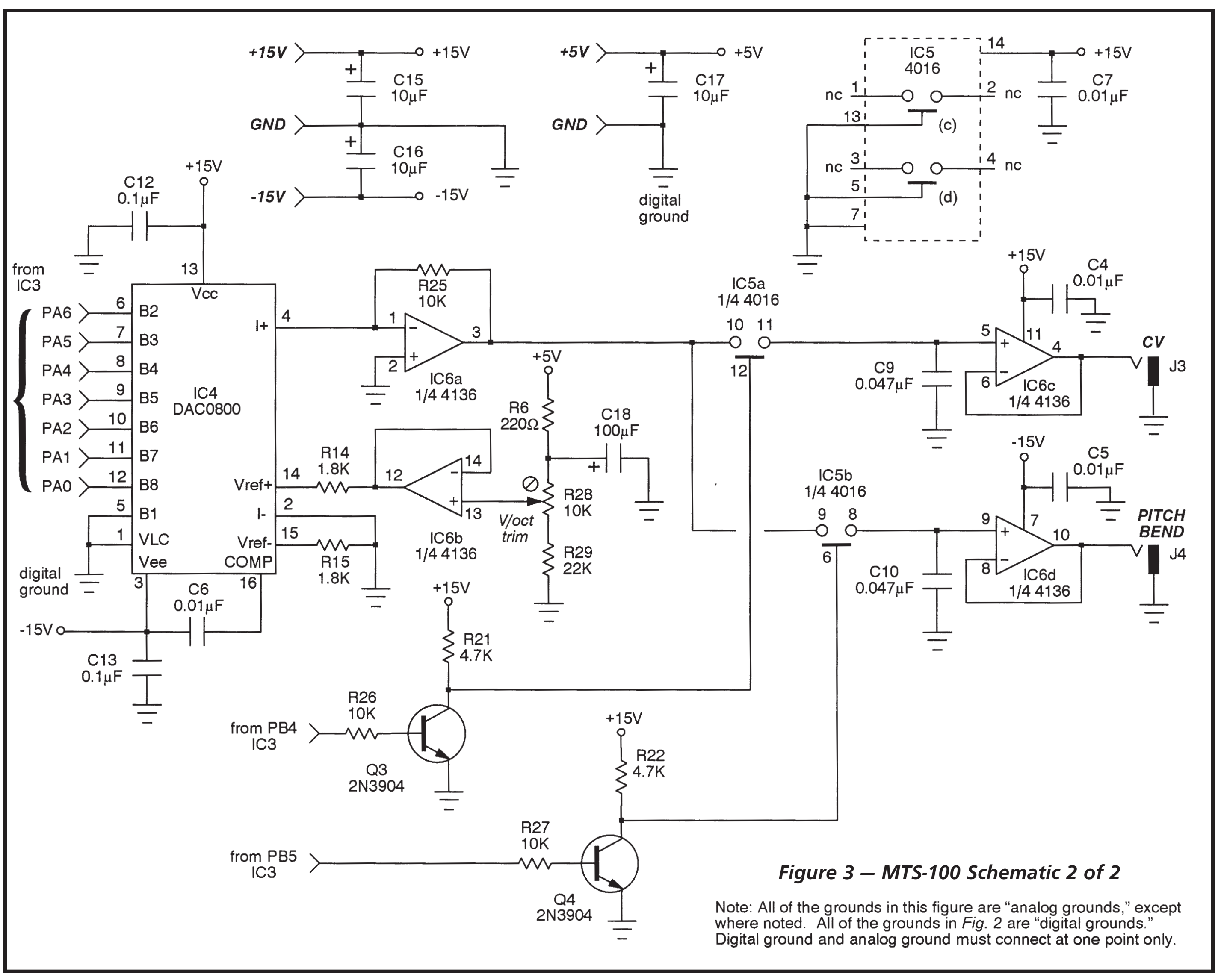


Figure 3 — MTS-100 Schematic 2 of 2

DAC.

In a similar way, putting S3 to the plus position will add 12. In effect, your short keyboard has now gained an octave on both the low and high ends. By the way, the firmware takes care of any potential goofiness should you attempt to transpose a note out of range. In this case, it's simply left as is and passed on to the DAC unchanged.

