Basic Electronics

Build our reaction timer

And find out just how safe a driver you are

Here is a simple and easy to make Reaction Timer. When the red light comes on, you go for the stop button as fast as you can. The time you take is registered on the meter. Normally, your time should be less than 250 milliseconds for the pushbutton or less than 400 milliseconds for a pedal switch. How fast are you?

by GERALD COHN

When you are driving, your reaction time in an emergency can make the difference between rapid evasive action and possible fatalities. It is well known that reaction time is affected by the driver's physical condition and his psychological outlook at the time. In some cases, the driver does not register the emergency at all and drives straight into a disaster.

Some people stoutly maintain that alcohol does not adversely affect their reaction time and may even improve it. Limited tests that the author has witnessed would indeed seem to indicate that a limited amount of alcohol does not affect physical reaction time to any extent. What is affected is judgement. But that is another story.

Eventually, reaction time testing may become part of the general driver licensing procedure. Even licence renewals may be conditional upon passing a reaction test and sight test. Who knows? In the meantime, we have produced a unit to measure reaction times up to one second. If your reaction time is longer than that you are disaster material anyway!

The unit presented here will enable a number of interesting reaction tests to be made. To perform the tests, two people are required. One acts as a starter and presses a button to light up an indicator on the tester. The other person is the one being tested, and must hit their button to turn off the light. The reaction time can then be read from the meter. The starter then has a reset button to zero the meter before the test is repeated.

An approach to measuring a small time interval of less than one second can take two general directions. First, logic circuitry can be used and the result displayed in digital form. All that would be required is a 100Hz square wave oscillator driving a couple of decade counters plus the associated decoders and drivers for the digital display. The test would be merely starting and stopping the clock. The readout would be in the form of two digits which would be multiplied by ten to give the result in milliseconds. For example, a readout of 34 would represent 340 milliseconds.

An alternative and simpler approach is to use an analog circuit. This produces a steadily rising voltage which is stored and held at the end of a given time interval which represents the reaction time.

But how do you produce a steadily rising DC voltage, ie, a voltage increasing at a constant rate for a maximum interval of one second? All that is required is to charge a capacitor at a constant current. The resulting voltage across the capacitor will rise at a constant rate.

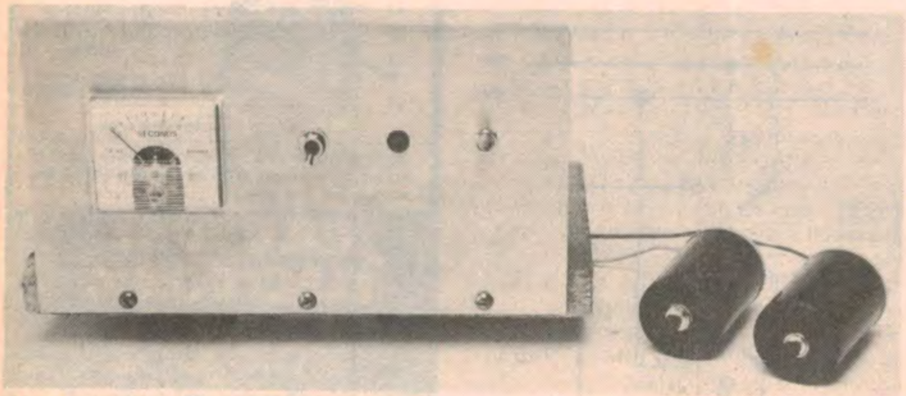
This can be shown by derivation from the fundamental relationship:

