Multivibrators . . . Basic Building Blocks

Elementary Electronics

by ROSS TESTER

The multivibrator, in one or other of its forms, is very much an integral building block in electronics. We aim to show you the various types, how they work, and some of the ways in which they are used.

There are three basic types of multivibrators. These are the astable (also known as the free-running), the monostable (also known as the one-shot) and the bistable, (also known as the flip-flop).

We will deal with each of these in turn. First, the astable. This is the most common type of multivibrator encountered in everyday electronics. As its second name suggests, it requires no stimulus or trigger pulse to start it, but keeps operating for as long as power is applied.

If a trigger pulse is provided, it can trigger the multivibrator before it would have triggered normally. This is useful in many applications where synchonisation or frequency division is necessary, but we will have more to say on this later.

The second type is the monostable, or one shot. The latter term is an apt description of its operation, for it gives one pulse out whenever it is triggered. It has only one stable state, which it reverts to immediately after being triggered.

The third type is the bistable. This is one of the basic parts for all computers and calculators. As its name suggests, it has two stable states. It remains in either state until a stimulus or trigger pulse is fed into it to change it to the opposite state. On the arrival of a second pulse, it reverts to its original state, and so on.

From figures 1, 2 and 3 it is obvious that all three types are similar. Both have two transistors, interconnected so that when one of the transistors is cut off, the other is saturated, or hard on. The difference is in the way they are interconnected.

The astable is purely AC coupled, because it is interconnected by capacitors only. If you have followed our Home Study Course, you will know that a capacitor blocks DC, but allows AC to pass.

The monostable is a mixture — one side of the circuit is both AC and DC coupled (via a resistor) and the other half is AC coupled only (via a capacitor). The bistable is AC and DC coupled on both sides, because resistors have replaced both capacitors.

Refer to figure 1. This is the circuit of a basic astable multivibrator. Two transistors are so connected, that when one is conducting, the other is not. This may seem a little strange, but it will be better understood if we explain what happens.

When power is first applied, one of the transistors will conduct harder than its partner, because of component tolerances (transistors with different gain, capacitors with different values, etc). It is virtually impossible to find two transistors which will both conduct by the same amount.

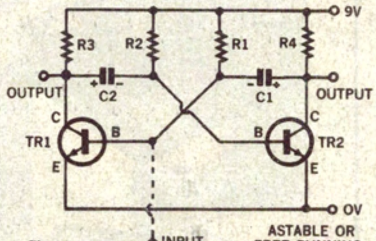


Fig 1

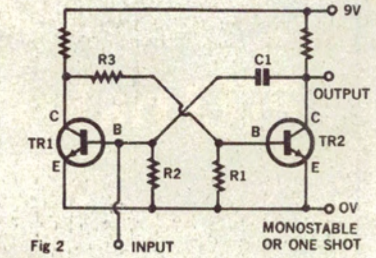


Fig 2

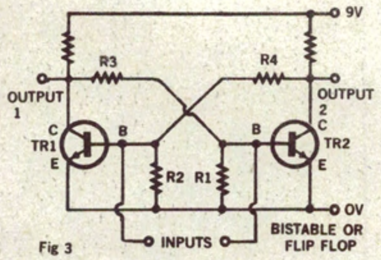


Fig 3

The three basic forms of multivibrator. While broadly similar, the differences are important, as discussed in the text.

Say, for example, it is TR1 which conducts hardest initially. Its collector voltage would drop to nearly zero volts (there is a small voltage across the transistor). Capacitor C2, which would have charged to the polarities shown almost immediately on switch-on, would now find its positive plate connected (via TR1) to the negative rail. There is nine volts potential difference between the positive and negative plates so it would, effectively, place a minus nine volts potential on the base, relative to the emitter, of TR2. This reverse biases TR2 and turns it off.

