Low-Frequency Dual-Pulse Generator

Offers digital-circuit experimenters a source of reliable clock pulses to 10 kHz

By Duane M. Perkins

If you intend to do serious experimenting with digital circuits, you will soon discover that you need a source of reliable clock pulses. You can, of course, buy an expensive pulse generator to meet your needs. However, for less than $100 you can build the Dual-Pulse Generator described here, using only readily available parts.

Each of the two pulse outputs is independently adjustable in phase, pulse width and amplitude. Though both are driven by the same oscillator, which provides for clocking a circuit that requires a two-phase clock, one output can be set up to provide a frequency that is a subharmonic of the other.

Circuit Description

Though the pulse generator provides two independently controllable outputs, it has a single oscillator from which the pulses are derived, as shown in Fig. 1. Therefore, the frequency of the pulses is established by the relaxation oscillator designed around unijunction transistor *Q1*. In addition to providing four frequency ranges for the internal oscillator, the generator's RANGE switch (*S2*) has a position for a 60-Hz pulse, derived from the ac line at the center tap of the power supply transformer (see Fig. 3), plus an input at *BP4* for an external signal source.

There are four internal oscillator frequency ranges. These are 1 to 10 Hz, 10 to 100 Hz, 100 to 1000 Hz and 1 to 10 kHz. These limits are only approximate. Exact range limits will depend on the intrinsic standoff ratio of the UJT used for *Q1*.

Because the pulse generator contains a ÷2 circuit, its output will be half the frequency of the oscillator. The 60-Hz output is generated from the 120-Hz pulses taken from the center tap of the power transformer.

Any waveform with an amplitude between 0.5 and more than 9 volts can be applied to the EXTERNAL INPUT at *BP4*. Output pulse frequency will be half the input frequency and can go as high as 15 kHz. For maximum phase control range, a sawtooth dc waveform with a peak amplitude of about 9 volts works best. However an ac sine wave will permit some degree of control. A square wave or pulse input will drive the pulse generator but will not permit phase control.

Referring to Fig. 1, the TRIGGER OUTPUT at *BP3* is taken from the base-2 (B2) terminal of *Q1*, after being amplified by *Q2* to a peak amplitude of about 5 volts. This amplitude is sufficient to assure positive triggering of an oscilloscope. Trigger frequency will be twice that of the output pulses from the generator circuits. PHASE control *R15* in Fig. 2 sets the amount of delay between the trigger pulse and the following output pulse. This delay permits events just prior to the output pulse to be viewed on an oscilloscope's screen.

Both pulse generator circuits are identical. Hence, when you refer to

Fig. 2, you will note two sets of component numbers and IC and transistor lead designations. Numbers in parentheses refer to components and connections for generator B, while those not in parentheses refer to generator A. Resistors *R13* and *R14* are common to both generators and are not repeated.

An input signal to the noninverting input of *IC3A* (taken from the output of the Fig. 1 circuit) is converted to pulses with fast rise and fall times by the LM339 voltage comparator. The reference voltage for *IC4A* is taken from the wiper of PHASE control *R15*, which determines the timing of the output pulse relative to the input signal cycle.

The pulse that appears at the comparator's output is used to clock ÷2 flip-flop *IC4A*. The symmetrically square pulse at the output of *IC4A* then goes to SQUARE/VARIABLE switch *S3*, which directs it to the output amplifier made up of *Q3* and *Q4*.

With *S3* set to SQUARE, the output of *IC4A* goes directly to the input of output amplifier *Q3/Q4*. Setting *S3* to VARIABLE diverts the output from *IC4A* to the trigger input of *IC5A* at pin 6. Before arriving at *IC5A*, however, the square pulses from *IC4A* are differentiated by the RC value of the network composed of *C11* and *R17*. From the output of *IC5A* at pin 5, the signal is routed to *S3*'s VARIABLE contacts and then on to the input of the *Q3/Q4* output amplifier.

The brief negative-going pulses are fed to the trigger input of *IC5A* to generate positive output pulses whose duration is determined by the RC value of the timing network connected to the discharge (pin 2) and threshold (pin 1) terminals of *IC5A*. Potentiometer *R19* provides a means for setting the timer's pulse duration, while SHORT/LONG switch *S4* selects the range by switching in either *C12* for a short-duration or *C13* for a long-duration pulse.

