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BUILD R-E's GRINCHWAL DIGITAL TEST EQUIPMENT

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A GERNSBACK PUBLICATION

The foundation or mainframe of a group of useful and inexpensive digital test instruments for the lab, service shop and experimenters' workbench. Accessories plug into the readout.

BUILD R-E's GRINCHWAL DIGITAL TEST EQUIPMENT

by DON LANCASTER

VIRTUALLY EVERY DIGITAL INSTRUMENT needs an accurate internal time or frequency reference. For instance, an electronic digital counter needs 0.1-, 1-, and 10-second time gates, while an electronic stopwatch may need a source of 10-microsecond wide time period pulses, or a digital voltmeter may need a stable source of 100-kHz timing signals for *dual-slope integration,* used for accurate voltage to frequency conversion. This internal reference is usually called a *time base.*

One cheap time base is the power line, but it's hard to use in a battery-powered instrument and it doesn't have enough accuracy or stability to do justice to 4 decades of counting. So, traditionally, you had to go to a crystal oscillator and a bunch of current-hogging RTL or TTL decade dividers.

The digital grinchwal* does things differently. It starts with a crystal all right, but it uses a *single* integrated circuit that will give you any time or frequency reference you ask it to, from 1 MHz to 1 pulse per hour! To make things even nicer, the integrated circuit only draws 5 mA.

Figure 1 is a block diagram of the Mostek MK5009 time-base integrated circuit. You hang a 1-MHz crystal and some biasing and trimming components on its internal oscillator. You then send it a four-line code command that tells it how much to divide by, and out comes a reference frequency or time period that talks to the grinchwal counter or that can drive an ordinary RTL, DTL, or TTL integrated circuit. To program the IC to a desired division ratio, you use the code of Table 1. There are four input lines, called A, B, C, and D. A digital "0" is equal to ground, while a digital "1" is at or near the +6-volt supply. For instance, if you start with a 1-MHz crystal, and apply the code 0101, or A = 1, B = 0, C = 1 and D = 0, the IC divides by five decades, or 10^5, giving you either a 10-hertz output signal or a 100-millisecond period square wave. Accuracy to four decades can be obtained by trimming the crystal against WWV or another frequency reference, but even without any trimming you get a very stable and very accurate output.

You also get a *reset* input. Ground it and the IC runs normally. Make it 6 volts positive and the chip puts all its dividers in the 0 state. This is handy to *gate* your reference frequency for things like electronic stopwatches and sports timers. The reset and counters are synchronous. This means the first output cycle will be within a millionth of a second of the width of all the rest of the cycles.

There are several precautions in using this chip. Never apply reverse supply voltage or you will instantly zap it. Also, the unused inputs must be connected exactly as shown in Fig. 2, for the IC has some internal-test speedup modes it can get into if you, say, try to use −12 volts instead of ground for a logic "0". Note the 1-MHz direct output is too fast for the MK5005 counter and display plug-in, and thus can only be used on external circuits. With the addition of resistor R1, the two chips can talk to each other at any other reference time or frequency. And, like any other MOS device, an exceptionally unreasonable amount of mishandling can damage the chip, so leave it in its conductive foam carrier until after you have checked all the rest of your circuit out; then quickly and carefully solder it in place with a small soldering *IRON* (No guns please) and fine solder.

Building the mainframe

The schematic is in Fig. 2. Circuit boards, complete kits, and any and all parts are available from the source shown in the parts list. The grinchwal is

*grinchwal. *n.* (originated by author): gizmo, gadget, thingamajig. The digital readout and timebase of a multipurpose test instrument featuring plug-in modules for various functions or operations.

built in an unbreakable impact plastic case 5 × 6½ × 2½ inches deep. The power supply or the batteries mount in the upper bottom of the case, underneath a main PC board that contains the timebase and connector for the plug-ins and the counter module. A front panel covers the top half of the case, supporting a red filter for the display module, the CHECK and RESET pushbuttons and the OVERFLOW indicator. Besides the timebase and connectors, the PC board contains some supply filtering and reverse-polarity protection, a pulser for the reset line, a driver for the overflow indicator, and a "relay" (Q2, Q3) to control the -12-volt supply.

The PC board is shown in Fig. 3. You can get this commercially or etch and drill your own, using this pattern. All the components except IC1 may be mounted in place, watching the polarity on all the capacitors and diodes. A small four-wire flat cable makes the front panel connections neater, but plain old wire can be used. Note that the overflow indicator, being a light emitting *diode* is polarity sensitive. Be sure to connect it exactly as shown in the schematic with the narrow pin going to the IND terminal and the wide pin going to ground. Don't add IC1 till after the preliminary checkout.

You have a choice of batteries or a line-operated power supply. The battery supply—for maximum portability—consists of two 9-volt transistor radio batteries and four type C cells (alkaline for long life) connected as in Fig. 4-a. Note that the +terminal of the 18-volt battery goes to the +terminal of the 6-volt battery, *not* to ground! Use the line-operated supply in Fig. 4-b if you don't really need extreme portability and like to leave test instruments on for long periods of time. If you want to use *both* a power supply and larger batteries or rechargable batteries, you'll probably want to go to a somewhat larger case. A two-transistor and transformer inverter may be used to convert the +6 volts to -12 volts if you want to do away with the two 9-volt batteries.

Whatever route you pick, the power source mounts under the main PC board, leaving the bottom half of the case open for the plug-ins. Power needs are 6 volts at 125 mA and -12 at 5 mA.

Using the mainframe

We'll be showing you several plug-ins from time to time, but if you're designing your own modules, the following guidelines should be of some help.

The power ON-OFF switch goes between +6 volts and +6SW. With the Q2, Q3 relay it also controls -12 volts. The decimal-point selector goes between DP IN and the chosen DP1, DP10, DP100, or DP1K. If you don't connect it or else connect it to DP1, you'll get just a number displayed with all three left-hand zeros lopped off. If you can arrange things so you get a "0" reading between measurements, this will radically extend the battery life.

The timebase is activated by switching a "1" (+6 volts) and a "0" (ground) to inputs A, B, C, and D following the truth table of Table 1. The timebase OUT terminal may be connected directly to the COUNT terminal of the counter/display, or else it will drive one TTL or DTL input. You reset the timebase by putting +6 volts on the normally grounded RST line.

The COUNT input may be connected to a RTL, DTL, or TTL output in your plug-in, to the timebase output, or to +5 volts through a capacitor. It free runs (self-oscillates) with the capacitor and follows the counting with either the timebase or your external low-impedance logic source. UPDATE will follow the counting if grounded and keep the old count if at +6 volts. Reset for the count module forces the counter to zero if it is grounded. If you push the RESET button, you get a brief pulse going to ground on this terminal every time you hit the button. You can use this for a resetting signal for your plug in. Note that the resets of the counter and timebase are backwards in action. If you decide to reset both at once, you need an inverter to ground the counter while applying +6 volts to the timebase. RESET only resets the counter, not the display. To get a 0000 reading, you have to simultaneously reset and update the counter module.

The OVERFLOW output goes to ground on count 10,000 and stays there until reset. It may be directly connected to the IND input to light the overflow lamp, or it will drive one logic load in your plug-in. If you want to independently light the overflow indicator, you ground the IND input instead of connecting it to the OVERFLOW output on the counter module. A ground lights the lamp; +6 volts puts it out.

