A Jumbo LED Digital Clock

Read it from 100 feet away, set it for a 12- or 24-hour format and 4 or 6 digits, use it on 50- or 60-Hz ac lines with battery backup if ac power fails

By C. Barry Ward

Most digital electronic clocks with so-called "jumbo" displays offer numerals that are no more than 1" high. If you are looking for a digital timepiece with a billboard-like display that can be easily read from 100 feet or more away, you can build the Jumbo LED Digital Clock to be described for little more than you would expect to pay for a good-quality commercial clock with only 1" display digits.

Our clock is versatile, too. For example, it can be used on either 50- or 60-Hz ac power lines. Furthermore, you can choose between a 6-digit hours/minutes/seconds or a less distracting 4-digit hours/minutes-only display format. And whether you wish to keep time in the usual 12-hour or the 24-hour format preferred by amateur radio operators and others, our clock offers a choice between the two.

Versatility is carried an important step further with the clock's battery-powered, crystal-controlled timebase oscillator. Any time ac power to the clock is interrupted, the dc-powered timebase automatically kicks in so that the clock keeps counting off the seconds until ac power is restored. There is no need to reset the clock every time there is a power failure or someone accidentally pulls the plug.

About the Circuit

Three special-purpose integrated-circuit "chips" are used in this clock. The main one is the popular MM5314 clock chip, which is designed to provide a display capability of either four or six digits. It contains all the circuitry needed for timekeeping and 7-segment digit generation. The second special-purpose chip is an MM5369 oscillator/divider that is used with a quartz crystal to provide the temporary 60-Hz timebase in the battery-backup circuit. The final special-purpose IC used in the clock is the PU4110 Darlington transistor array, two of which are used to provide segement drive for the display.

Two of these chips, the National Semiconductor 5314 and MM5369 (plus a common CD4066 CMOS quad transmission gate) are in standard dual-inline packages, or DIPs. The two PU4110 Darlington transis-

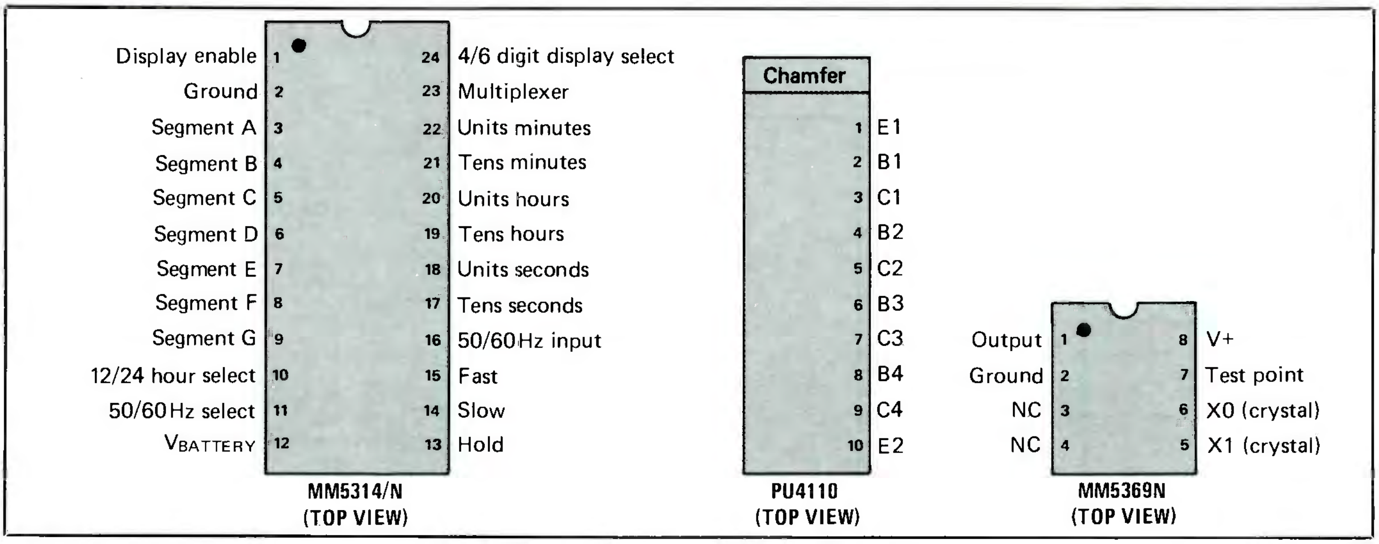
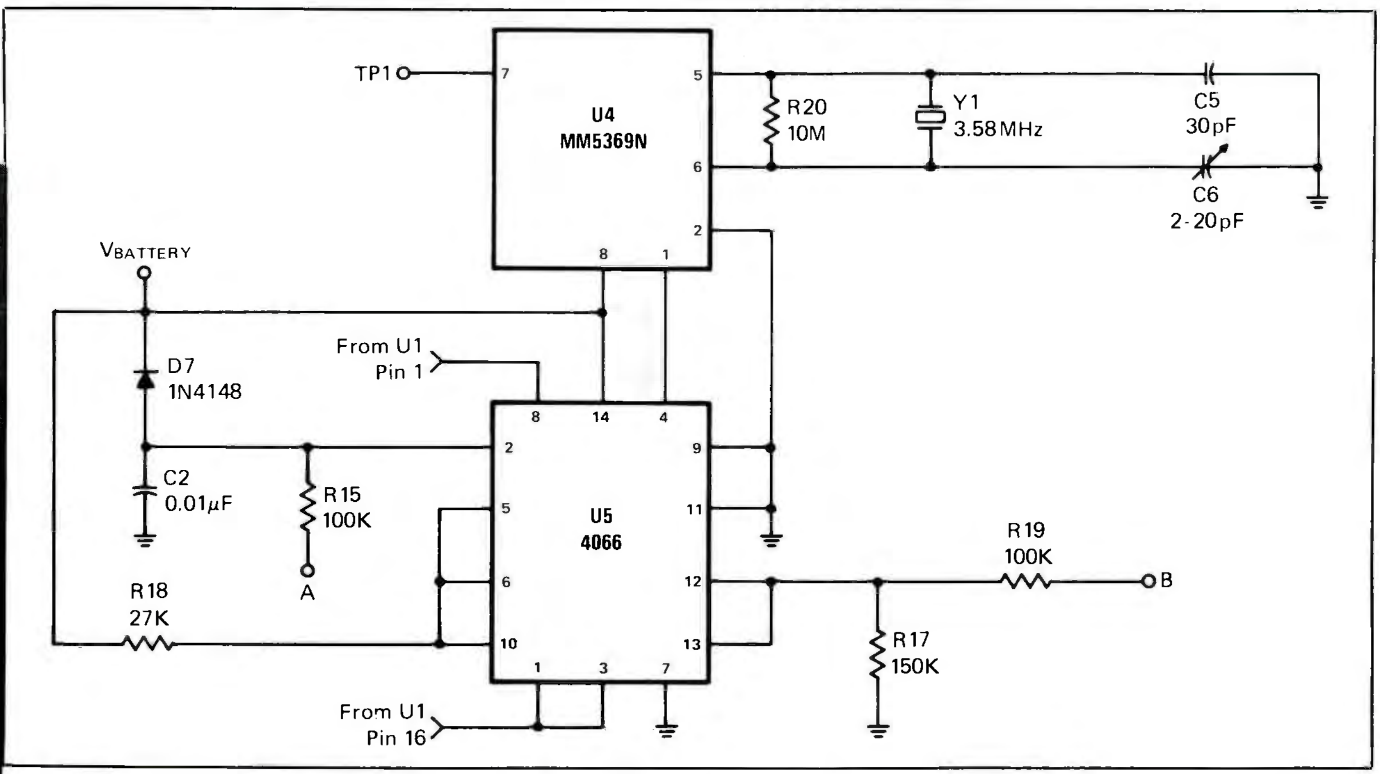