$Q = CV$

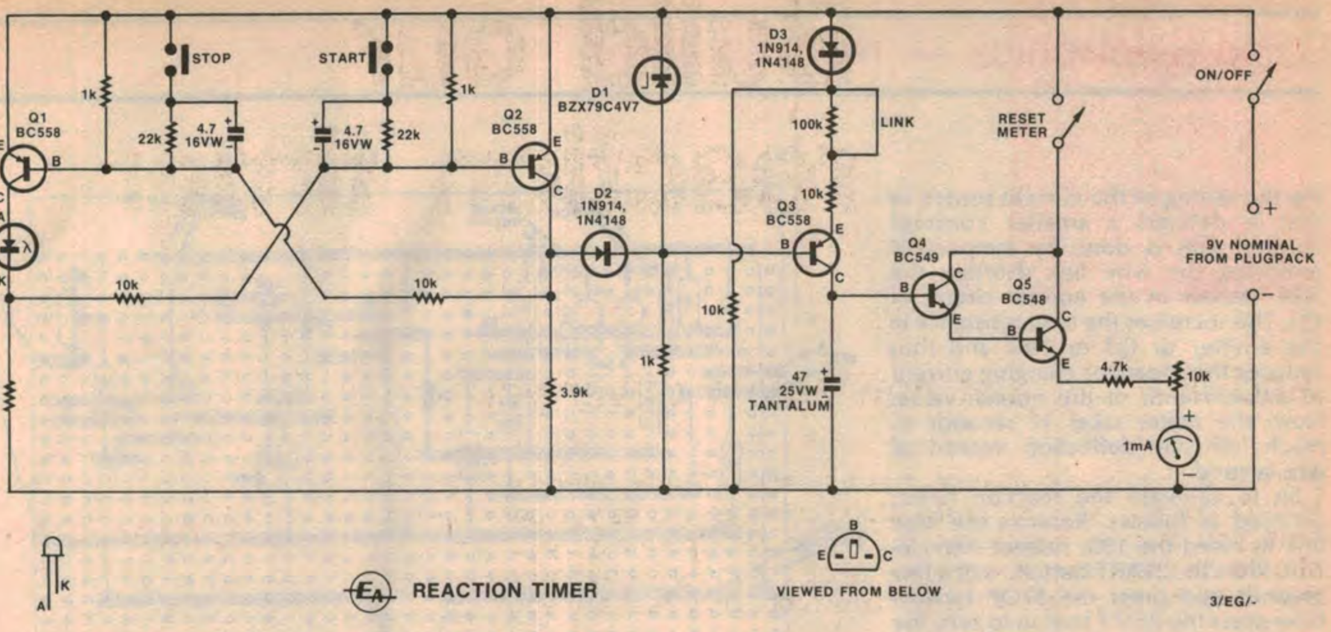
Where V represents voltage, Q represents charge in coulombs and C represents capacitance in Farads.

If we rewrite the above equation as $V = Q/C$ and then divide both sides by time in seconds, we get : rate of voltage change in volts per second is equal to the number of coulombs per second divided by the capacitance. But 1 ampere is equal to 1 coulomb per second, ie, current is the rate of charge flow. So dividing the capacitor charging current by the capacitance gives us the rate of voltage change. So the way to get a constant rate of voltage increase is to charge the capacitor with a constant current.

We can set the rate of voltage increase by selecting the value of constant current and the size of the capacitor. The capacitor must have very low leakage relative to the value of the charging current. The capacitor that we chose was a 47uF tantalum electrolytic. Aluminium electrolytics must not be used as their leakage is too high for this application. If we select a rate of voltage increase of 7 volts per second, the constant charging current required is 0.33mA.



Construction is not at all critical. We mounted the circuit board on a piece of timber with an aluminium front panel.



The circuit diagram of the timer. The flipflop (Q1, Q2) controls constant current source Q3, which provides the charging current for the 47uF capacitor.

Refer now to the circuit diagram (Fig 2). The constant charging current to the capacitor is provided by Q3 and its associated components. The basic circuit of a constant current source using one transistor is shown in Fig 1. A reference voltage provided by a zener diode is applied to the base of the transistor and the emitter resistor is selected to set the collector current. The voltage across the emitter resistor becomes the reference voltage minus the base-emitter voltage of the transistor.