The envelope generators in an analog synthesizer require a source of keyboard gate and trigger signals. A gate should normally be at 0V, but swing to +5V and stay there whenever a note is to be sounded. On the other hand, a trigger is a 0V to +5V pulse, several milliseconds wide. It is generated at the outset of a note, and can also be retriggered under certain other conditions.

For example, suppose you have pressed a key on a music keyboard for the first time. A trigger is created. Now imagine that you keep that key depressed and play another one in addition to it. The current note number is updated to the new value of course, but more importantly, another trigger is fired off as well.

What this means is that the MTS-100, like all good quality synths from the past, lets you use the musical technique known as a "trill." You can twiddle an extra note in addition to the currently held one and the envelope generator in the synthesizer will be automatically retriggered.

By the way, the description just given implies that the MTS-100 follows what is known in music circles as the "last note rule." This means that if you press more than one key, the unit will always respond to the most recent one. And of course, there's no such thing as "simultaneous" in MIDI, so one of the notes will always be the most recent!

The gate signal is created by port line PB0 of the 68705. During quiescence, this line is high, which keeps transistor Q2 turned on. This implies that the tip of jack J2 is at 0V as expected. (Also notice that LED D3 is off). But when the line goes low in response to a note number coming in, D3 shines and J2 goes to +5V.

The trigger signal is only slightly more complicated to create. When it's time for a trigger, port line PB1 swings low long enough for LED D2 to be plainly visible. At the same time, C8 and R30 differentiate the pulse, and Q1 squares it up nice and neat. What comes out of J1 is a good looking rectangular waveform, about five milliseconds wide.

And that pretty much wraps up the digital side of things in the MTS-100. Before leaving Figure 2, however, notice that port lines PA0 through PA6, and PB4 and PB5 haven't been accounted for yet. They'll resurface as we investigate how the analog portion of the MTS-100 works. So let's move on.

Turn your attention to Figure 3 now. When a note number is received by the 68705 from the MIDI input, it is transferred to IC4 via port lines PA0 through PA6. Notice that one of the bit inputs of the DAC (pin 5) is tied to ground and not used. This is because the MIDI spec dictates that note numbers should run from 0 to 127, which only requires seven bits to represent.

The DAC needs a stable current reference for operation. So, resistor string R6, R28, and R29 first create a tapped voltage. R28 is actually a trimmer potentiometer. This will let you tweak the MTS-100 for a precise 1V/octave response. (Virtually all of the better analog synths follow this standard). Electrolytic capacitor C18 stabilizes things a bit. But more importantly, the follower composed of op-amp IC6b buffers the tapped voltage and provides a good, low-impedance output source.

The voltage at the output of IC6b is converted to a current by R14, which then feeds the positive reference input of the DAC at pin 14. Incidentally, R15 is of the same value and is used to balance the negative reference input at pin 15 of IC4.

The output of the DAC is a current; it flows from pin 4. This needs to be converted to a voltage before proceeding and that is the purpose of R25 and IC6a. As mentioned earlier, the voltage will follow a 1V/octave response.

Now comes the interesting part. You will probably be interfacing a music keyboard to the MTS-100 for much of your work. Most modern keyboards have a pitch wheel on them. By bobbling this wheel, you can bend the pitch of the currently played note up or down. We definitely want the MTS-100 to take advantage of this neat feature. But won't that require an additional DAC? Nope, not if we use a multiplexing scheme!

Here's the basic concept. The DAC will share its time between two separate sample-and-hold (S/H) circuits. At one instant, it stores the control voltage in the first S/H, and in the next instant it stores the pitch bend voltage in the second. Then the process starts over again. Since the multiplexing is happening at such a rapid rate (about 100 microseconds per cycle), the S/H capacitors never have a chance to drop or lose their stored charges. The net effect? The DAC appears to have two separate outputs. Let's look into the details.

The output voltage of the DAC is found at pin 3 of IC6a, the op-amp follower. This signal splits in two now, going to analog switches IC5a and IC5b. When switch IC5a is closed, the DAC voltage is applied to the S/H configured around C9 and IC6c. The buffered voltage is then presented to jack J3, the control voltage output. On the other hand, if IC5b is closed then the DAC's output is instead routed to C10 and IC6d. The buffered pitch bend voltage is available at jack J4.