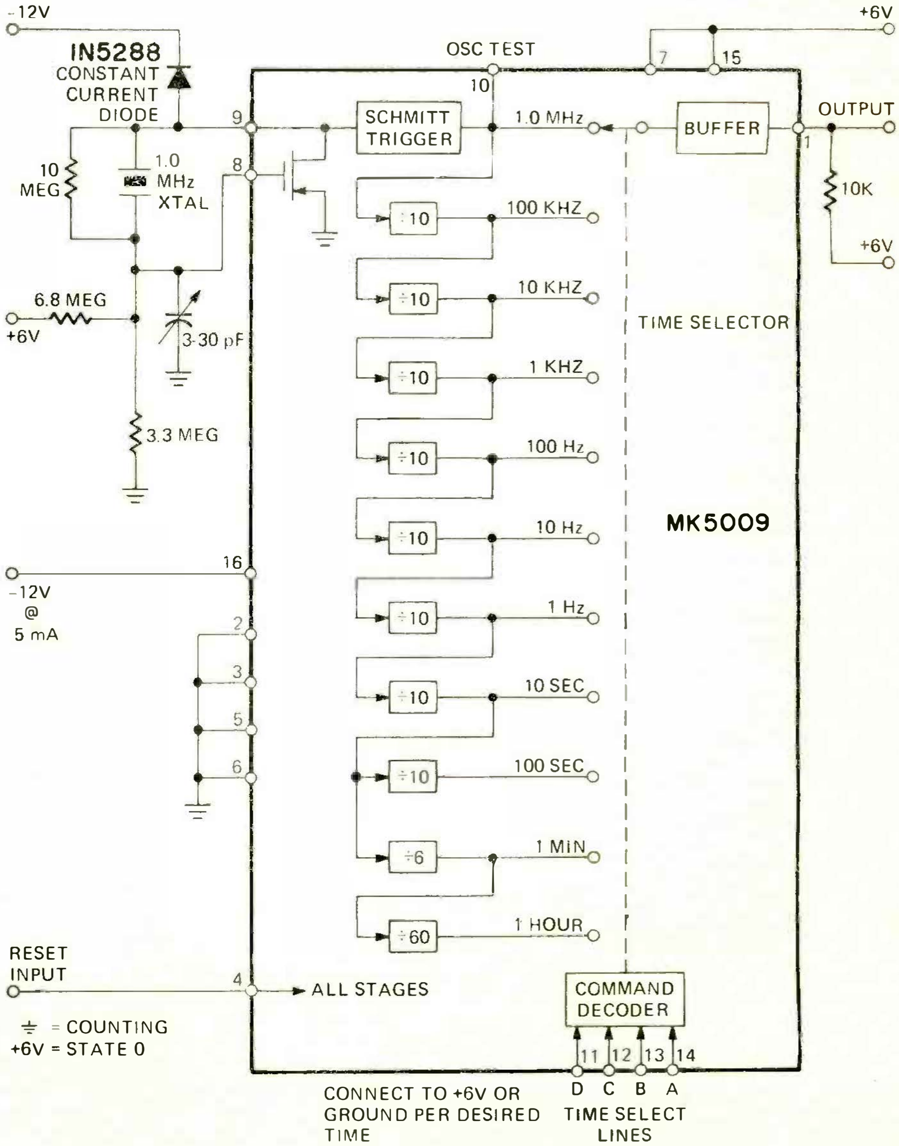


FIG. 1—BLOCK DIAGRAM of the time-base IC and the basic circuitry. This and the digital readout form the heart of several test instruments.

PARTS LIST

C1—3-30 pF trimmer capacitor
C2—5 pF mica capacitor—optional; needed only with certain cyrstals
C3, C5, C7—0.1 μF, 10-volts disc ceramic capacitor
C4—47 μF, 15-volt electrolytic
C6—220 μF, 6-volt electrolytic
D1, D2—1N914 diode
D3-D6—1N4001 diode
D7—1N5288 constant-current diode **DO NOT SUBSTITUTE**
IC1—MK5009P time base IC (Mostek), special design built for Don Lancaster projects.
LM1—MV5023 LED panel lamp or equivalent
S1,2—Spst momentary pushbutton
Q1,2—2N5139 transistor, silicon pmp
Q3—2N5129 transistor, silicon npn
R1,6,8—10K, ¼ watt carbon resistor
R2—2.2 megohm carbon resistor
R3—6.8 megohm, carbon resistor
R4—3.3 megohm carbon resistor
R5—1 megohm carbon resistor
R7—330 ohm carbon resistor
R9—4.7K, carbon resistor
SO1-4—10-pin chassis mounting socket, Molex 09-52-3103
XTAL 1—1.00 MHz crystal and mounting clip

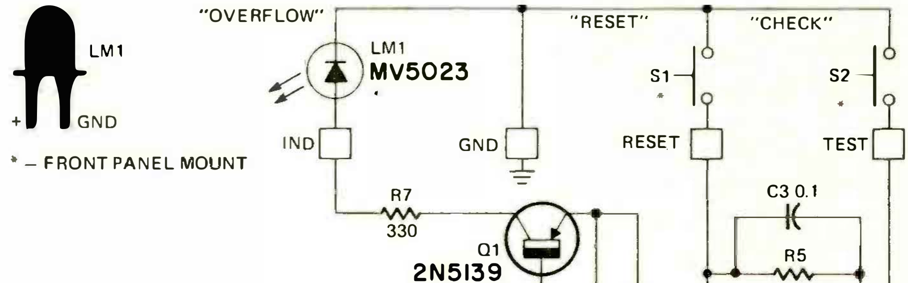
MISC: PC Board per Fig. 3, plastic case; 9-volt battery clips (2); spacer foam for batteries; Dual C holders (2); front panel; red filter; mounting hardware; wire; solder.

NOTE: The following are available from Southwest Technical Products, 219 West Rhapsody, San Antonio, Texas, 78216: PC Board, etched and drilled No. DGM-b, $4.85 postpaid. Circuit board for readouts, No. DGR-b, $3.85 postpaid. Kit of parts for readout, No. DR-C, $34.50. Kit of parts for mainframe and timebase plug-in, including case and front panel, No. DM-C, $26.75, less readouts and batteries, postpaid.

POWER SUPPLY PARTS LIST

C1—5000 μF, 10 V electrolytic
C2, 3—500 μF, 25 V electrolytic
D1, D2, D3, D4—1N5061 silicon power diode, 1 A to piv
D5—12-V Zener diode, 1N4742 or equivalent
F1—0.1 A fuse and fuseholder
IC1—6-V positive regulator, Fairchild 7806
R1—27 ohms, ¼ watt
T1—12.6 VCt, 100 mA transformer (Signal PC 12-100 or equal)

MISC: PC Board for power supply; line cord; PC terminals (Optional) (5); solder.