In the basic circuit we have shown a zener diode which provides a reference voltage of 4.7V. This would result in a voltage across the emitter resistor of 4.0V (allowing for a base-emitter voltage of 0.7V). Any tendency for the collector current to increase would increase the emitter voltage by the same amount, which would bias the transistor off which would drop the current back to where it should be, and so on. The reverse process applies if the collector current tends to reduce.

Later on in the article we will explain the component differences between Fig. 1 and the current source Q3 in the complete diagram.

Having described how to obtain a voltage which increases linearly with time using a constant current source to charge a capacitor, we can now discuss how to start and stop the current source. We do this with an RS flipflop consisting of Q1 and Q2.

The flipflop has uneven collector loads. Q1 has a 1k resistor in series with a light emitting diode while Q2 has a 3.9k load. This means that when power is first applied to the circuit, Q2 always turns on while Q1 is held off. Q2 effectively shorts out the voltage reference zener diode D1 via D2 which turns off the current source Q3. Just to make sure that Q3 is turned hard off, diode D3 is connected in series with the emitter. The diode voltage is held constant by bias current from the 10k resistor to the 0V line.

So the situation at switch on is that Q2 is on which holds Q3 off, and so the voltage across the 47uF capacitor remains at zero. To start charging the capacitor, the START button is pressed which momentarily removes the base voltage of Q2. This turns Q2 off and Q3 on allowing the capacitor to charge.

At the same time as Q2 goes off, Q1 comes on and illuminates the light-emitting diode. The person being tested must then hurriedly press the STOP button which reverts the flipflop to its original condition and turns Q3 off. The voltage which then appears across the capacitor represents the elapsed time. All that remains is to measure this voltage while making sure that the capacitor's charge is not bled away so fast as to make the meter pointer drop rapidly. In other words, we have to measure the capacitor voltage but make sure that the current drawn off by the measuring circuit is as low as possible.

Our method of monitoring the capacitor voltage is to use a Darlington transistor pair to drive a 1mA meter via appropriate resistors. With the high beta of the composite transistor the input current from the capacitor is very low — less than 1 microamp.

The Darlington transistor pair, Q4 and Q5 actually constitute a simple "sample and hold" circuit.

Several features of the circuit remain to be explained. First, the RESET button. This resets the meter to zero after a test so that it can be repeated. Notice that the capacitor is not discharged directly by shorting out. Rather, we remove the positive supply voltage from the Darlington, so that the capacitor discharges via the two base-emitter junctions and the meter circuit.

This effectively reduces the capacitor voltage to slightly less than the forward-bias base voltage of the Darlington pair, ie, slightly less than 1.2V. So instead of rising from zero at the start of a test, the capacitor voltage rises from approximately 1.2V. This means that as soon as the capacitor voltage begins to rise during a test, the meter pointer rises accordingly.

A simple, easy-to-reproduce calibration procedure presented a major problem in development of the project. No matter how ingenious or complex a circuit such as this might be, it is useless if it cannot be accurately calibrated by the would-be constructor who has a minimum of test instruments at his disposal. We believe we have solved this in a neat fashion.

The calibration is performed by alter-

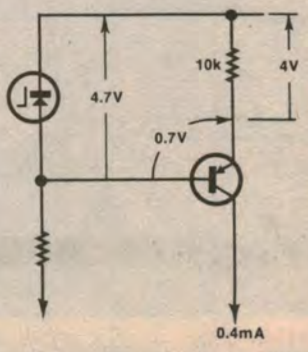


Fig 1. Basic constant current source.