Because output amplifier *Q3/Q4* uses complementary transistors in a

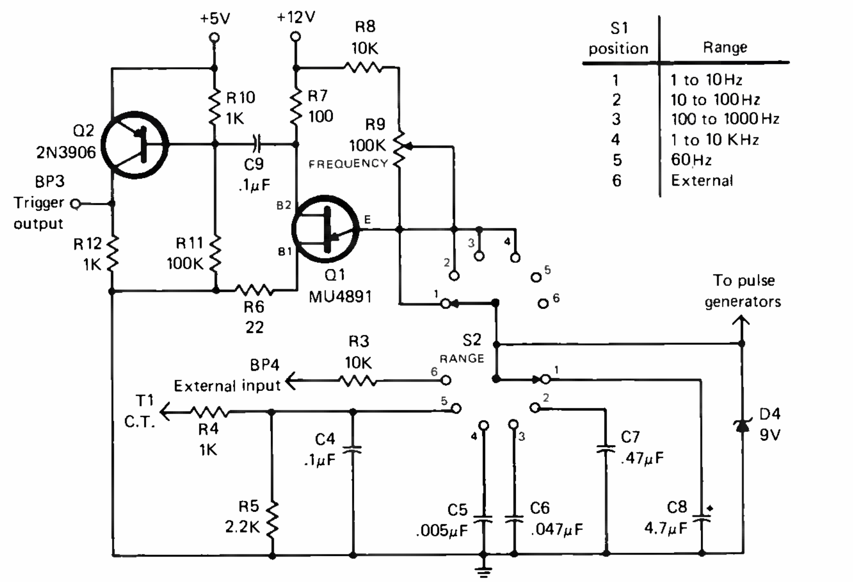


Fig. 1. Generator uses this single oscillator for both pulse channels.

PARTS LIST

Semiconductors
D1,D4—9-volt zener diode (1N4739 or similar)
D2,D3—1N914 switching diode
LED1,LED2—Light-emitting diode
IC1—7812 12-volt regulator
IC2—7805 5-volt regulator
IC3—LM339 voltage comparator
IC4—4013 flip-flop
IC5,IC7—556 dual timer
IC6,IC8—LM317 voltage regulator
Q1—MU4891 unijunction transistor
Q2,Q3,Q5,Q6,Q8—2N3906 transistor
Q4,Q7—2N3904 transistor
RECT1—VM08 or similar 50-PIV bridge rectifier

Capacitors
C1—3300-μF, 35-volt electrolytic
C2,C3—0.22-μF disc
C4,C9,C10,C17,C18,C19,C26,C27,C28—0.1-μF disc
C5,C13,C22—0.005-μF disc
C6—0.046-μF disc
C7—0.47-μF tantalum
C8,C16,C25—4.7-μF, 35-volt electrolytic
C11,C20—0.001-μF disc
C12,C21—1-μF tantalum
C14,C23—0.1-μF disc
C15,C24—22-μF, 35-volt electrolytic

Resistors (½-watt, 10% tolerance)
R1,R5—2200 ohms
R2,R4,R10,R12,R18,R28,R32,R42—1000 ohms
R3,R8,R16,R17,R26,R30,R31,R40—10,000 ohms
R6—22 ohms
R7—100 ohms
R11,R13,R14,R27,R41—100,000 ohms
R20,R21,R34,R35—470 ohms
R23,R24,R37,R38—15,000 ohms
R25,R39—100 ohms, 2 watts
R9—100,000-ohm linear-taper potentiometer
R15,R19,R29,R33—1-megohm, linear-taper potentiometer
R22,R36—5000-ohm, linear-taper potentiometer