Fig. 1. Pinouts for special ICs used in project.

tor arrays are in single-inline packages, or SIPs. Pinouts for the special-purpose ICs are shown in Fig. 1.

Four basic circuits make up the clock. The basic timekeeping and segment- and digit-drive circuit is shown in Fig. 2. The heart of this circuit is MM5314 clock chip *U1*. Note here that time setting is accomplished with HOLD, SLOW and FAST switches *SW1*, *SW2* and *SW3*, respectively and that jumper wires are installed to obtain a 12-hour display format, operation with a 60-Hz ac line and six digits in the display by grounding pins 10, 11 and 24, respectively, of *U1*. Omitting the jumper wires configures the clock for a 24-hour display format, 50-Hz ac-line operation and a four-digit display. If you wish to be able to reconfigure your clock at any time without having to solder and/or desolder connections, you can wire spst

Fig. 2. Oscillator/divider circuit drives basic clock circuit.



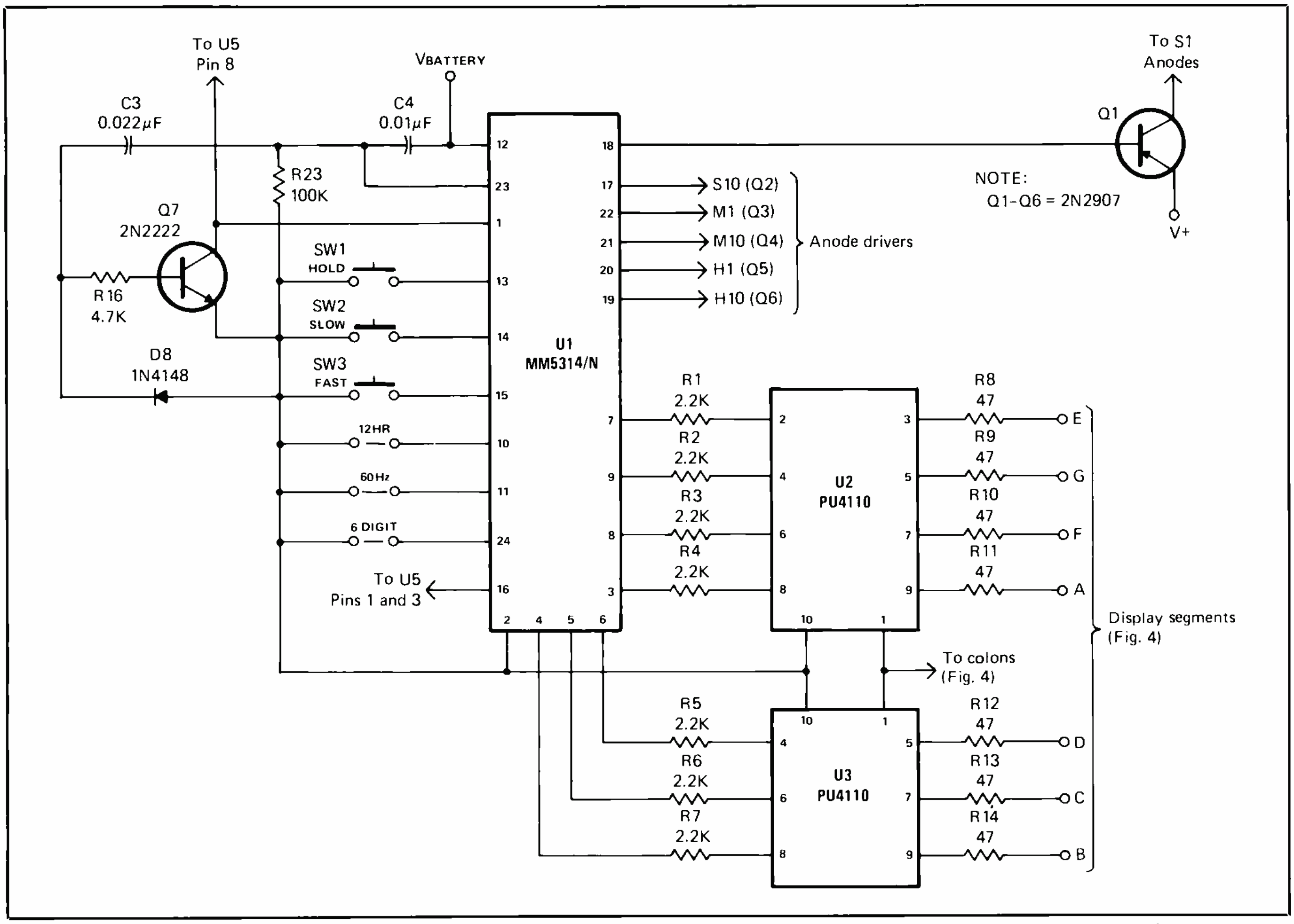


Fig. 3. Basic clock circuit's MM5314 clock chip offers 50/60-Hz, 4/6-digit and 12/24-hour options.

switches between pins 10, 11 and 24 of *U1* and ground.

Digit drive for the display decades is provided by pnp transistors *Q1* through *Q6* via multiplexed lines from pins 17 through 22 of *U1*. Only one digit-drive stage is shown. The *Q2* through *Q6* stages are identical to the *Q1* units-seconds (S1) drive stage. Transistors *Q2*, *Q3*, *Q4*, *Q5*, and *Q6* are the drivers for the tens-seconds (S10), units-minutes (M1), tens-minutes tens-minutes (M10), units-hours (H1) and tens-hours (H10) decades from pins 17, 22, 21, 20 and 19, respectively.

Drive outputs for Darlington transistor arrays *U2* and *U3* are obtained at pins 3 through 9 for display segments A through G, respectively.

Transistor *Q7* and its associated components are used to turn off the display when *U1* is changing the outputs from one digit to the next during multiplexing. This prevents unwanted "ghosting" of a digit number in an adjacent blank segment.

Figure 3 shows the schematic details of the colons that separate the hours and minutes and seconds in the display and the individual decades in the LED display. All decades are identical, except the tens-hours decade, which has no segment F, because it counts up to only 1 in the 12-hour format and 2 in the 24-hour format. Note that each segment is made up of four discrete light-emitting diodes (LEDs). There are 168 LEDs in the display, 164 in the six numeric decades and four in the colon circuits. If you decide upon a permanent four-digit display format, your circuit would not need the two seconds decades and the colon that precedes them.

Shown in Fig. 4 is the 60-Hz timebase oscillator that maintains timekeeping on battery-backup when an interruption of ac power occurs. The timebase oscillator's frequency is determined basically by *Y1*, a standard color-TV color-burst crystal. The frequency can be precisely trimmed to be "on the money" by adjusting trimmer capacitor *C6* while observing the display of a frequency counter connected between test point *TP1* and circuit ground.

A 60-Hz pulse train from the Fig. 4 circuit's output at pins 1 and 3 of *U5* is delivered to the clock input at pin 16 of *U5*.