In case you're wondering, the firmware within the 68705 makes certain that only one of these analog switches is closed at any given moment. Another thing to note is that the CMOS switches need to operate off of a +15V power supply. This is because the voltage from the DAC ranges on up to +10.58V (note number 127). So transistors Q3 and Q4,

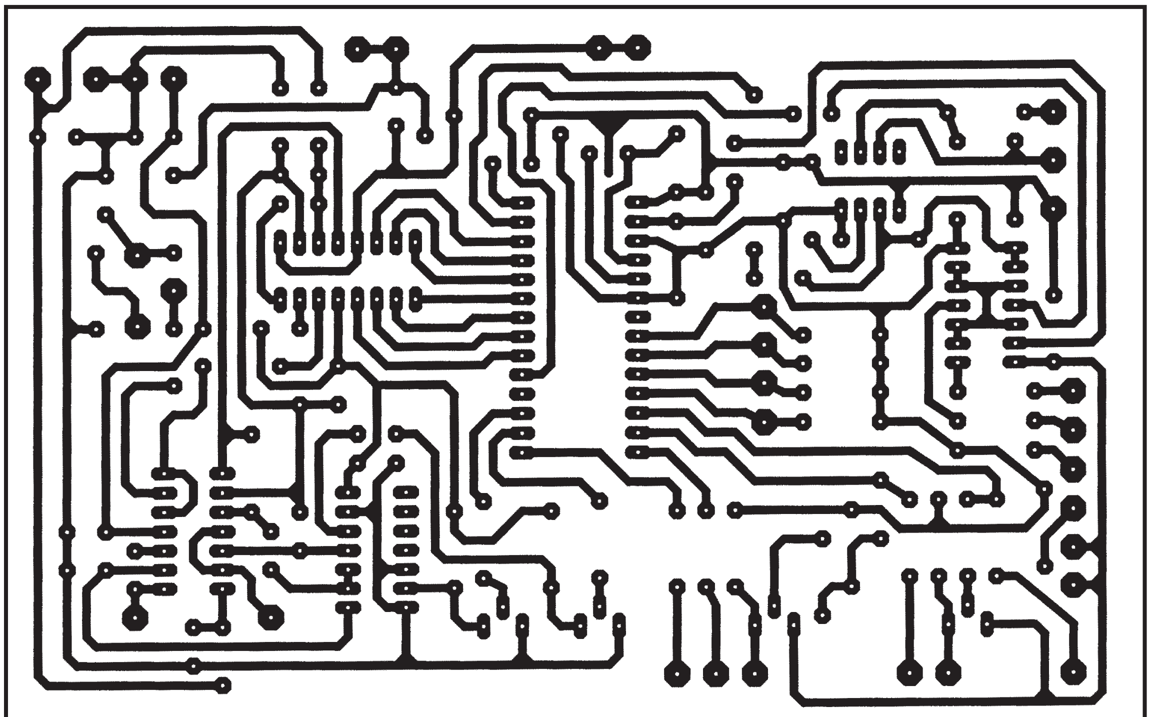


Figure 4 — Foil Side of the MTS-100 Printed Circuit Board

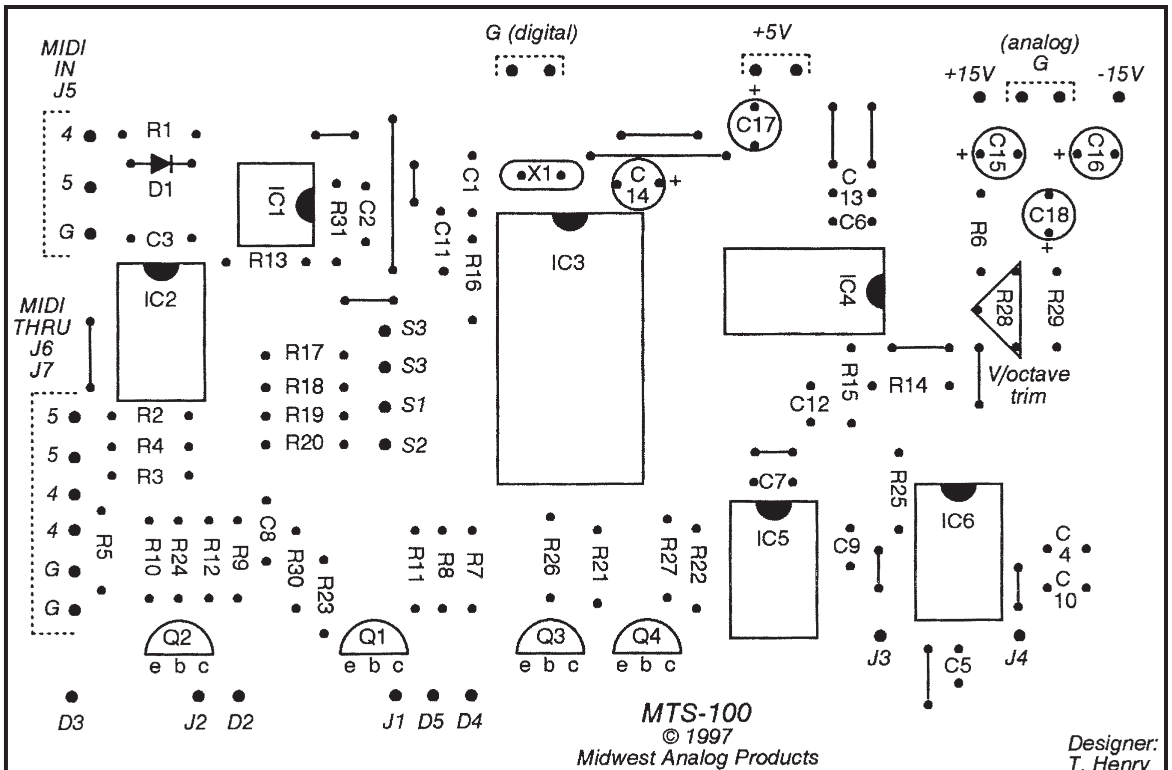


Figure 5 — The MTS-100 Circuit Board Parts Placement Guide

There are 15 jumpers. Each is represented as a solid line connecting two points.

Figure 6 — Front Panel