When TR2 is turned off, its collector voltage rises sharply to the positive supply voltage, and therefore commences to charge C1. The charging current for C1 flows through the base-emitter junction of Tr1 as forward bias, and therefore holds it on. This capacitor charges relatively quickly, as the resistance to its charging current is quite low. When the charging current falls to a level which would not normally hold the transistor on, the bias resistor R1 takes over this role and holds it on. It remains in this state until capacitor C2 has fully discharged, and the reverse bias is removed from TR2.

When this reverse bias ceases, TR2 is turned on by the bias resistor R2. Immediately this happens, the collector voltage drops to near zero. Because the positive end of capacitor C1 is now virtually connected to the negative rail, TR1's base (which is connected to the negative end of C1) is effectively at minus nine volts with respect to the emitter. This reverse biases TR1, and turns it off.

This begins the charge and discharge cycle once again, until the original state is reached (TR1 on, TR2 off). Then, the cycle repeats again, and again, and again . . .

This is the reason this type of multivibrator is known as the astable or free running. It has no stable state — it keeps on jumping backwards and forwards for as long as power is applied.

The waveform generated by an astable multivibrator is rectangular, though it is commonly, and sometimes erroneously, called a "square wave". If the two halves of multivibrator are perfectly balanced, the pulses from each half will be equal in length. This is normally referred to as a square wave. If the two halves are not balanced, perhaps deliberately, then the pulses will be of unequal length and the waveform is more correctly referred to as rectangular.

The values of R & C can be adjusted to give the required frequency of operation —

R1 & C1, or R2 & C2 will effect this. The amplitude of the output pulse, which may be taken from either transistor, is mainly dependent on the supply voltage.

As we said before, the monostable or one-shot has one of its capacitors replaced by a resistor. Referring to figure two, we can see that TR1 is provided with an input to its base, and TR2 with an output from its collector.

With the input terminal at OV TR1 is cut off, and its collector is at 9V with respect to the negative supply. TR2, therefore, receives heavy forward bias, and is driven into saturation. Its collector, and therefore the output, is at near zero volts. Capacitor C1 is essentially uncharged.

If the input is momentarily raised to a positive voltage level current flows through the TR1 base-emitter junction, forward biases it and turns it on. Its collector voltage falls to near zero and the forward bias is removed from TR2, which cuts off. This raises its collector (and the output) to +9V. Once this set of conditions prevails, the initating pulse is no longer required. It may be removed without having any immediate effect on the state of the circuit.

Capacitor C1 is now effectively connected to the positive supply rail via R4 and to the negative rail via the base emitter junction of TR1 and R2 in parallel. It therefore commences to charge. Because the base-emitter junction constitutes a low resistance path relative to R2 most of the charging current flows through this junction in the form of forward bias. Thus TR1 is held in the "on" state until C1 is almost fully charged, that is, until the charging current falls below the minimum bias saturation level.

When TR1 is deprived of forward bias it can no longer conduct, the voltage on its collector rises to the +9V rail level, TR2 is biased on, and the circuit reverts to its original state. It will remain locked in this state until another pulse is applied to the input terminal.

If the input pulse had not ended before the capacitor had ceased charging, the monostable would not revert to its normal state. Rather, it would remain triggered until the input pulse stopped, whereupon it would change back almost immediately.

In this case, the monostable would not stretch the pulse length as it does in the case where a short input pulse is applied; rather it would merely square up the corners of the pulse and increase the amplitude.

A typical use for the monostable would be in television relay systems, where the synchronising pulses may be degraded after transmission via a microwave or satellite link. The degraded incoming pulse can be used to trigger a monostable which will generate a new, correctly shaped pulse.

The third type of multivibrator, shown in figure 3, is, in its simplest form, also known as a flip-flop. When power is applied to the flip-flop, one of the two transistors will saturate, forcing the other to cut off. If TR1 is turned on, TR2 will be cut off, and its collector (and output 1) will be at +9V.