PARTS LIST

Semiconductors
D1 thru D5,D9,D10—1N4004 or similar 100-volt, 1-ampere diode
D6,D7,D8—1N4148 or similar diode
LED1 thru LED168—Red T-1¾ light-emitting diode
Q1 thru Q6—2N2907 pnp transistor
Q7—2N2222 npn transistor
U1—MM5314 clock chip
U2,U3—PU4110 Darlington transistor array
U4—MM5369A CMOS oscillator/divider
U5—CD4066 CMOS quad transmission gate

Capacitors
C1—1,000-μF, 16-volt axial-lead electrolytic
C2,C4—0.01-μF disc
C3—0.022-μF Mylar
C5—30-pF disc
C6—2-to-20-pF trimmer

Resistors (¼-watt, 5% tolerance)
R1 thru R7—2,200 ohms
R8 thru R14—47 ohms
R15,R19,R23—100,000 ohms
R16—4,700 ohms
R17—150,000 ohms
R18—27,000 ohms
R20—10 megohm
R21,R22—100 ohms

Miscellaneous
B1—9-volt battery
SW1,SW2,SW3—Normally-open, momentary-action spst pushbutton switch
T1—12-volt, 1-ampere ac plug-in wall transformer
Y1—3.59545-MHz crystal
Printed-circuit board; suitable enclosure (see text); 9-volt battery snap connector; IC sockets (optional—see text); flat black paint; rubber feet; hookup wire; solder; etc.

Note: The following items are available from NRG Electronics, P.O. Box 24138, Ft. Lauderdale, FL 33307: actual-size etching-and-drilling guide for pc board—send SASE; complete kit of parts (including Plexiglass enclosure) for $59.95 plus $4.50 for P & H; etched and drilled pc board for $25.00; MM5314 clock IC for $3.95; PU4110 for $4.95 each; MM5369 oscillator/divider IC for $2.95; 168 matched red T-1¾ jumbo LEDs for $16.80; Plexiglass enclosure for $25.00. Florida residents, please add state sales tax.

The final circuit that makes up the clock is the ac power supply shown schematically in Fig. 5. Ac power is stepped down to 12 volts by plug-in wall transformer *T1*. The 12 volts ac thus obtained is rectified by the bridge circuit made up of *D1* through *D4* and is filtered to clean dc by *C1*. Power going to the clock must be well-filtered to prevent flickering that could be caused by a "beat frequency" between the multiplex and ac-line frequencies.

Diodes *D5* and *D6* isolate the backup-battery supply (V_{BATT}) from the V+ main power line for the LED display. This assures that the timekeeping circuits will remain operational via the oscillator/divider circuit during periods when ac power to the clock is interrupted.

In operation, the clock can be driven from either of two different time references. When operated from the ac line, the main reference is the 60-Hz signal picked up from the secondary side of *T1* in the power supply. This reference is extremely accurate. Though it may not be precisely 60.0000 Hz at any given moment in time, corrections are being constantly made by the utility companies to maintain an extremely precise long-term accuracy over any 24-hour period. Hence, this reference is considerably more accurate over the long haul than is the battery-powered oscillator/divider circuit that provides the timebase reference when ac power is interrupted.

Stabilization of the alternate-reference crystal-controlled oscillator over a long period of time is difficult to obtain. Any of a number of physical factors (temperature, humidity, etc.) can cause the crystal oscillator's frequency to drift. Therefore, the crystal-controlled trimebase reference is used only as a backup to the main ac power line reference. It can, of course, be used as the primary reference when the clock is continuously powered from a dc power source, such as in an automotive or marine environment.

CMOS transmission gate *U5* in Fig. 3 directs either the power-line or the oscillator/divider reference frequency to the clock chip. During periods when the normal ac-line reference is being used, one transmission gate in *U5* (call it *U5A*) is turned on by power from the diode bridge in the power supply, pulling pin 10 of this IC low. This turns off two of the gates in *U5* (call them *U5B* and *U5C*). The *U5C* gate's output at pin 8 controls display blanking. It turns off both the digit and segment drives to conserve power when the clock is operating from the battery-backup system and routes the oscillator reference to the clock during battery operation.

A small part of the 60-Hz power-line signal is filtered by *C2* and *R15* and is clamped by *D7* in Fig. 3. This signal is the power-line reference frequency. The *U5A* gate routes this signal to the clock chip during normal ac operation of the clock.

Construction

Because there are several hundred connections that must be made in wiring together this large clock project and the need for a reliable means of physically lining up all the display LEDs, printed-circuit wiring is almost mandatory. If you wish, you can etch and drill your own pc board. Though we usually print our pc etching-and-drilling guides actual-size so that readers who wish to fabricate their own boards can use them di-