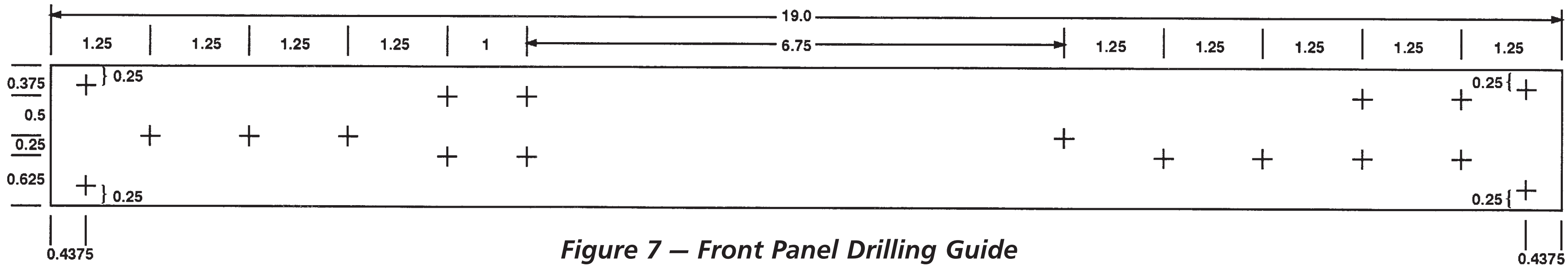


Figure 7 — Front Panel Drilling Guide

along with their associated resistors, translate the TTL control signals from the 68705 to a suitable +15V level.

To wrap things up, notice that there have been numerous capacitors not mentioned in the circuit description so far. Most of these are decoupling, bypass, or compensation caps. In general, these caps are used to stabilize the operation of the various chips. Even though they don't seem to do anything very glamorous, all of them are essential for proper performance.

Well, you're probably sick of circuit descriptions, so let's move on now and see how to actually construct the MTS-100!