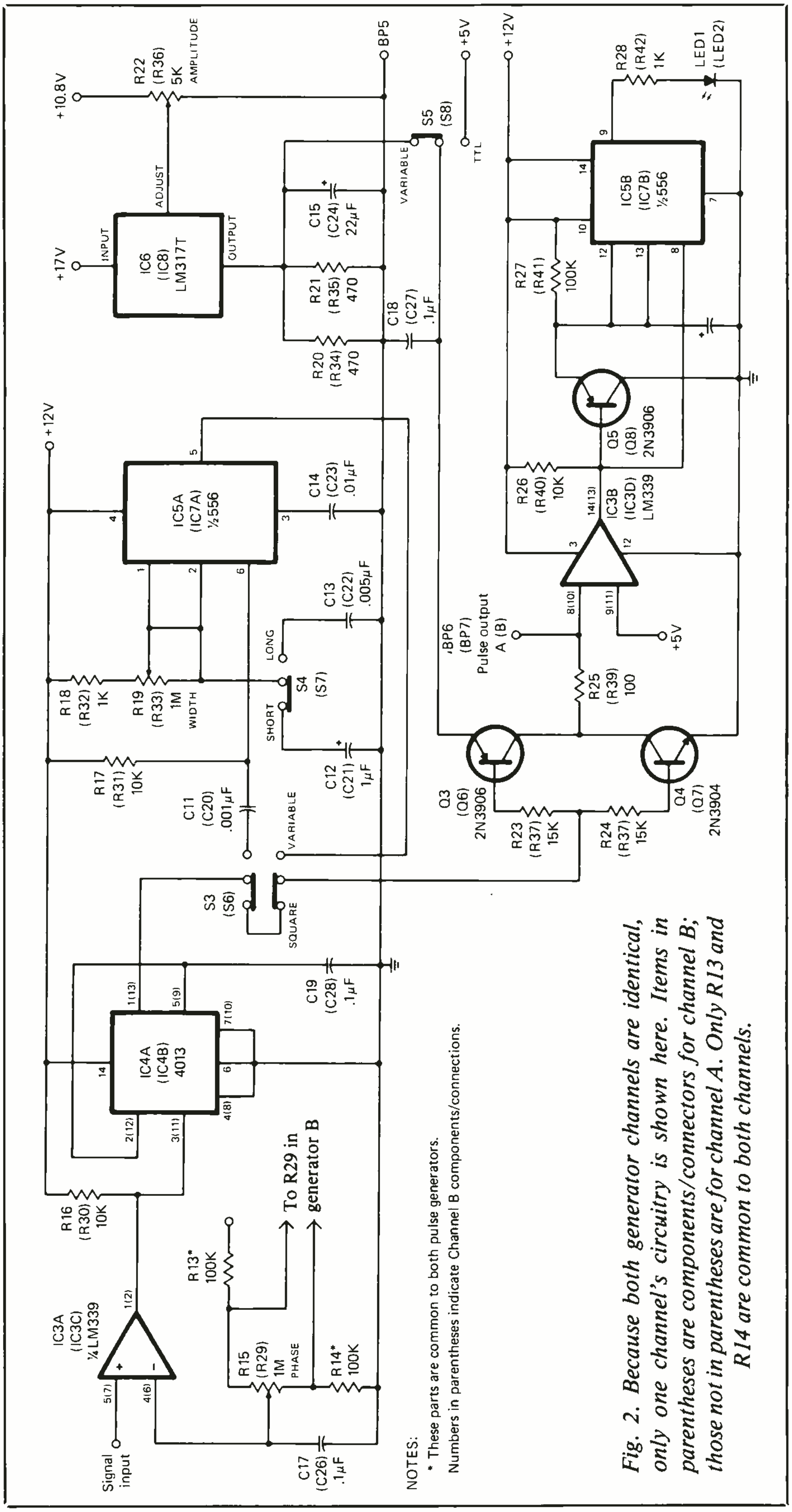
Miscellaneous
BP1 thru BP7—Five-way binding posts (five red, four black)
I1—Panel-mount neon lamp assembly with current-limiting resistor
S1—Spst slide or toggle switch
S2—6pdt nonshorting rotary switch
S3,S5,S6,S8—Spdt miniature slide or toggle switch
S4,S7—Dpdt miniature slide or toggle switch
T1—12.6-volt, 1.2-ampere, center-tapped power transformer
Printed-circuit board; 14-pin DIP IC sockets (4); metal cabinet (see text); four-lug (none grounded) terminal strip; panel clips for LEDs (2); pointer-type control knobs (8); line cord with plug; plastic strain relief or rubber grommet; plastic cable ties or lacing cord; lettering kit or tape labeler; aerosol clear lacquer; stranded hookup wire; machine hardware; solder; etc.

totem-pole configuration, one transistor will be saturated while the other is cut off. Hence, the output is alternately switched between ground and the supply voltage. This enables the amplifier to sink or source a large current with equal ease and results in very fast rise and fall times.

Since the output amplifier is an inverter, it is the intervals between pulses from the timer that become positive output pulses. The pulse WIDTH control, *R19,* has the direct effect of varying the interval between output pulses, which directly varies pulse width. This becomes apparent if the control is set for a certain pulse width and the frequency is then changed. Pulse width varies with frequency, but the interval between pulses remains fixed.

By varying the supply voltage to the output amplifier, the amplitude of the output pulses is also varied. Adjustable voltage regulator *IC6* permits a range of from 1.2 to 12 volts. Alternatively, amplitude switch *S5* can be set to TTL to supply the output amplifier from the fixed 5-volt supply. This arrangement maintains a constant output impedance regardless of amplitude. Resistor *R25* prevents damage to the transistors in the event that the output is short-circuited to ground or a positive supply voltage. Since output impedance at the collectors is very low, output impedance at the output terminals is essentially equal to the 100-ohm resistance.

The voltage-sensing circuit connected to the output consists of voltage comparator *IC3B* with a 5-volt reference and missing-pulse detector *IC5B* and *Q5* with a timing cycle of about 0.5 second. If the amplitude of the output signal exceeds 5 volts, the pulse will be inverted by the comparator. The negative-going pulse causes *Q5* to conduct, discharging timing capacitor *C16,* and trigger the timing circuit to begin a 0.5-second positive output pulse that causes *LED1* to turn on. The timing cycle



NOTES:
* These parts are common to both pulse generators.
Numbers in parentheses indicate Channel B components/connections.

Fig. 2. Because both generator channels are identical, only one channel's circuitry is shown here. Items in parentheses are components/connectors for channel B; those not in parentheses are for channel A. Only R13 and R14 are common to both channels.