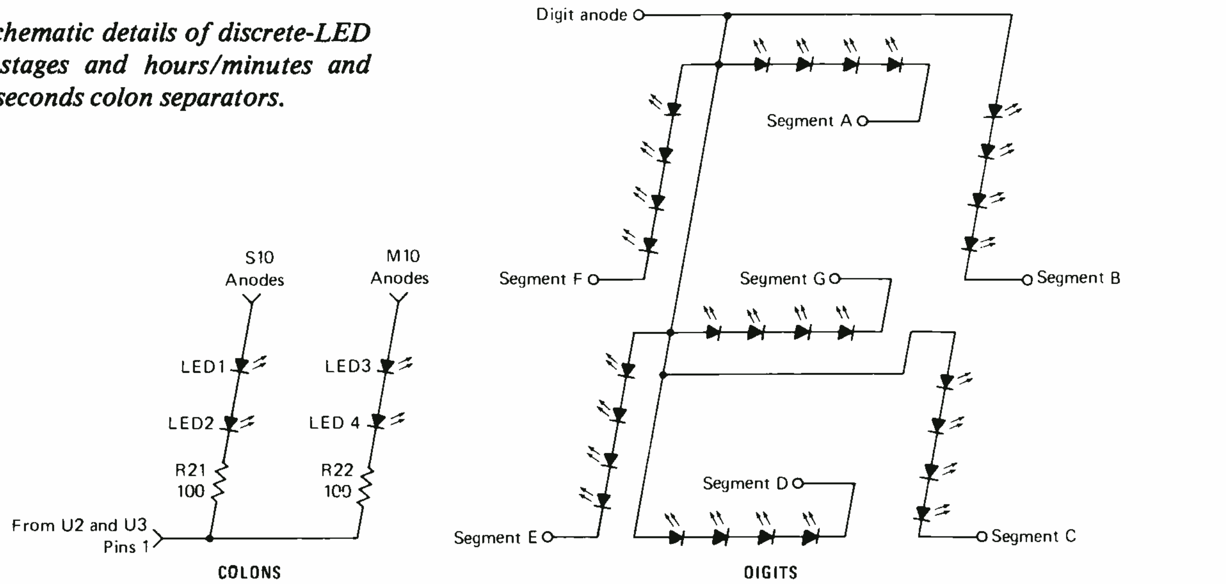


Fig. 4. Schematic details of discrete-LED numeric stages and hours/minutes and minutes/seconds colon separators.

rectly, the very large size of the board required for this jumbo clock precluded actual-size reproduction of its etching-and-drilling guide here. However, we have reproduced it half-size in Fig. 7.

Those readers who wish to fabricate their own pc boards can have the Fig. 7 guide photographically blown up to twice the size shown or can send a self-addressed, stamped envelope to the kit supplier given in the Note at the end of the Parts List to obtain a full-size guide. Alternatively, you can purchase a ready-to-wire board from the same source.

Before mounting any components on the top of the pc board, give it a coat or two of flat black spray paint to prevent the background against which the display LEDs are mounted from showing through the display window. When the paint has fully dried, use a pin or needle to clear the paint from every hole on the board. If you fabricate your own board, you can paint the component side before drilling any holes, which obviates the need to clear paint away later on.

Begin wiring the pc board by installing the 14 wire jumpers in the locations indicated. You can use solid bare hookup wire for the jumpers. If you plan to use your clock on a 50-Hz power line, you prefer a 4-digit display (hours and minutes only) or you want a 24-hour display format, leave out the associated wire jumpers. Installing all jumpers sets the clock up for 60-Hz, 6-digit and 12-hour display format operation. Optionally, you can install spst slide or toggle switches in place of the options jumpers to allow you to reconfigure the clock whenever you wish or as needed.

Install all resistors and capacitors (make sure you properly polarize *C1*). Note that *R17* and *R23* mount on the bottom of the board. Take careful note of how they are to be installed by referring to Fig. 7. Then flip over the board and mark with a pencil the traces to which the resistor leads are to be soldered. Trim the leads of both resistors as needed and carefully tack-solder them into place. Make sure that the resistor leads contact only the traces to which they are supposed to connect. Install

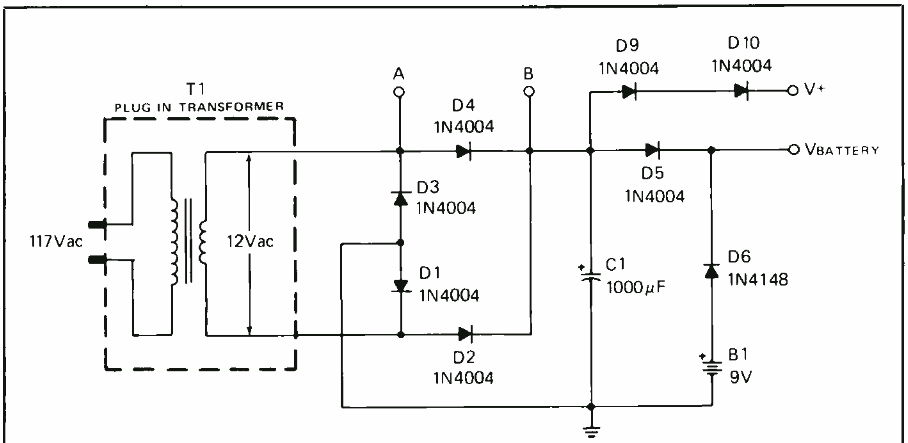


Fig. 5. Ac power supply circuit has battery backup to maintain time, not display, during brief power interruptions.