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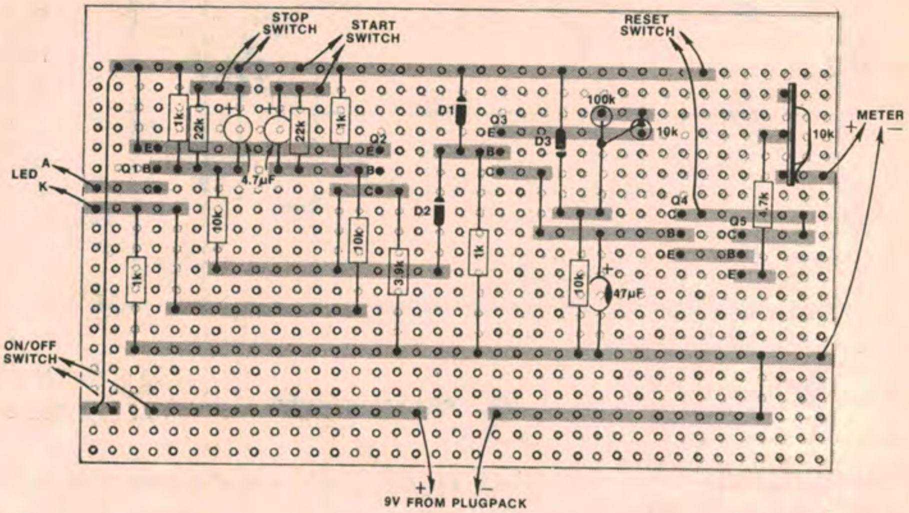
ing the setting of the current source so that it delivers a smaller constant current. This is done by temporarily removing the wire link shorting the 100k resistor in the emitter circuit of Q3. This increases the total resistance in the emitter of Q3 to 110k and thus reduces the capacitor charging current to one-eleventh of the normal value. Now, the meter takes 11 seconds to reach full-scale deflection instead of one second.

So to calibrate the reaction timer, proceed as follows. Remove the wire link to insert the 100k resistor into circuit. Press the START button, wait a few seconds and press the STOP button. Now press the RESET button to zero the meter. Now press the START button, wait exactly 11 seconds and press the STOP button. Now set the 10k preset potentiometer so that the meter reads full scale. This will have to be repeated a few times because the meter reading drops slowly.



The overlay diagram showing the cuts in the copper tracks and the placement of the components. Note the orientation of the transistors, diodes and capacitors.

Having set the 10k preset potentiometer so that the meter takes exactly 11 seconds to rise from zero to full scale, the wire link can be replaced to short out the 100k resistor and the unit is ready to perform testing. Ideally, the 10k and 100k resistors should be 1pc units, but in practice 5pc units will be close enough.

We specify an LED in the circuit because it has almost instantaneous response time, ie, light is emitted as soon as voltage is applied. The use of an incandescent lamp in this role would inevitably cause errors because of the thermal lag of the filament.

Notice that the 10k resistor in the base voltage divider of Q2 is fed from the junction of the LED and the 1k resistor, and not from the collector of Q1. This is to avoid the small current flowing in the 10k resistor from partially lighting the LED.

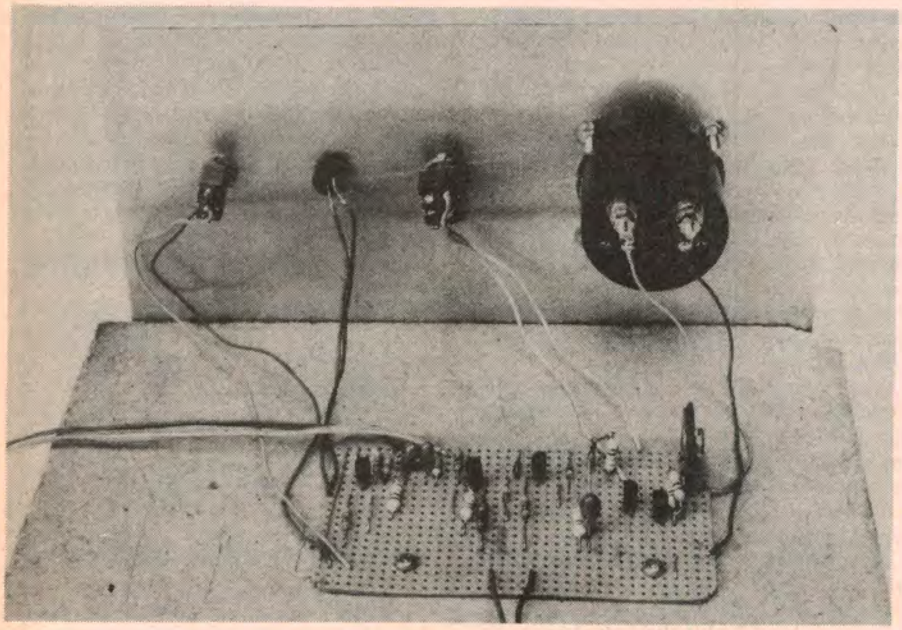
Construction of the reaction timer is not critical as far as layout is concerned. It can be built cheaply onto a piece of timber or "dressed" up to look the part of a piece of test equipment. Our approach to the construction is shown in the photographs, but this is only a suggestion.