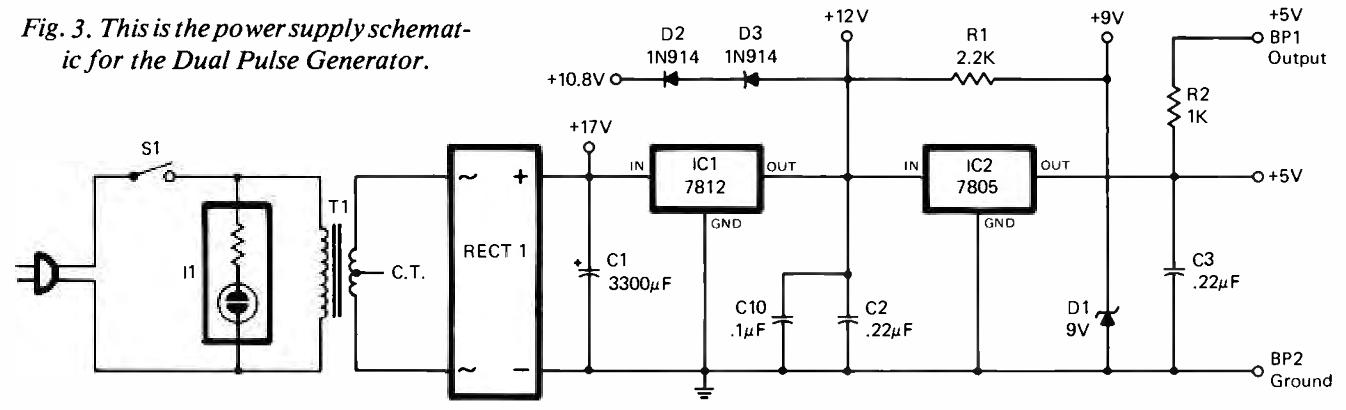


Fig. 3. This is the power supply schematic for the Dual Pulse Generator.

will be continually retriggered as long as output pulse amplitude exceeds 5 volts, and *LED1* will glow continuously if the frequency exceeds about 1 to 2 Hz, depending on pulse width. At lower frequencies, *LED1* will turn on and off in time with the pulses.

The power supply, shown in Fig. 3, is a straightforward circuit consisting of bridge rectifier *RECT1* across the 12.6-volt secondary of *T1* and fixed 12- and 5-volt regulators *IC1* and *IC2*. Zener diode *D1* provides the 9-volt low-current supply for the phase control circuits. Silicon diodes *D2* and *D3* in series drop the 12-volt supply to 10.8 volts to limit maximum supply voltage to the output amplifiers to 12 volts. (The output of the LM317 regulators is 1.2 volts above the voltage at the ADJ terminals of *IC6* and *IC8*).

Construction

Due to the relatively complex nature of the circuitry and the need for low-impedance ground and positive-voltage supply buses, a printed-circuit board is almost mandatory for this project. You can fabricate your own pc board, using the actual-size etching-and-drilling guide in Fig. 4 and wire it according to the accompanying components-placement diagram.

Wire the pc board exactly as shown in Fig. 4. Take care to orient the components as shown so that electrolytic capacitors, diodes and LEDs are properly polarized and the bridge rectifier, ICs and transistors have their pins go into the proper holes in the board. Incidentally, it is an excellent idea to use sockets for all dual in-line package (DIP) ICs and reserve installation of these ICs for last, after voltage checks have been made.

When making connections to the pc board, use heat and solder judiciously. Use only enough to assure good electrical and mechanical connections. Take particular care to avoid creating solder bridges between the closely spaced pads between IC pins and transistor leads.

Note in Fig. 4 that, because of the large number of wires that interconnect the board with the components on the front panel, all but two of the connection pads are arranged along two edges of the pc board. This makes it possible to neatly bundle the wires into a cable, using plastic cable ties or lacing cord. It also makes it easy to flip up the board assembly for circuit tracing should this become necessary. To this latter end, it is recommended that you use stranded hookup wire throughout project assembly.

Your next task is to machine the metal cabinet in which the pulse generator is to be housed. The cabinet will have to be fairly large in order to accommodate the large pc board and power transformer and all the various controls, switches, indicators and binding posts on the front panel, along with their identifying legends. The author chose Radio Shack's Cat. No. 270-270 cabinet for his prototype. This cabinet measures 9¼"W × 6¾"D" × 5⅜"H and easily accommodates all components, as shown in the photos.

In his prototype, the author used miniature slide-type switches for *S1* and *S3* through *S8*, which require three holes each for mounting (two round for securing it to the panel with machine screws and one rectangular for the toggles). If you wish to simplify the machining operation, you can substitute miniature toggle switches, which require a single round hole. Bear in mind, however, that toggle switches normally operate exactly opposite the manner in which slide-type switches operate. That is, if you flip a horizontally mounted toggle-type switch to the left, the *right* contacts will close. Therefore, you will have to either reverse the front-panel legends for these switches or wire the switches backward from the directions shown in Fig. 5.