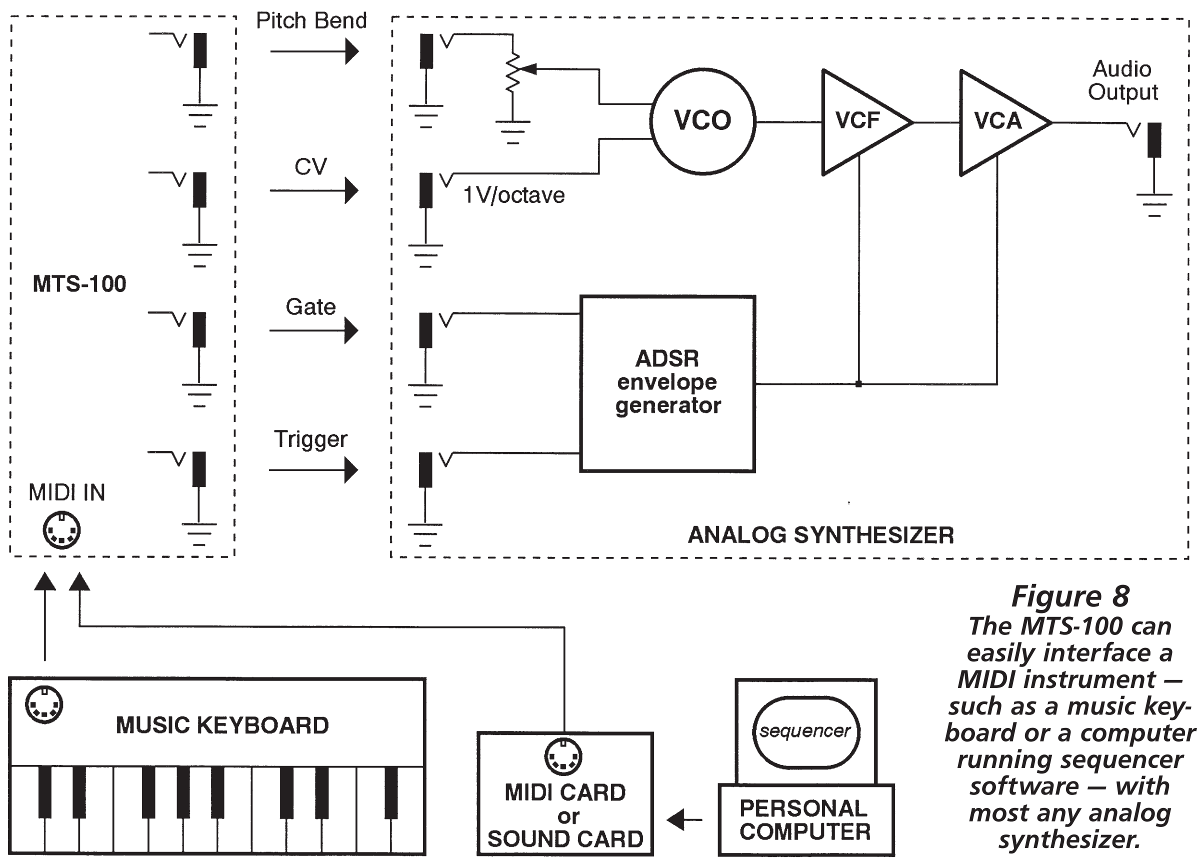


Figure 8
The MTS-100 can easily interface a MIDI instrument — such as a music keyboard or a computer running sequencer software — with most any analog synthesizer.

BUILD IT!

Besides the hardware just described, it also takes firmware to put the MTS-100 through its paces. If you'd like to try a complete homebrew approach, then first obtain a blank 68705 chip. Jameco Electronics (1355 Shoreway Road, Belmont, CA 94002) is a good source for the part, and has them for under $15.00.

Next, you'll need to get your hands on the program for the firmware. Even though the object code is quite short (about 700 bytes), it's still too long to appear in this article. However, the complete annotated assembler source code is available free of charge for download on the World Wide Web. See the Parts List for details.

Next, you'll need to assemble the code and burn it into your chip. There are dozens of excellent freeware and shareware cross-assemblers available on the Internet; try your favorite search engine and see! As for programming the microprocessor, get your hands on a 68705 Motorola manual. You'll find complete directions for programming the internal EPROM.

But if the thought of hassling around with software doesn't appeal to you, then you might want to consider purchasing the kit of parts which includes a programmed 68705. Refer to the Parts List for ordering information.

All of the other components in the MTS-100 are available from a variety of sources. A quick check of the ads in this magazine or the catalogs of some of the better mail order houses will fill in the gaps almost immediately.