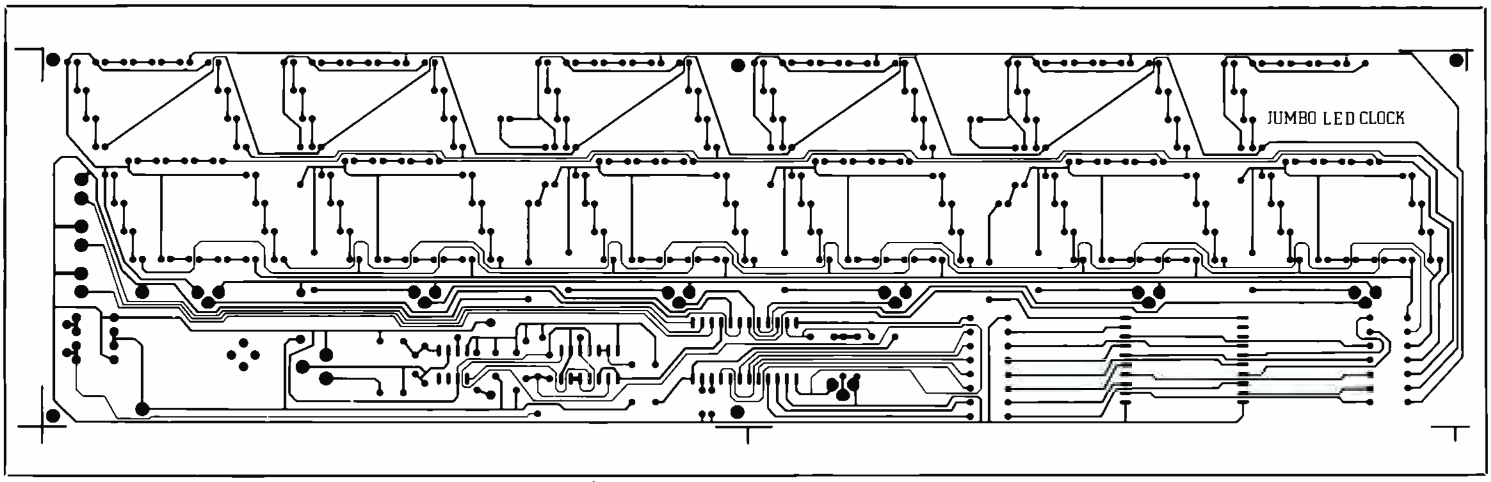


Fig. 6. Etching-and-drilling guide for clock's pc board is shown half-size to fit on a page. To use this to make a board, photographically enlarge it by 200%.

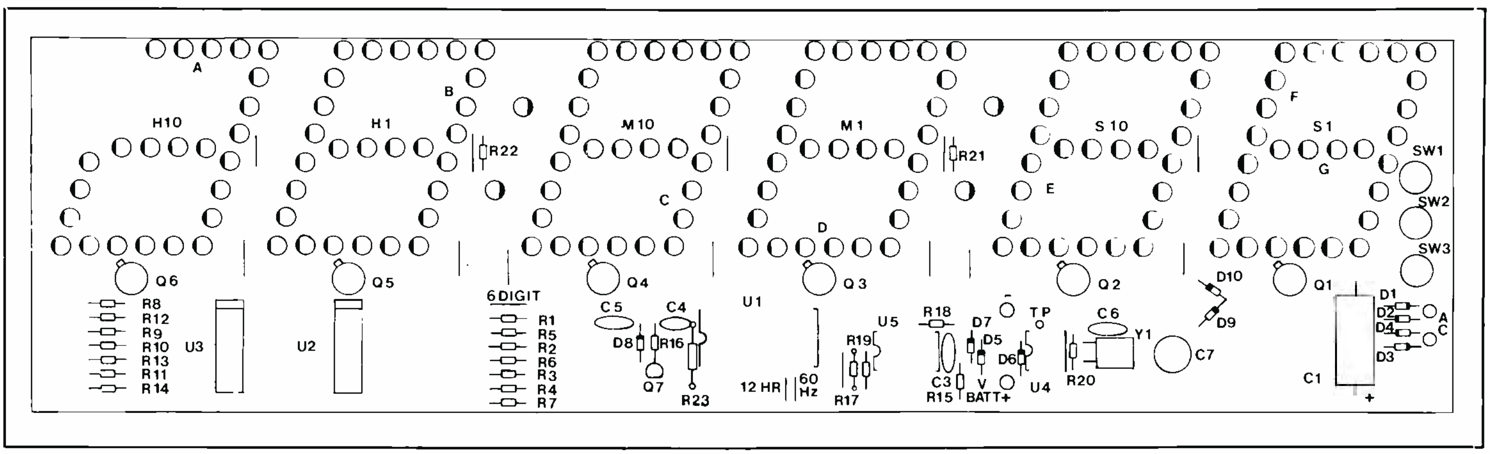


Fig. 7. Wiring guide for pc board. Exercise care when installing LEDs, transistors and ICs.

the diodes in their respective locations, again making sure that they are properly oriented before soldering their leads to the copper pads. Then install and solder into place the trimmer capacitor.