If you use slide-type switches, you will have to drill and cut a total of 46 holes in the cabinet, one in the rear wall for the line cord, six in the bottom for mounting the pc board and power transformer, and the remain-

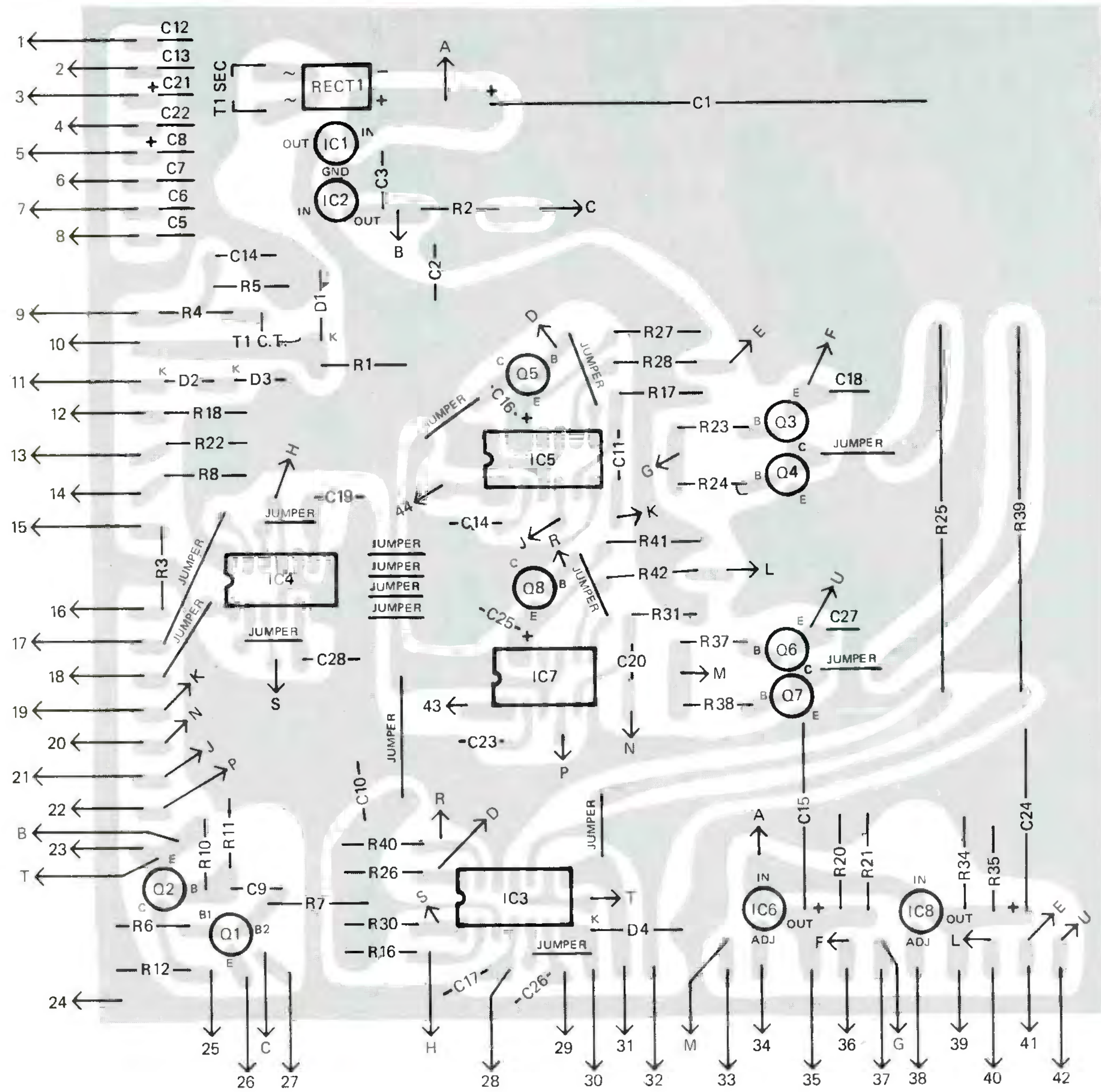
Fig. 4. Above is the actual-size ething-and-drilling guide; opposite page is components-placement diagram.

der in the front panel for the switches, controls, indicators and binding posts. By substituting toggle-type switches, you can reduce the number of holes to 33 (one for mounting the terminal strip for *R13* and *R14*), all of them round, though of different diameters.

After machining the cabinet and deburring all holes, test fit the switches, controls, indicators and binding posts on the front panel. The only component that must be securely mounted at this time is RANGE switch *S2,* since you will have to place its pointer knob on its shaft and rotate it through each position to mark off the range locations on the panel. This done, remove the components and set them aside.

Carefully label the front panel with the appropriate legends, using a dry-transfer lettering kit or a tape labeler. If you use a lettering kit, spray two or more *light* coats of clear lacquer over the entire surface of the front panel to protect the lettering. Allow each coat to dry before applying the next. Do *not* try to get by with only one or two heavy coats; if you do, the lettering will almost certainly lift and dissolve.

