SEMICONDUCTOR INTERVAL TIMER

By DONALD E. LANCASTER

Semiconductor gate-controlled switch makes practical an all-electronic timer that can be set from 1 to 100 seconds in discrete 1-second steps.

This timer was specifically designed for use as an enlarger control center for a custom photo finisher and thus lends itself well to most darkroom applications. There are many non-photographic applications for this device, ranging from sequence timers for displays, electronic automatic checkout equipment, process control, to other applications requiring the accuracy and ease of operation not found in many other control devices.

Parts cost should not exceed $45 and no special tools or components are needed to build this unit.

Operation

The basic circuit consists of a bridge rectifier, a gate controlled switch, and a zener-stabilized transistor-unijunction timing circuit. This is combined with suitable switching that provides for momentary or sustained load power in addition to the normal time cycle.

A gate controlled switch is the new SCR-like device with the added advantage that the GCS may be turned off, as well as on, by gate pulses of the proper polarity. Since these are unilateral devices, a full-wave bridge rectifier is required for the GCS and the load. Fig. 1A shows the simplified power-control circuit, while Fig. 1B shows the timing circuit. The output of the rectifier is filtered only enough to provide holding current for the GCS during the zero’s of the a.c. line. This produces the waveform shown in Fig. 1A across the load. Once the GCS is pulsed on, it latches on, and stays on cycle after cycle until a negative gate turn-off pulse appears.

A 20-μF filter capacitor is used, loads of between 25 and 500 watts may be accommodated by the timer. The output voltage varies somewhat with load changes in load, as shown in the regulation curve of Fig. 2.

In operation, a “Time-Start” pulse turns on the GCS and the load. The GCS turn-on also provides power for the timing circuitry. At the end of the time interval, the timing circuit produces a turn-off pulse, shutting down the GCS, load, and timing power supply.

The timing circuit (Fig. 1B), consists of a zener-regulated power supply and a unijunction transistor. An RC network between the –20V line, the emitter of the UJT, and the circuit common provides the time function. In operation, the charge across C1 (Fig. 1B) is zero at the start of the time period. Resistor R starts charging C1 and the emitter voltage of the UJT gradually becomes more and more positive. When a critical emitter voltage is exceeded (the intrinsic stand-off ratio), the UJT abruptly turns on. This also turns on the gating transistor (Q1) which “dumps” the charge on C2.
into the GCS gate. This turns off the GCS, the timing circuit, and the load.

By switch-selecting R in a digital manner, the time interval may be selected. A "units" and a "tens" decade is used to give incremental one-second intervals between one and 100 seconds.

There is a major problem inherent in UTJ timers that is eliminated in the upside-down circuit configuration. In a normal UTJ, after turn-on and capacitor discharge, there is still a charge remaining on the timing capacitor. This charge slowly bleeds off and ultimately reduces to zero over a long time period. The timing error introduced between starting with no charge and starting with some charge is considerable and can approach 40% of the time period. To overcome this problem, a set of mechanical contacts is almost always used to reset the UTJ and its capacitor to zero charge. While this method is widely used, it is neither convenient nor practical to have to reset a timer mechanically each time cycle.

The fact that the supply voltage, but not the supply impedance, disappears at the end of the time cycle is used to automatically reset the timer. This is a function of diode D (Fig. 1B). When the 20-volt supply is operative, D is reverse biased and does not interfere with the normal time cycle. When the time cycle ends, the supply voltage disappears. Any charge remaining on C1 now forward biases diode D, providing a discharge path through resistors R1, R2, and R3. Note that this is independent of the timing resistor, giving an equal recovery time regardless of the setting of the time interval selectors. The recovery time of the circuit is on the order of a half second to give a repeat accuracy error of less than 2 percent.

By selecting suitable values of R resistance, use of high-quality timing capacitors and zeners, and by waiting only a few seconds between cycles, this timer may be made to have an accuracy of better than 0.5 percent, and perhaps as good as 0.2 percent. This figure includes both repeat accuracy and long-time stability.

Final Circuit Arrangement

Fig. 3 shows the final circuit. The input power may be either conventional power line or d.c. between 100 and 130 volts. Fuse F1 is rated slightly above the load power to protect the circuit. Capacitor C6 is a filter to reduce AM radio noise during turn-on and turn-off of the time cycle. Switch S1

![Fig. 3. Schematic and parts list. Note that the circuit can be started either manually (S4), or by remote switch (S5).](image)

![Fig. 4. Additional driver circuits may be added for loads that will not operate on inverted a.c. supply. (A) All-electronic approach using a bilateral SCR. (B) Using an external relay.](image)

**Fig. 4.** Additional driver circuits may be added for loads that will not operate on inverted a.c. supply. (A) All-electronic approach using a bilateral SCR. (B) Using an external relay.