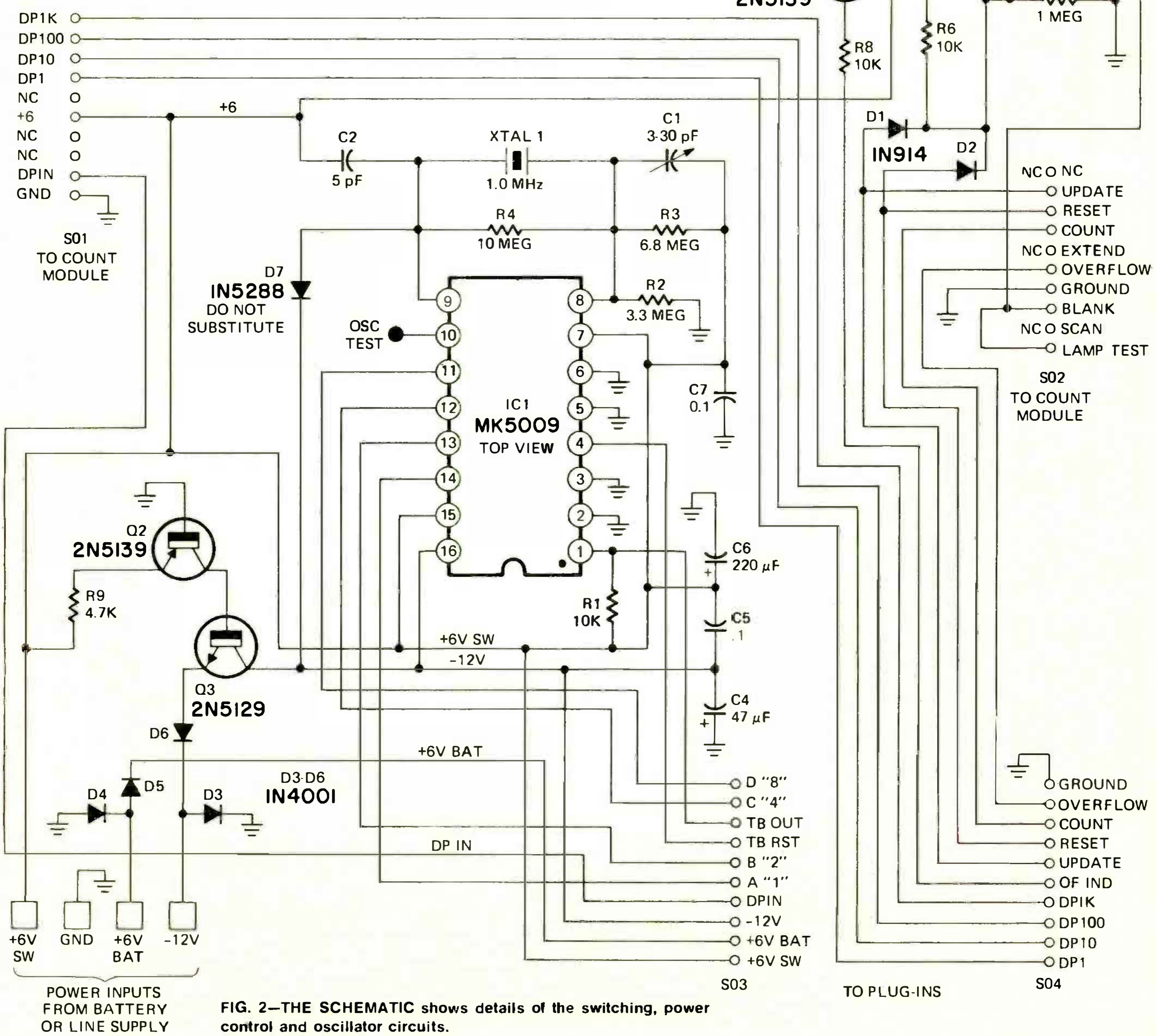


FIG. 2—THE SCHEMATIC shows details of the switching, power control and oscillator circuits.

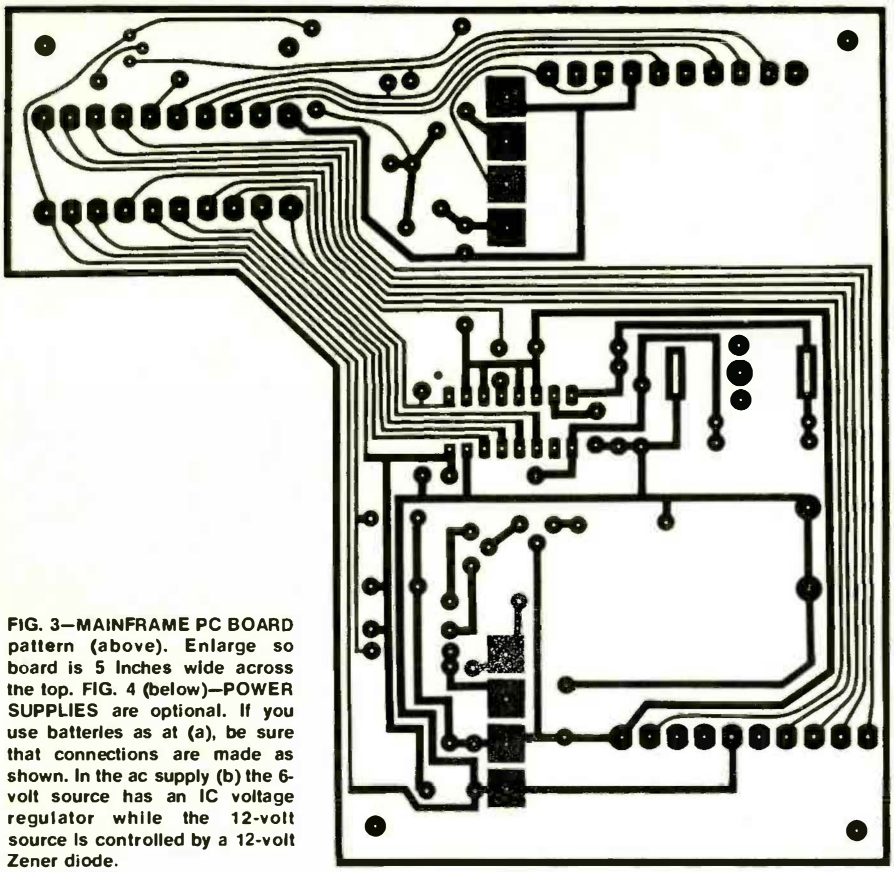
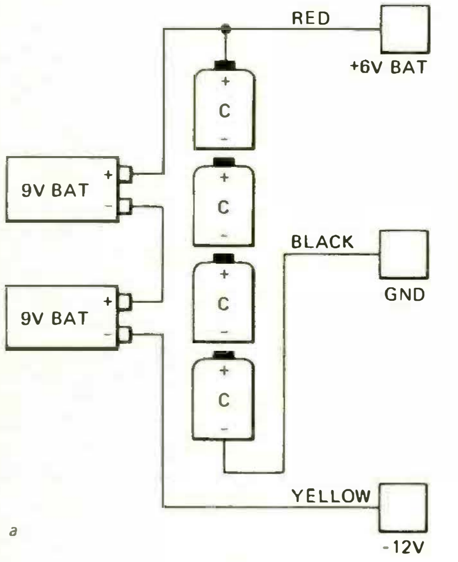
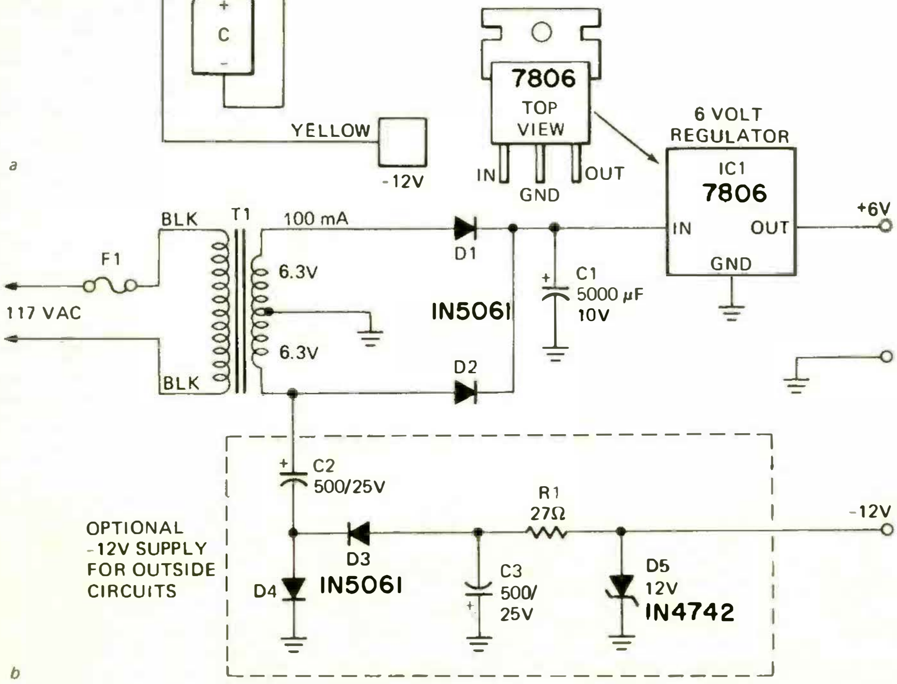