When the final coat of lacquer has completely dried, mount the front-panel controls in their respective locations, with *LED1* and *LED2* set into panel clips. Place the knobs on the shafts of the potentiometers and *S2* and check that they point straight up



When installing polarized components, make certain you properly index their leads and pins as shown here.

at mid-rotation for the pots and properly index to the marked locations on the panel for *S2*. Then mount the power transformer to the floor of the cabinet with machine screws, lockwashers and nuts.

Next, split apart the conductors at the free end of the line cord for a distance of about 8″ and cut off 5″ from one conductor. Trim ¼″ of insulation from each conductor, tightly twist together the fine wire conductors in each and lightly tin with solder. Pass the free end of the cord through the hole in the rear wall of the cabinet and secure it in place with a plastic strain relief, about 4″ from the split point. Alternatively, line the hole with a rubber grommet, pass through the cord, and knot it about 4″ from the split point, thereby eliminating the need for a strain relief.

Front-panel wiring in Fig. 5 is keyed to the components-placement diagram in Fig. 4. That is, numbered points in both figures mate with each other. Note in Fig. 4 that there are also several lettered points. These do not connect to similar points on the front panel but to the same lettered points on the circuit board itself. In essence, they are long jumpers but are treated as part of the cable wiring.

Study Figs. 4 and 5 before actually wiring the board to the front panel. Once you are satisfied you know what goes where, place the circuit board on the floor of the cabinet with one row of pads facing toward the

Applications

Different families of digital integrated circuits have different input voltage requirements. As a rule, though, the input voltage should not exceed the circuit's positive supply voltage nor go below the circuit's reference ground. However, the nearer the input voltage's excursion comes to the circuit's positive supply and ground, the more reliable will the IC change state when it should.

TTL devices, for example, operate with a positive supply of +5 volts ±0.5 volt. When driving a TTL device with the pulse generator presented here, output amplitude switch *S5 (S8)* should be set to TTL to assure that the maximum allowable voltage will not be exceeded.

The input of a TTL device is a current source. When the input voltage is low (logical 0), the pulse generator must sink enough current to pull the voltage below 0.8 volt. A regular TTL device requires a current of 1.6 mA per input. Low-power and low-power Schottky devices require considerably less current.

Since the pulse generator's output resistance is 100 ohms, the maximum current it can sink without exceeding the 0.8-volt limit is 8 mA. Accordingly, it can drive four regular TTL inputs, or any combination of inputs that requires less than 8 mA.

When the input voltage of a TTL device is high (logical 1), there is very little current and the output of the pulse generator will be nearly 5 volts. It is not possible to obtain more drive by increasing the voltage. This would cause the supply voltage of the TTL circuit to be exceeded, and damage the IC.

The CMOS family can be operated with a wide range of supply voltages, from a minimum of about 3 to a maximum of 16 volts. Split supplies are often used so that V_{ss} is below ground level. When driving CMOS with a split supply, the pulse generator's ground should be connected to V_{ss}, rather than the ground of the circuit.

When driving CMOS, the output voltage should be adjusted to a level that is well above the mid-point between V_{ss} and V_{dd}, but sufficiently below V_{dd} to assure that the input voltage does not exceed V_{dd}. A voltage of 80% to 90% of the difference between V_{ss} and V_{dd} will assure positive operation.

The voltage level of the output pulse can be set by using a dc voltmeter. Simply obtain a square output and measure the voltage. The peak voltage will be twice the measured voltage. When pulse width is varied, peak voltage will remain the same even though there will be a change in average voltage.

CMOS inputs require very little current. Therefore, any reasonable number of CMOS inputs can be driven without concern for the power required.

The +5-volt output can be used to calibrate a voltmeter or dc scope. This output has a 1000-ohm series resistor *(R2)* to prevent short-circuit damage. It is *not* intended for use as a power supply for other circuits.

An ac or dc scope can be voltage calibrated by setting the output pulse amplitude to 5 volts. Rotate the AMPLITUDE control to the point where the LEDs turn on. Peak voltage will be 5 volts, regardless of pulse width. If there is no load on the output, the TTL amplitude will also be 5 volts.

One of the two outputs can be adjusted to a frequency that is a submultiple of the other. Rotate the WIDTH control counterclockwise until the timer locks in on the submultiple desired, then continue counterclockwise rotation slightly to obtain the desired pulse width.