If we apply a positive voltage pulse to the base of TR2, it saturates, and the collector voltage drops to near zero. This removes the forward bias from TR1, and cuts it off. Therefore, its collector (output 2) increases to 9V. Then, if we shift the input pulse back to TR1 once again, the reverse happens, and the circuit reverts to its original state.

Applying a positive pulse to the transistor which is switched off is not the only way we can trigger the flip-flop. An alternative is to apply a negative pulse to the transistor which is switched on, thereby switching it off. A variation on this theme is to simply connect the base of the switched on transistor momentarily to its emitter, again switching it off.

Figure 3 shows two inputs and the triggering pulse must be directed to whichever input is appropriate to the circuit's state at

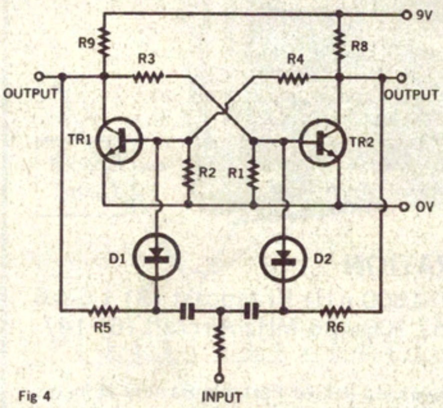


Fig 4

Simplified T or Gated R-S flip flop. The diodes steer the incoming pulses according to which transistor is "on".

that time, in order to trigger it into the opposite state. Sometimes, when the pulses are derived from separate sources, this is quite convenient. When they come from the same source it is obviously not convenient to physically change the connection from one input to another.

If the pulse is simply applied to both transistor bases without a gate to steer it to the correct place, the flip-flop will not toggle as it should. If the pulse is negative, it will certainly turn off the conducting transistor, but it will also hold off the non-conducting transistor until the pulse ends.

When the pulse ends, both transistors turn on and a race is established to see which can force its partner to turn off. The result is completely unpredictable. Naturally, the converse is true with a positive pulse. Such a situation is obviously undesirable.

For this reason, flip-flop circuits have been developed which automatically direct the pulse to the appropriate input. These are known as the Gated R-S and the J-K flip-flops.

A simplified form of such a circuit is shown in figure 4, and its operation is easily understood. The main additions to the circuit are the diodes D1, D2 and the biasing resistors R5, R6.. Let us suppose that TR1 is saturated and TR2 cut off. In these circumstances the cathode of D1 will be connected to the negative rail, via R5 and TR1, while the anode will be connected to the positive rail via R4 and R8. Thus the diode will be heavily forward biased and will pass current readily in either direction.

At the same time, D2 has its cathode connected to the positive rail via R6 and R8, and its anode to the negative rail via R3 and TR1. It is therefore heavily reversed biased, and will not pass current in either direction.

If we now apply a negative pulse to the input terminal this will be directed to the base of TR1. The effect will be to cut TR1 off and, in the manner we have already explained, bias TR2 on. At the same time the conditions pertaining to D1 and D2 are reversed; D1 is now reverse biased and D2 forward biased. Thus, the next negative pulse which arrives will be directed to the base of TR2, which will then be cut off.

In this way alternate pulses are directed to opposite sides of the circuit, switching it back and forth from one state to the other. An interesting sidelight on the circuit's behaviour, which can be readily understood at this point, is that it gives out one pulse for every two pulses in, and thus functions as an extremely reliable two-to-one frequency divider. It is used extensively in this role in computer circuits, forming the basis of binary counting.

Earlier, we mentioned the ability of a multivibrator to be locked by synchronising pulses. This ability can be used to perform frequency division. Theoretically, quite large orders of division are possible, but they are seldom used to perform more than a divide-by-ten function, as the reliability of the system becomes poor above this figure. Normally, a divide-by-five multivibrator would be preferred.

Figure 5 shows the way frequency division occurs. It shows the voltage waveform at the base of the non-conducting transistor. The initial pulse, for our purposes, can be disregarded as it is the one which previously flipped the multivibrator over. The first and second pulse after this would have no effect, as they would arrive while the transistor is conducting anyway.