FIG. 3—MAINFRAME PC BOARD pattern (above). Enlarge so board is 5 inches wide across the top. FIG. 4 (below)—POWER SUPPLIES are optional. If you use batteries as at (a), be sure that connections are made as shown. In the ac supply (b) the 6-volt source has an IC voltage regulator while the 12-volt source is controlled by a 12-volt Zener diode.



next month

SPACE LIMITATIONS prevent us from presenting the remaining printed-circuit diagrams and construction information in this issue. All remaining diagrams and text will appear next month.



When you're using the grinchwal with your plug-ins, there are two additional design quirks you have to allow for that could cause you some headaches if you don't know about them. First, note that resetting the counter also resets the internal digit scanner. If you reset the counter too often, some of the numbers will not get displayed, or some of the digits may vary cyclically in brightness. To get around this, limit the number of *new* measurements you make to less than 30 per second. If you must go faster, the scanning capacitor (C1) on the counter plug-in could be reduced in value, but too small a C1 causes decimal-point ghosting and possible leading-edge blanking problems.

The second thing you have to allow for is to make sure that at least one count happens *after* you update if you want to keep the old answer and not reset immediately. This means you can't directly use the falling edge of an input gate as an update if it does away with the input at the same time. The input signal should continue at least one count after updating—making it nearly continuous is one obvious way around the problem.

Ideas for plug-ins

Timebase—Bring out the timing signals and you have a precision scope calibrator, source of timing signals, precision digital clock pulses, a source of timing clocks for lab experiments, an ultra-stable squarewave generator, etc.

Stopwatch—Simply gate the timebase with a set-reset flip-flop to get the time between events, or gate it directly to get the duration of a single event. You can measure any time interval from 10 microseconds to 9999 hours. Use it for a sports timer, a rally computer, photographic stopwatch for shutter testing, physics experiments, ballistic velocity checks, etc . . .

Frequency counter—Use the 0.1-, 1-, or 10-second output of the timebase to turn on and off a signal whose frequency you want to measure. The input frequency should be conditioned by going into a digital comparator. Maximum direct operation is around 200 kHz, but you can easily add scalers to count any frequency you want. With Schottky TTL. you can count beyond 100 Mhz, and by using more than one trip through the counter, you can get more than 4 decades of accuracy. For instance, a 10-second gate and scalers can give you a six-digit accuracy, for any input above 100 khz.

This list could go on and on. What can you do with a completely portable instrument that will measure or monitor anything you want to 0.01% accuracy? We'll show you how to do some of the common plug-ins. How about you showing us newer and better uses for the Grinchwal? **R-E**

BUILD GRINCHWAL

by DON LANCASTER

HERE ARE THE FINAL DETAILS TELLING how to build the mainframe for your grinchwal digital test equipment mainframe. Plug-ins start in February.

Preliminary checkout

You'll need a previously tested and working counter module and your power supply for checkout. Hookup the circuit of Fig. 4-a and check out the counting unit for normal brightness, counting, and "hold-follow" operation. Next checkout the reset and lamp test modes. Finally, check the overflow lamp by resetting the counter and watching it light and stay lit on count number 10,000.

Now, go to the circuit for Fig. 4-b. Doublecheck the voltages on your PC board for IC1, making sure you have -12 volts **only** on pin 16, +6 **only** on pins 7 & 15, and ground **only** on pins 2, 3, 5, and 6. You can now solder IC1 in place using a small *iron* and fine solder. When you reapply power, the counter should promptly start running at a 100-Hz rate. If it doesn't, first make sure you are in the FOLLOW position, and then try several adjustments of the trimmer capacitor. In case of difficulty, the 1-MHz oscillator output may be monitored with an oscilloscope with a 10× probe directly on pin 10 of IC1.

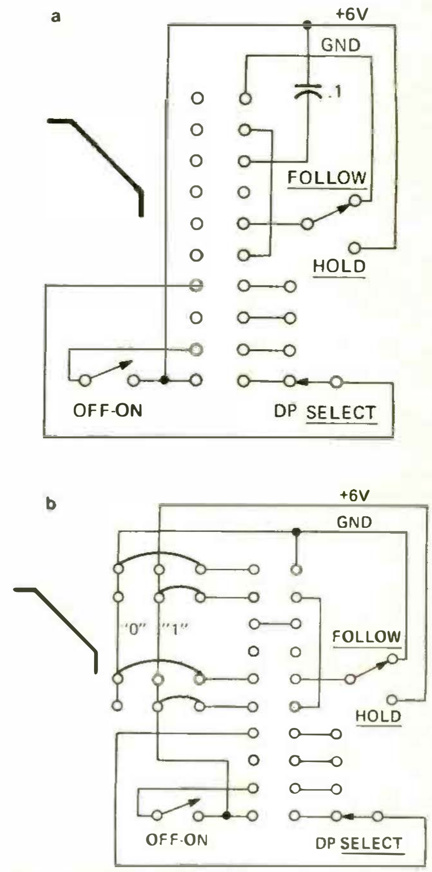


FIG. 4—WHEN UNIT IS ASSEMBLED test for proper operation with these two circuits.

When you switch off the +6-volt line, the -12-volt line is also switched off through "relay" Q2 and Q3. A connector PC pattern for the plug-in is shown in Fig. 5.

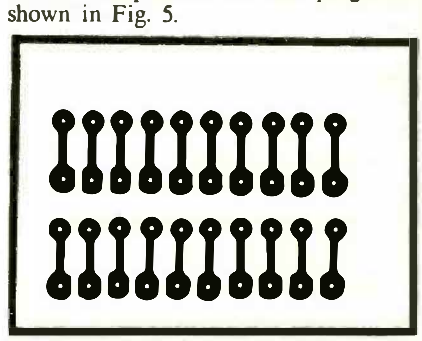
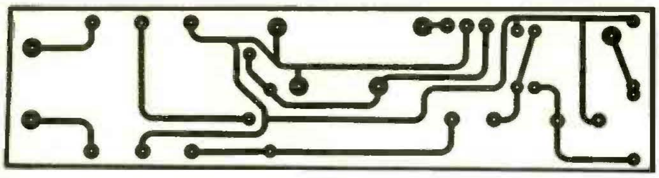
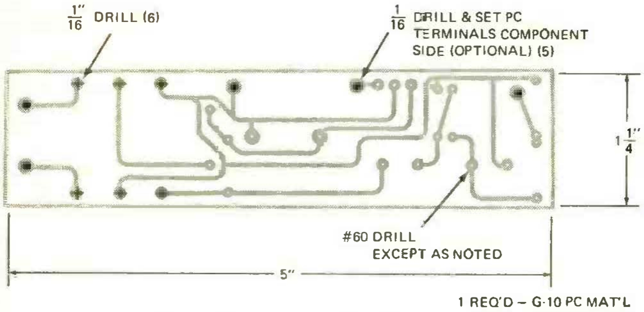


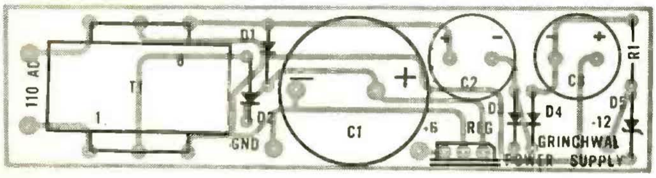
FIG. 5—CONNECTOR FOIL PATTERN. Each plug-in will use one of these connectors.