Use of sockets for the ICs is optional but recommended. Use standard DIP sockets for *U1*, *U4* and *U5*. For *U2* and *U3*, which have only one row of pins, you can use either Molex Soldercons or a 20-pin DIP socket carefully separated down the middle to yield two 10-pin SIP sockets that will work fine. Whether or not you use sockets for the ICs, do not install the ICs themselves at this time. The CMOS devices are easily damaged by static electricity and should be left for last. Once you have installed the IC sockets, install the seven transistors in their respective locations. Make sure you do not mix up the two types and that the transistor leads go into the appropriate holes in the board.

The most tedious part of construction is installation of the 168 LEDs that make up the numeric/colon display. To get the proper effect from the display, all LEDs must be closely matched in intensity. Even a slight difference in intensity between LEDs can be quite noticeable when the clock is operating. A good way to assure that the LEDs are properly matched is to purchase all of them at the same time from the same manufacturer's lot. If you wish, you can purchase matched LEDs from the kit supplier given in the Note at the end of the Parts List.

Mounting the LEDs on the board can become tedious, due to the quantity that must be installed. Work carefully, making sure that each Led is properly polarized before soldering its leads to the copper pads on the bottom of the board. All cathodes in Fig. 7 are identified by the heavy black "flats" in the case outlines. Note that the orientations of the LEDs in the colons (*LED1* through *LED4*) are opposite those for the numerals. Make sure you match the flats on the cases of the LEDs with the flats on the wiring guide.

Mount the LEDs with the bottoms

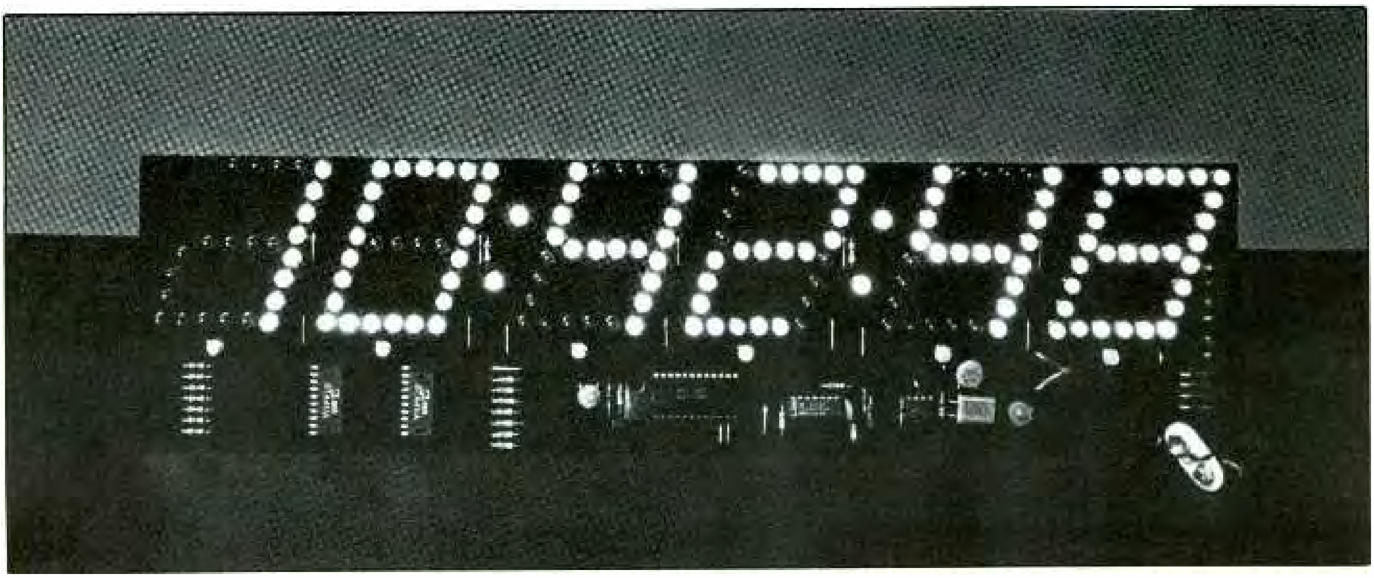


Fig. 8. Wired board ready to install in enclosure.

of their molded cases flush with the top of the board. If necessary, use a sharp hobby knife to trim away any excess plastic that prevents any LED from seating flat. Mount and solder into place no more than eight LEDs at a time. Avoid excessive heating that can damage the LEDs during soldering. One way to avoid excessive heat is to solder only one lead of each LED in an installed string and then return to the first LED and solder each LED's other lead.

Finish wiring the board by connecting and soldering into place the leads from plug-in wall transformer *T1* and mount the three time-setting switches (*SW1*, *SW2* and *SW3*) on the *foil* side of the board. Finally, wire the battery snap connector into the circuit from the foil side of the board, taking care to properly polarize its leads.