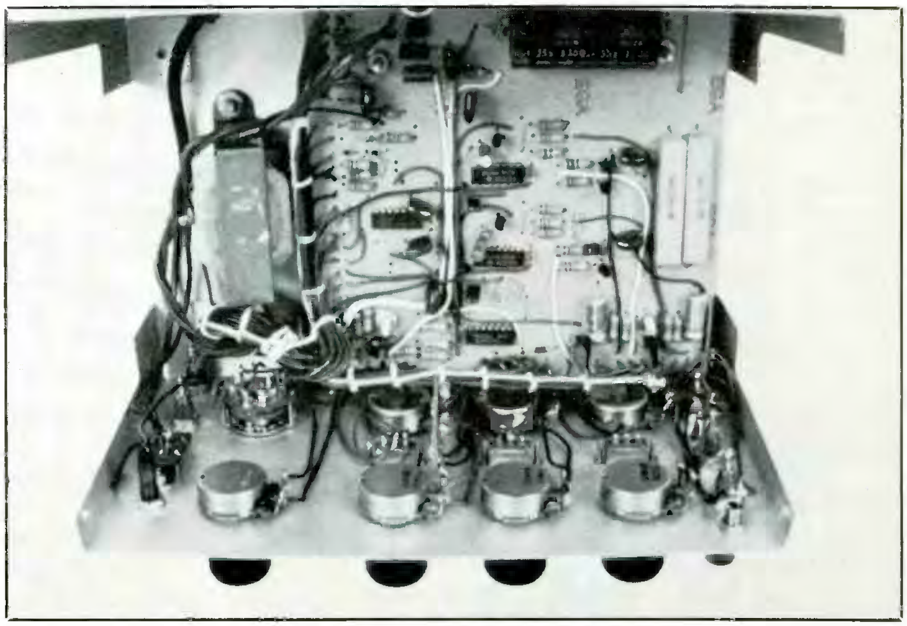
front panel and the other row facing the power transformer.

Make the stranded wires that connect the board to the front panel 3" to 4" longer than really necessary to allow the board to be removed from the cabinet should troubleshooting ever be needed. Make the wire jumpers only as long as needed to route them through the cable harness.

As you proceed with wiring, make sure to isolate the common ground from the cabinet. If you do not and connect the generator to the negative supply of a circuit being driven, you may create a short circuit.

Once wiring is complete, mount the circuit board on ½" spacers to the floor of the cabinet. Then gather the wires together into a bundle and secure it every 1½" or so with plastic

Pc board and T1 go on floor of enclosure, everything else on front panel.