NOTE: The following are available from Southwest Technical Products, 219 West Rhapsody, San Antonio, Texas, 78216: PC Board, etched and drilled No. DGM-b, $4.85 postpaid. Circuit board for readouts, No. DGR-b, $3.85 postpaid. Kit of parts for readout, No. DR-C, $34.50. Kit of parts for mainframe and timebase plug-in, including case and front panel, No. DM-C, $26.75, less readouts and batteries, postpaid.

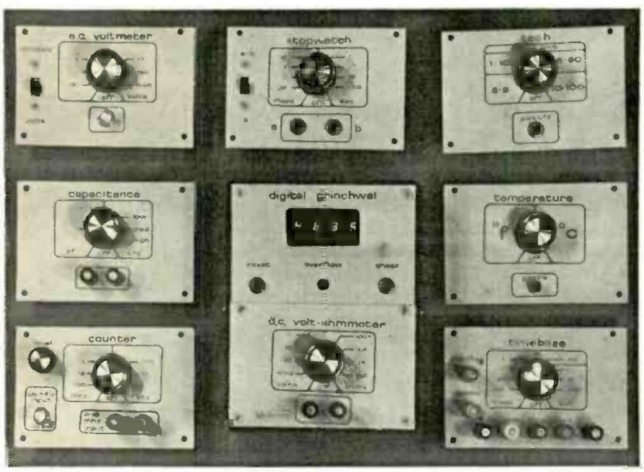
DIGITAL TEST EQUIPMENT



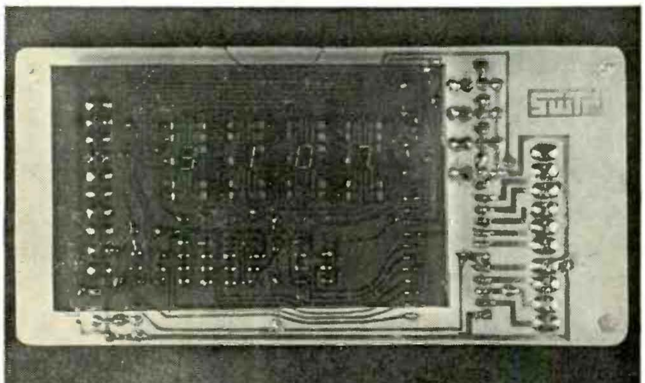




POWER SUPPLY CIRCUIT BOARD DETAILS. Three diagrams are shown. At the top is the foil pattern for the board. Next is the drilling guide. Last is a diagram showing parts placement on the circuit board.



THESE ARE SOME OF THE PLUG-INS that go along with the Grinchwal digital instrument. You'll want to have them all.

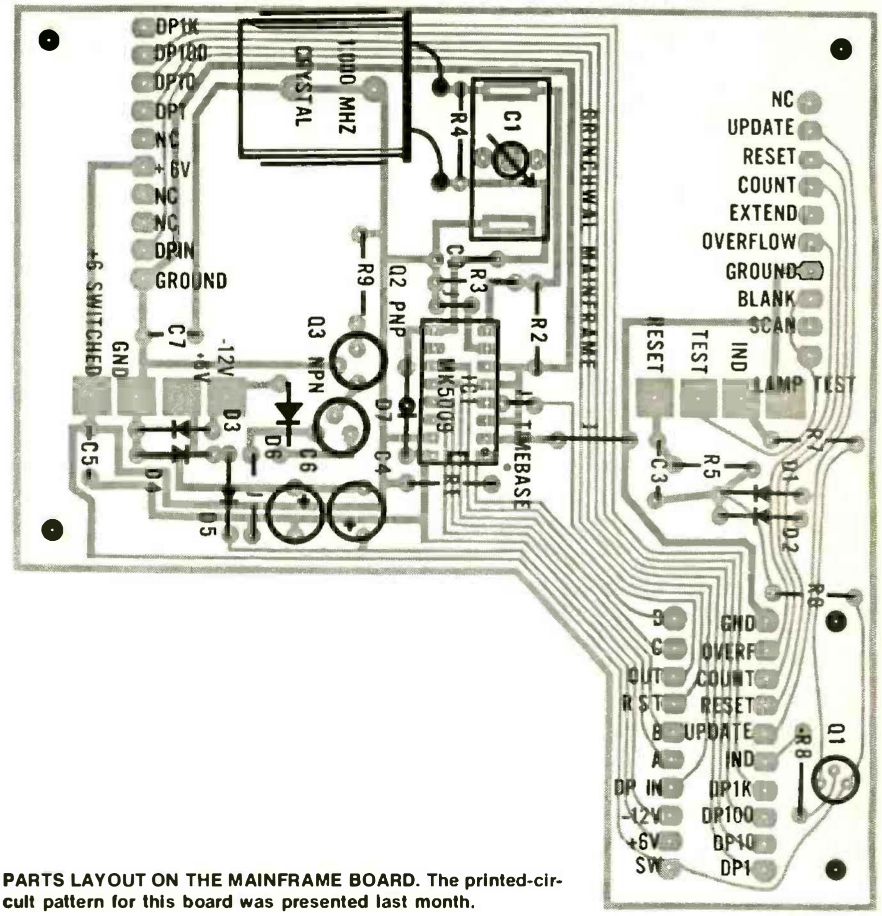


AN ASSEMBLED READOUT BOARD. The numerals are illuminated for this photo. Do not operate your unit out of its case.

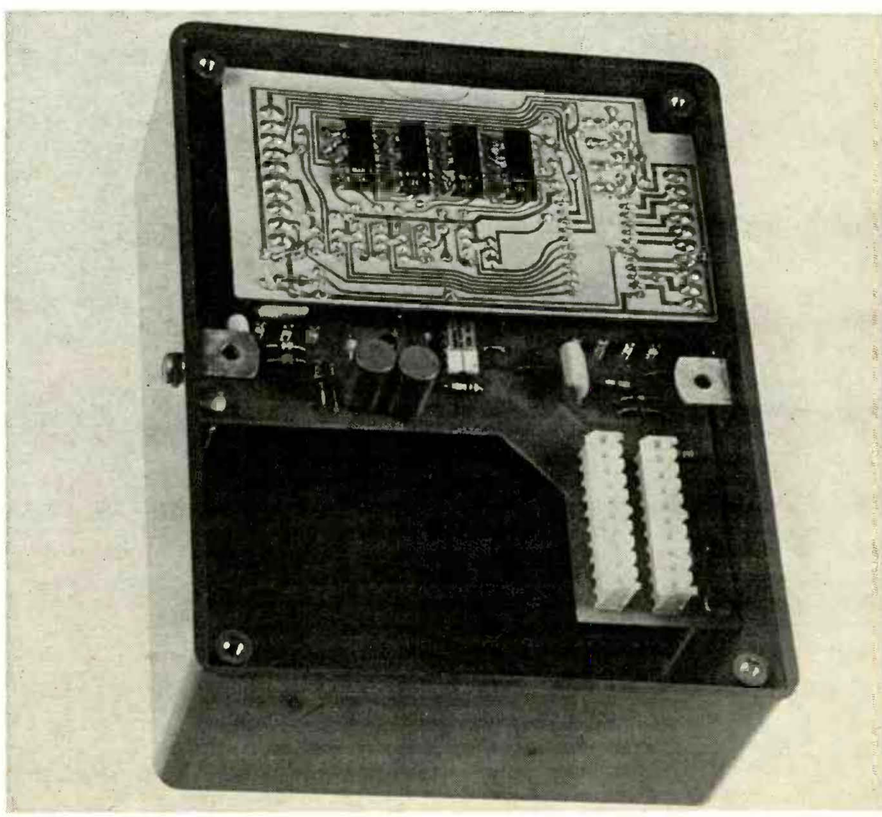
(continued on page 96)

GRINCHWAL TEST EQUIPMENT

(continued from page 95)



PARTS LAYOUT ON THE MAINFRAME BOARD. The printed-circuit pattern for this board was presented last month.