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May, 1966
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is the power switch which also selects between timed and sustained ("on") operation of the devices.

The GCS used is the Texas Instruments TIC-12 rated at 5 amperes and 200 volts. (Editor's Note: As this is written, the TIC-12 costs $9.60.) It is in a diamond-shaped power transistor package and mounts in the usual manner. Both SR1 and the GCS must be mounted on a heatsink, with the GCS insulated from the heatsink.

The network consisting of C2, R2, and R3 provides the GCS positive gate pulse required for turn-on. This is a one-shot network, required to make the time cycle independent of the length of time the "Time-Start" push-button (S1) or foot switch (S6) is depressed.

The timer power supply consists of R5, R6, R18, R1, D1, D3, C3, and C4. Unless GCS1 is conducting, there is no voltage drop across the load and no voltage across this power supply. This is a conventional zener supply except for its negative output. Unijunction transistor Q2 provides the time function when its emitter voltage exceeds the value required for breakdown. Timing is provided by a selected interval resistor charging up C5. A high-quality capacitor with low leakage must be used here; otherwise leakage and time degradation will affect timer performance.

The obvious way to select a time interval would be to use twenty precision resistors in values of 1, 2, ... 10 and 20, 30, ... 90, and switch these one at a time to obtain the desired time interval. By adding a second deck to each switch, and using the switching scheme shown in Fig. 3, only eight resistors are required. Note that at least one resistor must always be in the circuit. It is quite important that non-shorting selector switches are used.

The exact value of the resistors is determined by using an oscilloscope whose time base may be used for calibration. The one-second resistor value is then determined experimentally. All the other resistors are precision multiples of this original value. Once the "tens" decade series of resistors have been determined approximately, a conventional electric clock, equipped with a second hand, can be used to accurately trim the resistor values. Set the clock's second hand to 12, plug the clock into the timer output, and select the time values with the "tens" decade switch. Each "tens" decade switch position should cause the clock to indicate the correct number of seconds. The pertinent resistors can be trimmed as required.

The actual resistance may be obtained by several means. The simplest is to use all one-percent resistors. A second alternative is to use one- or two-watt carbon resistors and a file to raise them to the exact value. (Start with a resistor that gives you a time somewhat shorter than that desired.) The resistors must be resealed after filing to make them humidity and time stable. A third method is to use a large number of half-watt resistors and keep trying parallel combinations until the exact values are obtained. In all these cut and try methods, an accurate timing device (oscilloscope or other accurate timer) is required.

The final circuitry consists of gating transistor Q1 which is used to discharge capacitor C5 into the gate of the GCS via current-limiting resistor R4.

Two two-circuit push-buttons are used to provide the "Time-Start" and momentary bypass controls. Four-prong connectors bring these connections to the rear of the timer, allowing footswitch control. The "Time-Start" footswitch (S6) is in parallel with the "Time-Start" push-button (S4) while the momentary bypass footswitch (S7) is in series with the "Manual-Operate" push-button (S5).

Footswitch S7 must be a s.p.d.t. switch having heavy enough contacts to handle the load power. A jumper must be substituted for the normally closed connection of this switch if foot-switch operation is not to be used. S6 is a s.p.s.t. footswitch and need only have a contact rating of half an amperes. This switch must not have a built-in neon pilot light because this type will not allow proper operation of the turn-on pulse network.

Reasonable size wire, at least #20, should be used for all internal connections that must carry the load current.

The timer is intended for use only with loads which will operate off inverter a.c. This includes all incandescent lamps, heaters, and most universal motors (motors with brushes). If a highly inductive load is used, a diode or varistor should be added to the output as a surge eliminator. The timer will not operate a fluorescent lamp directly or the "cold boxes" occasionally found on enlargers. The timer will not directly control an a.c. induction motor of any type.

Additional Drivers

If fluorescent lamp or induction motor operation is required, additional circuitry will be required to provide a switched a.c. output. Two possibilities are shown in Fig. 4. In Fig. 4A, the timer output actuates an optical link ("Rayswitch") which in turn gates a bilateral SCR. Loads of between 10 and 600 watts may be switched with the bilateral SCR. The output waveform of this circuit is identical to the input powerline waveform, except for a drop in voltage. Fig. 4B shows how a conventional mechanical relay may be coupled to the timer and used for special switching requirements.

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