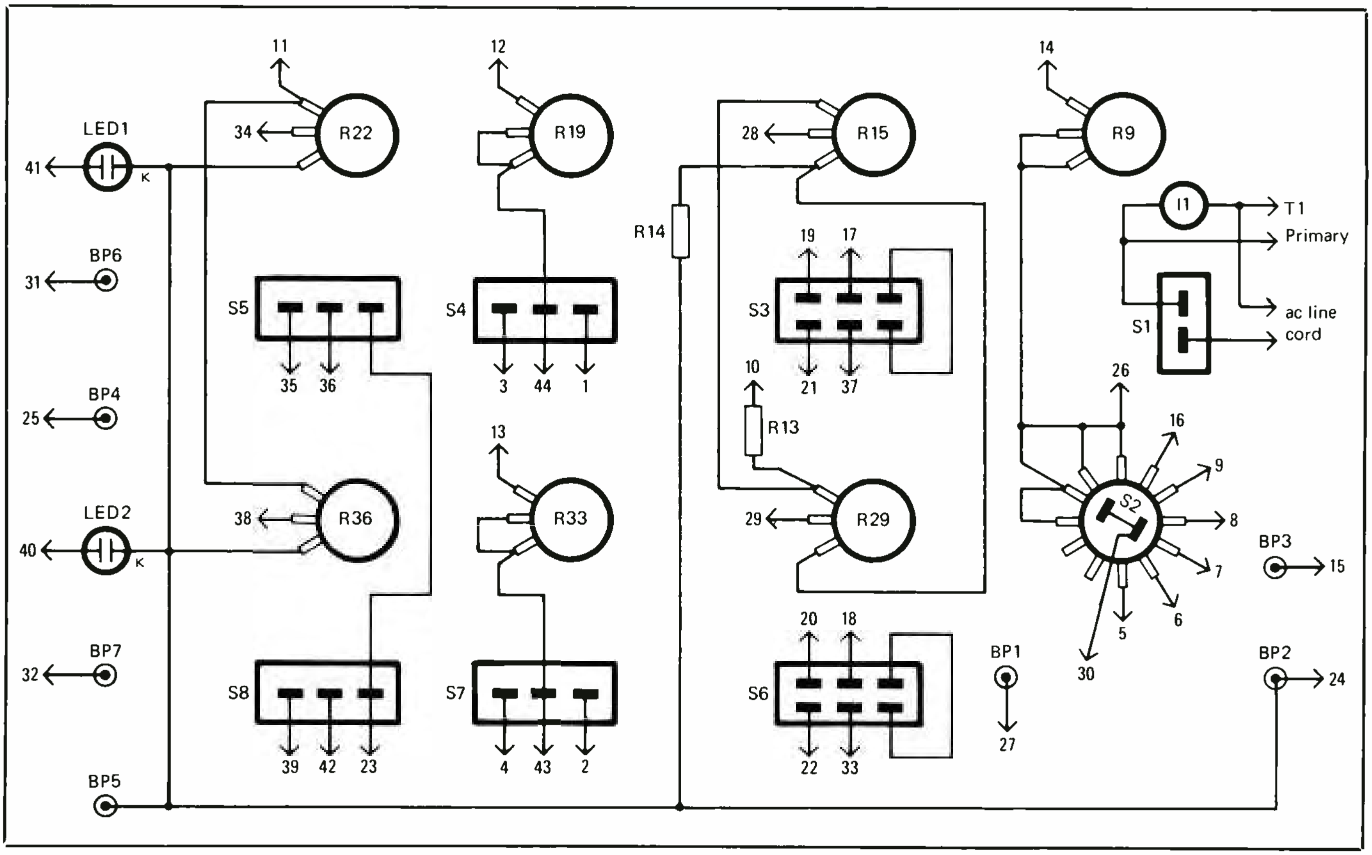


Fig. 5. Details for wiring front-panel-mounted components into rest of generator's circuitry.

cable ties (or lace with cord) to form a neat cable harness.

Checkout

With *IC3, IC4, IC5* and *IC7* still not installed on the board, plug the generator's line cord into an ac outlet and flip the POWER switch to on. The neon lamp should light. Now, referring to Figs. 3 and 2, measure the voltage at the points indicated in the power supply and at the supply pins of IC sockets. When you are satisfied that all is okay, turn off the power and unplug the line cord. Wait a minute or so for the capacitors to discharge. Then install the DIP ICs in their respective sockets, taking care to properly orient them and practicing safe handling procedures for CMOS *IC2*.

Plug the line cord back into the ac outlet and flip the POWER switch to on. Set the RANGE switch to any of the generator's internal oscillator ranges and use an oscilloscope to check for the presence of a sawtooth waveform at the emitter of *Q1*.

Next, check each pulse generator as follows:

Set the PHASE controls to about the middle of their ranges. Using the scope, check the outputs of the comparators in *IC3*. All should be delivering positive dc pulses. Rotate the PHASE controls while observing on the screen that the widths of the pulses vary as you do this.

A square-wave pulse should be observed at the outputs of *IC4* at pins 1 and 13. Set *S3 (S6)* to SQUARE and *S5 (S8)* to TTL. The output pulses at A and B OUTPUT terminals *BP5* and *BP7* should be square and have an amplitude of 5 volts. (This part of checkout will be easier to perform with a two-channel scope that can simultaneously display the outputs from generators A and B.) Set *S5 (S8)* to VARIABLE and rotate AMPLITUDE control *R22 (R36)*. Observe that the amplitude of the displayed pulses varies between 1.2 and 12 volts and that *LED1 (LED2)* lights when the control is rotated past the 5-volt position. If this does not occur, measure the supply voltage at the output of *IC6 (IC8)* as the control is rotated.

Check for output pulses from both generators with all four frequency ranges and over the full range of the FREQUENCY control. Set the RANGE switch to LINE and check for 60-Hz output pulses. It may be necessary to rotate the PHASE control to a point below mid-position to obtain an output pulse. Set the RANGE switch to EXTERNAL and apply an appropriate signal to EXTERNAL input *BP4*.

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Rotate the PHASE control to a position that results in an output pulse.

Return the RANGE switch to the LINE position and rotate the PHASE controls as necessary to obtain output pulses. Set *S3 (S6)* to VARIABLE and *S4 (S7)* to SHORT. Slowly rotate WIDTH control *R19 (R33)* counterclockwise from its fully clockwise position. Observe that the pulse, which will be almost equal to the period of the fully clockwise position, becomes shorter as the control is rotated counterclockwise.

Set the RANGE switch to its highest range and the FREQUENCY control to about the middle of its rotation. Set *S3 (S6)* to SQUARE and observe the square pulse output. Set *S3 (S6)* to VARIABLE and *S4 (S7)* to LONG. Rotate WIDTH control *R19 (R33)* fully clockwise and then slowly counterclockwise. As you do this, the pulse width will become narrower and continue to narrow until it suddenly becomes wide again and drops to half the original frequency. Further counterclockwise rotation will cause the pulse to narrow again until the frequency drops to a third of the original, and so on.

Feed the TRIGGER pulse output at *BP3* into the scope. You should observe a very narrow positive pulse with an amplitude of 5 volts. Because this pulse is very brief, it may be difficult to observe on the CRT screen. If your scope has a triggered-sweep capability, use this pulse to trigger the sweep while observing one of the output pulses. Note that the PHASE control varies the position of the pulse on the CRT screen.

For details on how to use the Dual Pulse Generator, refer to the "Applications" box.

In Closing

From the foregoing, it should be obvious that this is no ordinary "experimenter's" instrument. With its two independently adjustable generators, it offers a flexibility not usually expected in an instrument that costs as little as this one does to build. **ME**