COMPLETED MAINFRAME WITH front panel removed to show the location of major components inside the case.

GRINCHWAL READOUT MODULE

Complete your mainframe. Build this 4-digit readout assembly using LED's and get ready for the plug-ins that follow

by DON LANCASTER

HERE'S A FRESH, HIGH PERFORMANCE approach to digital counting and display—combine a bright red light emitting diode (LED) display with a *single* new high performance, MOS Integrated Circuit, and you come up with an easy-to-build *four decade* 0-9999 digital counter and display that neatly fits a single 2½" x 5¼" plug-in PC card. *Total* supply current, *including the readouts,* is a mere 6 volts at 100 mA, easily provided by ordinary flashlight cells. Now you can go truly portable with your digital instruments, free of any line cords, bulky storage batteries, or high-voltage display supplies. While the maximum counting frequency of this display is 250 kHz, you can easily count to 100 MHz and beyond by suitable scaling.

Figure 1 shows a simplified block diagram of the counting module. Practically everything is crammed inside the single *Mostek* MK5005 integrated circuit. *Monsanto* MAN-4 light-emitting-diode (LED) displays are used. These are a fifth of an inch high and readable beyond eight feet. Brightness is good enough for almost any reasonable room lighting, and you can even hold back on brightness to extend the battery life and still come up with a highly viewable display.

Construction

Figure 2 shows the actual circuit. Darlington driver transistors are needed to get the IC outputs up to a suitable level for display drive. These are pnp or npn transistor pairs as shown and have gains in the ten thousands. They cost 45 to 60¢ each. Ordinary transistors, even high gain ones, may NOT be substituted.

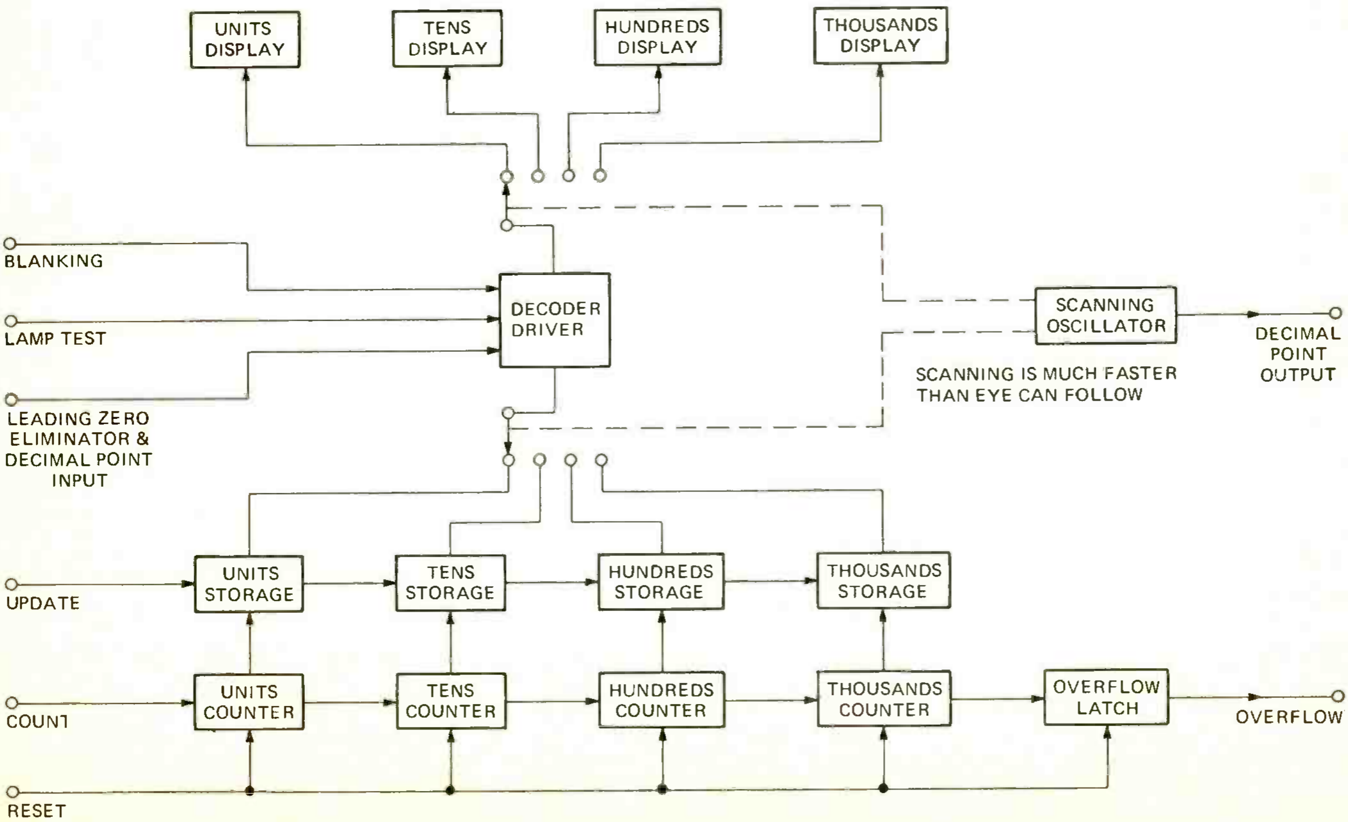
Capacitor C1 sets the scanning rate for the multiplexing while C2 gives a speed-up to the decimal point input that eliminates ghost decimal points. Feedback from the decimal point driver to the chip controls the leading zero blanking.

Brightness is controlled by resistors R2 through R9. The values shown are the *minimum* recommended values that give *maximum* display brightness. If desired, the resistors may be raised in value to give a not as bright display that has longer battery life.

A printed-circuit board is a must for this project. You can get one commercially or else you can use Figs. 3, 4 and 5 to make your own.

While the MOS integrated circuit

FIG. 1—DISPLAY MODULE BLOCK DIAGRAM. Single low-power integrated circuit does the job. It replaces more than a dozen conventional ICs.