After gathering the parts together, ponder what method of construction you will employ. Most of the project is non-critical, but keep in mind that the S/H circuits, as well as the crystal oscillator, demand neatness. (Stray capacitance and the like can wreak havoc.) So, if you decide to handwire it, be sure you keep everything nice and tidy.

The best approach by far, however, is to use a printed circuit board. This is much more fun to put together, looks pretty, and will probably minimize any potential wiring errors. Many hobbyists are becoming old hands at etching their own boards nowadays using a laser printer and iron-on transfer material. If you'd like to give it whirl, refer to Figure 4 which shows the 1:1 positive artwork for the foil side. Conveniently, it all fits on a 4" by 6" board, which is a standard copper clad size.

See Figure 5 for the parts placement guide. Loading the board is pretty straightforward as long as you obey the usual rules. For example, be sure to observe the orientations of all of the polarized components. Diode D1 is marked with a standard schematic symbol. A plus sign indicates the positive lead of electrolytic capacitors C14-C18. The emitter, base, and collector leads of Q1-Q4 are called out with their initial letters.

Finally, don't forget to install the 15 jumpers. These are indicated as straight lines connecting pairs of points on the diagram.

After loading the printed circuit board, you can then proceed to the final wiring of the front panel. A rack-mounted unit is perhaps best, since most pro equipment comes that way nowadays.

The MTS-100 fits nicely behind a standard 1U rack panel (1-3/4" by 19"). Figure 6 shows a sample design, while Figure 7 gives the related drilling guide. The circuit board mounts behind the panel on standoffs or little angles, using #4 hardware to secure things.

To connect the circuit board to the panel, notice that all of the relevant pads are labeled on the parts placement guide in Figure 5. Even so, here are a few additional tips. For best results, twisted triples should be used to connect up jacks J5-J7. The schematic in Figure 2 shows the pin arrangement of these jacks, as seen from the solder lug side. Notice that G, the ground wire of the triple going to the MIDI input, does not connect to J5. Clip if off, and let it float.

The purpose of this wire is simply to provide a degree of shielding for the other two wires in the triple. It is left unconnected at the panel side to avoid ground loop problems.

On the other hand, G does connect to MIDI THRU jacks J6 and J7. Solder the respective ground wire of each triple directly to pin 2 of each of these.

Switches S1-S3 are daisy chained, with a final lead running back to one of the digital ground pads on the printed circuit board. The ground lugs of jacks J1-J4 are also daisy chained, with their final run going to one of the analog ground pads. (You'll see why there are separate digital and analog grounds in just a moment.) Finally, the anodes of LEDs D2-D5 are daisy chained back to one of the +5V pads.

The remaining connections to the switches, LEDs, and jacks are trivial, and easily identified from the designations on the parts placement guide.

At this point, you should have only five more pads to hook up: digital ground, +5V, -15V, analog ground, and +15V. They connect to your power supplies. Notice that these are standard synthesizer voltages, so you may be able to tap them from an existing supply. Plan on drawing about 120mA from the +5V supply, 10mA from the -15V side, and 15mA from the +15V side.

Connect up these last five lines. Now here is an easily overlooked, but vital point to remember. In any hybrid analog/digital circuit, it is essential that digital ground and analog ground connect at one point only! This helps to minimize interference and other gremlins. So, complete the hook-up by joining digital ground to analog ground right at the output of the power supplies.

For emphasis, this is the only place where the two grounds connect (not at the circuit board and not at the front panel). If you've followed these directions carefully, then you should be all set. Give your handiwork a once over and, if it looks good, then proceed!

MAKING MUSIC WITH THE MTS-100

Before you can make music with your new system, you need to calibrate the voltage response of the MTS-100. Here's a quick way to do it. The firmware has been programmed so that at power up, the current note defaults to number 60 (middle C). This corresponds to a control voltage of +5V. So simply turn on the power supply, and monitor the CV output at jack J3 with a digital voltmeter. Adjust trimmer potentiometer R28 until you obtain a reading of +5V.

By the way, most electronic components need a "break in" period, so you might want to tweak this up several hours later after the parts have aged a little.