All the circuit components are mounted on a small section of Veroboard, 60 x 95mm. We used Veroboard with 2.5mm conductor spacing which is the most readily available type.

Take care to observe the orientation of the transistors and the polarities of the diodes and the elecrolytic capacitors. These are shown in the wiring diagram.

The two resistors, 10k and 100k, associated with the constant current source, Q3, are wired "end on" and a loop of hookup wire is soldered to their ends to short out the 100k resistor. The details are shown in the wiring diagram. The idea is just to "tack" the wire with your soldering iron so that it is easily removable for the calibration procedure.

The LED, toggle switches and meter are mounted onto a piece of aluminium sheet fastened at right angles to a piece of timber. The Veroboard is also mounted on the piece of timber. The START and STOP



A rear view of the completed timer showing the wiring etc. The link across the 100k resistor can be seen just to the left of the pot.

We estimate that the current cost of parts for this project is approximately

$20

This includes sales tax but does not include the cost of the DC plugpack.

buttons were mounted in plastic film containers (pill cases would also be suitable) for easy use.

We used a 1mA meter movement and changed the units that are read from the meter to seconds instead of mA. This was done by erasing the letters "mA" and then replacing them with "SECONDS" using rub on lettering.

The STOP switch could be mounted in a floor jig with both a brake and an accelerator pedal to simulate the braking procedure, ie lifting the foot from the accelerator pedal and onto the brake pedal to halt the car. Here the STOP switch will require protection from mechanical abuse.

The unit is powered from readily available plugpack type power supplies, delivering a nominal 9V at 300mA. The voltage will normally be more than 9V at the current drawn by the circuit, and will probably be between 10 and 11 volts. Actually the circuit will function with supply voltages between 9 and 18 volts.

Well, there you have it, a device that will tell you whether or not you stand to qualify for the "Traffic Menace Of The Year Award". Go to it then. How fast is your reaction time?

Parts List

1 1mA meter movement
2 miniature SPDT toggle switches
2 miniature N/O contact pushbuttons
1 9 volt plugpack/battery eliminator (not included in price estimate)
1 piece Veroboard 60 x 95mm

SEMICONDUCTORS
3 BC558 PNP transistors
1 BC549 NPN transistor
1 BC548 NPN transistor
2 1N914 or 1N4148 diodes
1 BZX79C4V7 zener diode
1 red LED

RESISTORS (¼ or ½W, 5% tolerance)
4 x 1k, 1 x 3.9k, 1 x 4.7k, 4 x 10k, 2 x 22k, 1 x 100k
1 x 10k trimpot

CAPACITORS
2 x 4.7uF/16VW electrolytic
1 x 47uF/25VW tantalum

MISCELLANEOUS
Timber, aluminium sheet, solder, hookup wire, screws etc.

Note: Components with higher ratings may generally be used providing they are physically compatible.