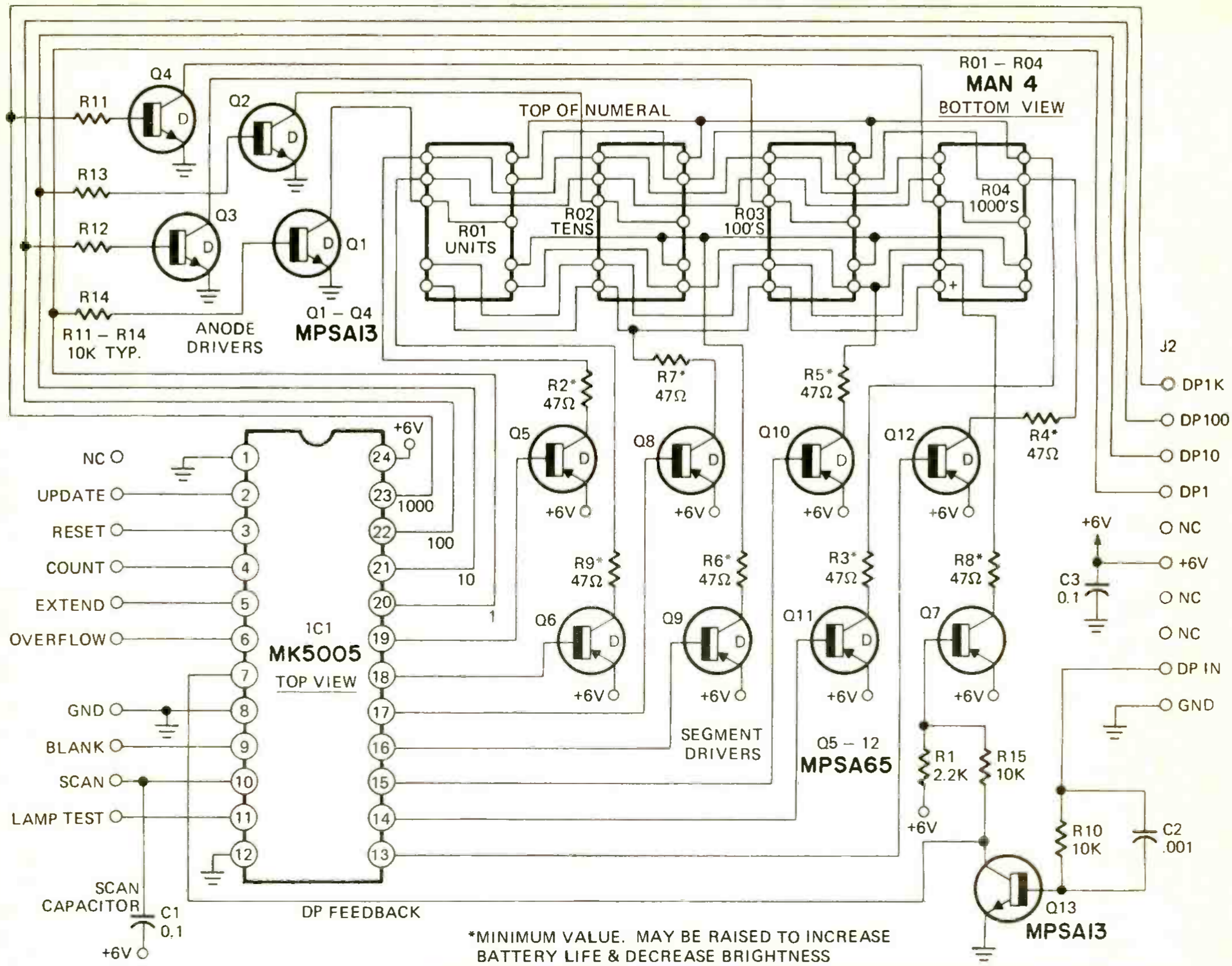
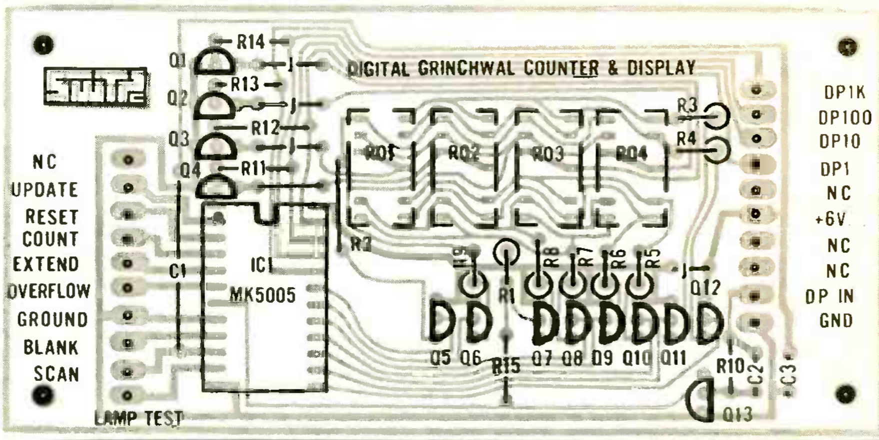
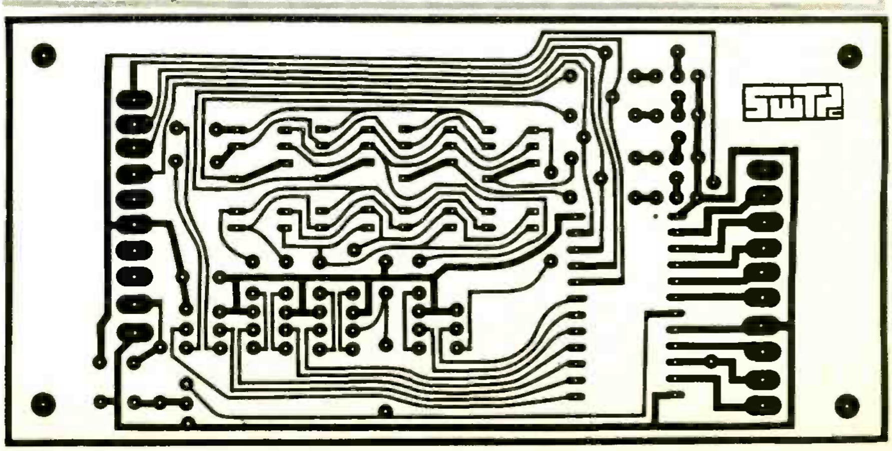


FIG. 2—(above) COMPLETE schematic of the readout circuit.
FIG. 3—(bottom right) FOIL PATTERN of the readout board is 5¼ x 2½ inches.
FIG. 4—(right) PARTS PLACEMENT for the readout board.