That's it; you're all set to go! So, dig out your analog synthesizer and connect it up to an audio amplifier. Next, patch in the MTS-100 using 1/4" phone plug cables. Depending on the modules in your synthesizer, there may be several ways to do this. Then decide how you will drive the MTS-100; a music keyboard is the easiest for your initial testing. Naturally, you will need to use some standard MIDI cables for this. Figure 8 shows the details of a simple set-up, just to get you started.

Commence your testing by pressing the Omni button; confirm that the Omni LED lights up. Now start playing some notes on your keyboard. The Gate and Trigger LEDs should flash, letting you know that keys are being detected. Next, turn up the amplifier and play a few scales.

Now rotate the pitch wheel on your keyboard. Confirm that the VCO sweeps up or down appropriately. Your VCO input should have a pot on it, so dial in the amount sweeping action you like best. For example, you might want to attenuate the pitch bend so that a complete rotation covers only an octave.

Now shut off the MTS-100 and turn it on again, as you set it for a new channel. This was described earlier in the article. Follow this by pressing the Channel button one more time to confirm that the LED properly indicates the number you just chose.

Lastly, hook up your personal computer to the MTS-100. Of course, you'll need a MIDI port on the PC to do this. But remember that I described a do-it-yourself Sound Blaster 16 to MIDI interface in the April '97 issue of *Nuts & Volts Magazine*. This puts a MIDI port within reach of most everyone.

While running some sequencer software, experiment by sending various MIDI control messages. You should be able to turn Omni on and off, reset the pitch bend to its mid position value, turn off stuck notes, and do a complete system reset. Refer to the Implementation Chart in Figure 1 for details. If you've passed these tests, then you're all set to resuscitate that old dinosaur. You will now have the best of two worlds: the fat sound of an analog synthesizer, all under MIDI control! **NV**

Acknowledgments: *I am extremely grateful to John Simonton of PAiA Electronics, whose pioneering work in computers and synthesizers made this design all that much easier to accomplish. I also wish to thank Bernie Hutchins, publisher of the legendary ELECTRONOTES newsletter, for putting up with way too many questions, and patiently helping me track down circuit goblins.*

PARTS LIST

All resistors are 1/4-watt, 5% values.

R1 - R6	220 ohms
R7 - R10	470 ohms
R11, R12	1K
R13	1.2K
R14, R15	1.8K
R16 - R22	4.7K
R23 - R27	10K
R28	10K trimmer potentiometer
R29	22K
R30	100K
R31	220K

All capacitors are 16V.

C1	22 pF dipped silver mica
C2 - C7	0.01 mfd disc
C8 - C10	0.047 mfd mylar
C11 - C13	0.1 mfd disc
C14	1 mfd electrolytic
C15 - C17	10 mfd electrolytic
C18	100 mfd electrolytic

Semiconductors

D1	1N914 or 1N4148 diode
D2 - D5	Red LED
Q1 - Q4	2N3904 NPN transistor
IC1	6N138 optocoupler
IC2	74LS00 quad NAND gate
IC3	MC68705P3 MPU (programmed)
IC4	DAC0800 D-to-A converter
IC5	4016 quad SPST switch
IC6	4136 quad op-amp

Other components

X1	4 MHz crystal
S1, S2	SPST pushbutton switch
S3	SPDT (on-off-on) toggle switch
J1 - J4	1/4" phone jack
J5 - J7	Five-pin DIN jack (180 degrees)

Miscellaneous: printed circuit board, LED holders, IC sockets, front panel, wire, solder, etc.

ORDERING INFORMATION

A kit of parts for the MTS-100 is available from the source below. Included with the kit is an etched, drilled, and tinned printed circuit board, programmed microprocessor, all resistors, capacitors, semiconductors, crystal, switches, jacks, LED holders, sockets, and Assembly Guide. Does not include front panel, wire, or solder.

- MTS-100 Kit (#K210)-$69.95

US and Canadian orders add $5.00 shipping and handling. E-Mail or write for shipping information to other countries.

Prices shown in USA dollars. Remit US funds only. Money orders and checks only. MN residents add 6.5% sales tax. Prices and terms subject to change without notice.

Order from: **Midwest Analog Products**
P.O. Box 2101
N. Mankato, MN 56003

The complete source code for the MTS-100 firmware may be downloaded free of charge from the WWW homepage of Midwest Analog Products.

WWW: http://prairie.lakes.com/~map
E-Mail: map@prairie.lakes.com