Now install the ICs in their respective locations. If you are using sockets, just plug them in. Make sure as you plug in the DIP devices that no pins fold under or overhang the sockets as you install the ICs in their sockets. All pins must go squarely into the sockets. The SIP devices plug into their half sockets and are held in place with double-sided foam tape between their cases and the surface of the board. If you have decided to install the ICs without sockets, do this now. Whichever method you use, handle the ICs with the care required for any CMOS device and make sure you properly orient them. This done, plug a fresh 9-volt battery into the snap connector and secure the battery to the bottom of the board with a strip of double-sided foam tape.

Now that all soldering is complete, check your wiring. Carefully examine all solder connections for good soldering. If any connection appears to be questionable, reflow the solder on it. Be on the lookout for solder bridges between traces on the bottom of the board, particularly between the closely spaced pads into which the IC socket pins are installed. Flip over the board and double check all component orientations.

Your Jumbo LED Clock can be housed in any type of enclosure that suits your taste. For example, you can make a large shallow box out of thin lumber or tinted Plexiglass. Whatever material you use for the enclosure's walls, however, you should use a red filter in front of the display area to increase contrast and legibility of the numerals. If you decided to add the optional switches to the 50/60-Hz, 4/6-digit and 12/24-hour select lines, mount them in a location where they will not interfere with the rest of the circuit and label each accordingly.

If you plan to use your clock on 50-Hz ac power, install a jumper wire between pin 11 of *U1* and pin 13 of *U5*. This arrangement automatically switches the MM5314's clock frequency select input between 50 Hz for ac-line operation to 60 Hz for battery backup.

To use the clock in a dc-only application, connect a jumper wire from pin 12 of *U5* to ground. This puts the Crystal-controlled timebase into continuous operation and assures proper clock operation.

Checkout and Use

When you are sure that your wiring is correct and that your soldering is okay, plug the wall transformer into an ac outlet to power up the clock. If everything is indeed okay, the LED display should light up with a random time readout. If one segment in a given decade does not light, carefully inspect that segment to determine if you installed one or more LEDs backward. If this is not the case, one or more of the LEDs is bad.

There is a simple way to isolate the problem to a bad LED. Using a short length of insulated solid hookup wire with about ⅛" of insulation trimmed form each end, temporarily short out one LED at a time by jumpering its pads on the bottom of the board with the wire. Do this while the clock is powered, but make sure you short out only the one LED's pads—not one pad to a different part of the circuit. Short out only one LED at any given time. If you should short out more than one, the remaining LEDs in the string or the segment driver circuit can be permanently damaged.

As you short out each successive LED, somewhere along the line, the remaining LEDs in the segment should flash on. If this occurs, you have isolated the problem to the LED that is currently being jumpered. All you have to do then is remove the jumper wire, power down the clock and replace the bad LED with a good one. With the repair made, you can return the clock to service.

When all clock segments in all decades are checked out and the seconds decades are repeatedly counting up from 00 to 59, the clock is working. At this point, press and hold FAST pushbutton switch *SW3* and note that the seconds decades count up so rapidly that they appear to be blurred, while the minutes decades count up fast but not so fast that you cannot follow the count, and the hours decades advance at a rate of about one per second. Release the FAST button and press and hold SLOW pushbutton switch *SW2*. This time, note that the seconds and minutes decades count up at what appears to be the same rates the minutes and hours decades did when the FAST button was pressed and held. Releasing the SLOW button and pressing and holding HOLD pushbutton switch *SW1* should "freeze" the displayed count for as long as the button is held.

Now check out the battery-backup crystal timebase. To do this, first check the voltage between pin 10 of *U5* and circuit ground with the clock running on ac power. The meter should indicate a potential of less than 1 volt. This is the power-failure signal. The clock will not function properly unless the potential on pin 10 of *U5* is about 1 volt or less during normal operation.

With a fresh 9-volt battery connected into the circuit, unplug the wall transformer from the ac line. Within a few seconds, the measured potential on pin 10 of *U5* should jump to greater than 7 volts, which indicates that the automatic changeover circuit is functioning properly.

If you own or have access to an accurate frequency counter, you can trim the timebase oscillator's frequency to precisely 60 Hz. To set the timebase, connect the frequency counter between pin 7 of *U4* and ground. While observing the counter's display, adjust trimmer capacitor *C6* for a frequency of exactly 3.579540 MHz. This adjustment is not supercritical if your clock will normally be powered from the ac line because the timebase oscillator will be used only when there is a power failure. Of course, if you plan on using the clock in a mobile environment where the only power is 12 volts dc, the more accurate you make the trimmer adjustment, the more precise the timekeeping.

Once you know that your clock is operating properly and you have checked out and adjusted the crystal-controlled timebase circuit, you can set the time. This is very easily accomplished. Just use the FAST button to get the hours and tens of minutes decades to within about 10 minutes of the proper time. Then use the SLOW button to zero in on the next highest minute to the actual time. Finally, press the HOLD button to freeze the display until the clock or watch you are using as the reference comes up to the exact time to which the display is frozen and release. ME