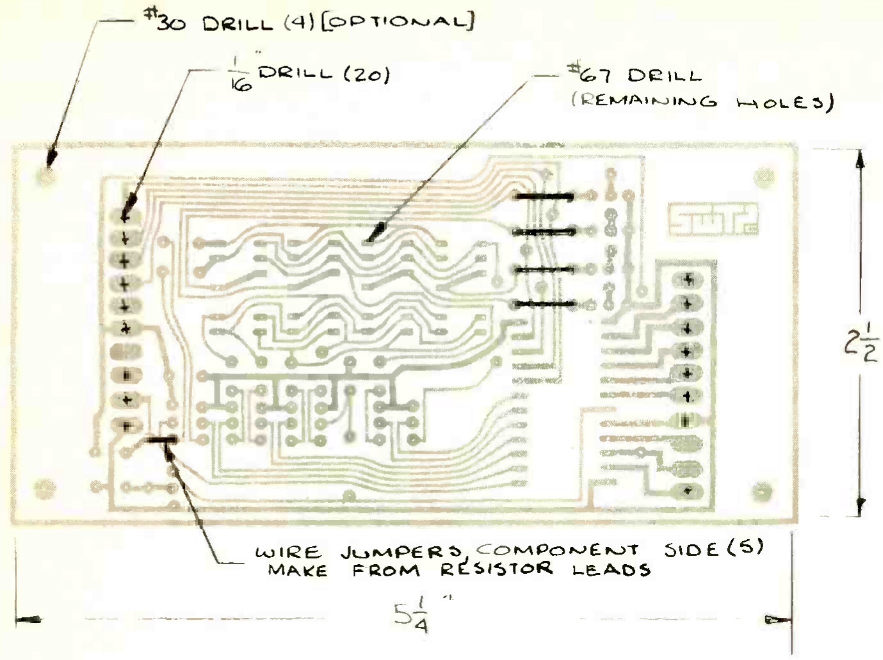


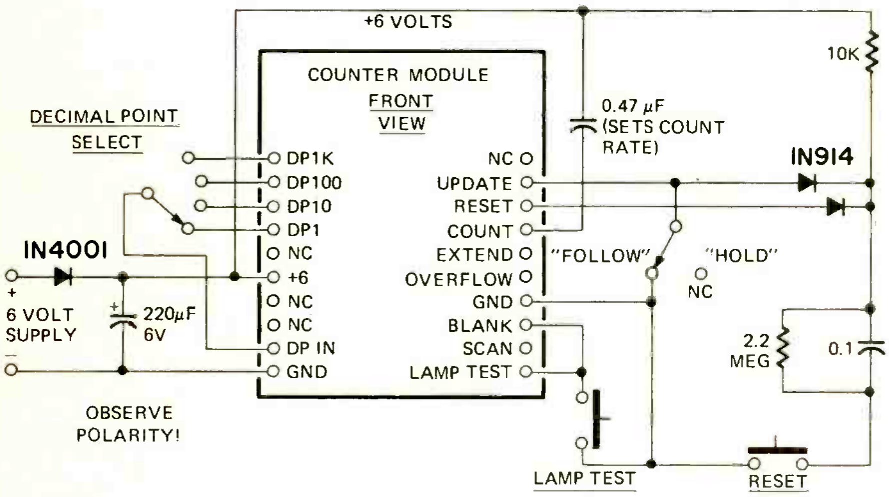


is now pretty well protected against static and overvoltage, REVERSED SUPPLY POLARITY WILL IMMEDIATELY AND PERMANENTLY DAMAGE THE DEVICE. IN ALL OF YOUR CIRCUITS AND ALL OF YOUR CHECKOUT WORK, A SERIES DIODE OR OTHER "IDIOT PROOFING" *MUST* BE PLACED BETWEEN THE MODULE AND THE SUPPLY.

Before starting assembly, note three very important details: (1) don't unwrap the MOS integrated circuit or remove its protective foam until immediately before you solder it in place; (2) note that the readouts mount *foil* side, *opposite* the rest of the components; and (3) note that the pins on the plug in connectors stick out from the component side, opposite to the foil side that supports the readouts.

A deep red optical filter is absolutely essential for proper display contrast. A piece of ⅛" red plexiglas





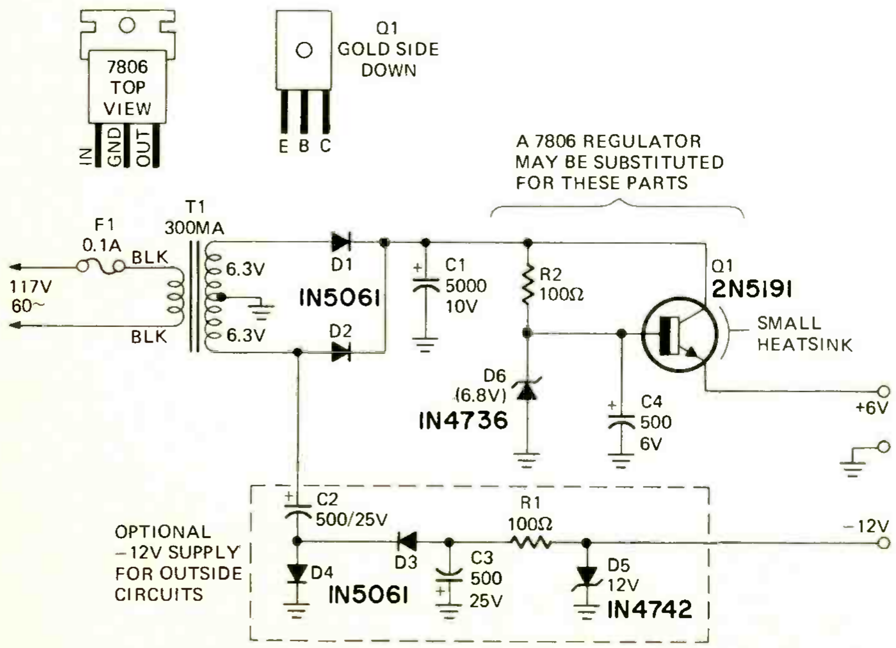


FIG. 5—(top) DRILL AND JUMPER GUIDE for the readout circuit board. FIG. 6.—(middle) TEST CIRCUIT for breadboarding initial checkout. FIG. 7—(bottom) RECOMMENDED POWER SUPPLY fpr ac operation. For portable use simply use four "C" or "D" cells connected in series.

PARTS LIST (Fig. 2)

R1—2200 ohms, ¼ watt, 10%
R2, R3, R4, R5, R6, R7, R8, R9—47 ohms, ¼ watt, 10% (see text)
R10, R11, R12, R13, R14, R15—10,000 ohms, ¼ watt, 10%
C1, C3—0.1-μF disc ceramic
C2—1000 pF disc ceramic
IC1—MK5005P (Mostek) DO NOT SUBSTITUTE
J1, J2—10-pin male connector (modified Molex 09-57-1105)
Q1, Q2, Q3, Q4, Q13—MPS A13, npn Darlington transistor pair (Motorola) DO NOT SUBSTITUTE
Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12—MPS A65, pnp Darlington pair (Motorola) DO NOT SUBSTITUTE
RO1, RO2, RO3, RO4—MAN-4 LED seven-segment readout (Monsanto)
MISC: PC board; 5 jumpers; red filter, 1¼ x 2½ x ⅛" #2423 Plexiglas; sockets for J1 and J2, Molex 09-52-3103

NOTE: The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Tex. 78216.
Etched & drilled circuit board—DGR-b, $3.85.
IC1—$20
Kit of all parts—DR-c, $34.50

PARTS LIST (Fig. 7)

R1, (R2*)—100 ohms, ½ watt, 10%
C1—5000 μF, 10V, electrolytic
C2, C3—500 μF, 25V, electrolytic
C4*—500 μF, 6V, electrolytic
D1, D2, D3, D3—1N5061 silicon diode
D5—1N4742, 12V, 1W, Zener diode
D6*—1N4736, 6.8V, 1W, Zener diode
F1—0.1 A fuse and fuseholder
Q1*—2N5191 npn silicon transistor
T1—transformer: primary, 117Vac; secondary, 12.6V, 100mA with ct
*Regulator: A Fairchild No. 7806 regulator may be substituted for these parts.
MISC: PC board, line cord, strain relief terminals, mounting hardware

NOTE: The following items are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Tex. 78216
Etched & drilled circuit board—DRP-B, $2.50
Kit of all parts—DRP, $8.75

#2423 is ideal for this and may either be bolted directly to the module (using long enough spacers to clear the readouts) or the filter may form a front window for a display or instrument package.

Using it

The module may be powered from a six volt unregulated supply, four D cells, or a regulated supply. One suitable line operated supply is shown in figure seven. This particular supply also puts out -12 volts which is handy for a companion time base chip, the MK5009, or for other external circuitry.

The display goes out before the counter quits. If ultra-long battery life is essential, you can reduce the brightness by increasing the values of R2 thru R9 to perhaps to 220 ohms, or to whatever tradeoff between battery life and brightness you want. Or, you can go to alkaline D cells or NiCad's. Ordinary heavy-duty D cells should last you around 40 hours of intermittent operation. R-E