The third pulse would arrive while the transistor was cut off, and it would be added to the negative voltage to make it less negative. However, this would not have any effect, as the transistor is still heavily reverse biased and the combined voltages (that of the pulse and the capacitor) would still be much less than zero. Similarly for the fourth pulse. It would come closer to making the sum of voltages zero, but would just miss out.

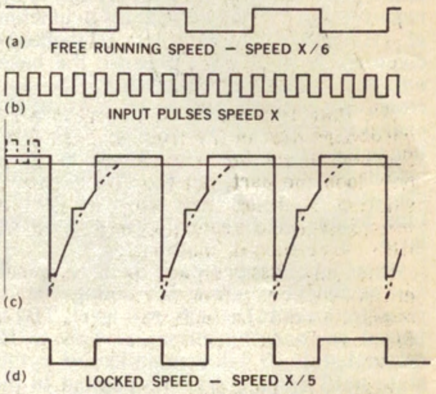


Fig 5. Frequency division. Diagram (c) shows the input pulses added to the negative base voltage to force the transistor to conduct early.

The fifth pulse arrives when the capacitor is very nearly discharged. In other words, the multivibrator is nearly at the point where it would flip over of its own accord. However, the pulse makes it do this early. The sum of the voltages is either zero, or slightly positive, so the transistor can be turned on by its bias resistor. Therefore, the period of the pulse given by this multivibrator is equal to that of five pulses in — or a five-to-one division.

The reason the system becomes unreliable at higher divisions should now be obvious. With so many pulses arriving during the cycle, there is a risk of the multivibrator triggering early on the wrong pulse — particularly if the amplitude of the pulse is a little higher than it should be. Or it may trigger late — if the amplitude of the correct pulse is not enough. Therefore, the amplitude and the pulse width must be substantially constant if this method of frequency division is to be successful.

A variation on this theme involves locking the multivibrator to synchronising pulses, without involving frequency division, ie, the multivibrator operates at the same frequency as the pulses. All that is

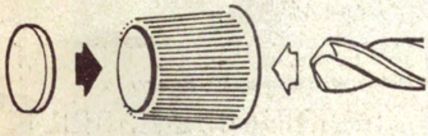
(Continued opposite)

Elementary Electronics Ideas Worth Trying

Inexpensive Knob

Anyone who has constructed anything with a large number of potentiometers on it will know that the control knobs are a major factor in determining panel size. Finding suitable knobs can sometimes be a problem. I recently had this trouble, having completed a project only to find that very small knobs were not available.

I realised I would have to innovate. I finally settled on toothpaste tube tops as pot knobs. Not only were they the right size, but came in a variety of colours. They needed only a small modification. This was done with a ¼in twist drill. The elastic quality of the plastic will allow it to expand as the drill goes through, so when the drill is withdrawn the hole will contract to slightly less than ¼in, making it a snug force fit on a ¼in pot shaft.



All that remains is to insert a small cardboard disc in the front and the job is finished. These home made pot knobs not only look the part, but they have good insulating qualities, are easy to fit, give torque overload protection and come free with every tube of toothpaste.

The only disadvantage is a somewhat cranky wife or mother when the toothpaste oozes out onto the bathroom shelf. (From Mr M. Cuffe, 48 Market Street, Naremburn, NSW.)

Editorial comment: One of our staff members hit on this idea quite independently. To fill the end of the cap he used a small brass washer, with the hole in the washer filled with solder and sanded flat on the outer side. Finish was with black wrinkle lacquer from an aerosol can and the finished product is fully professional in appearance. The main advantage as far as this case was concerned was that the knob was smaller than those normally available, and allowed an extra control to be fitted to an already rather crowded control panel.

Printed Wiring

Here is a useful hint concerning printed wiring boards. Normally, a protective paint is used to define the pattern, but I have found it difficult to get straight, thin lines using this method. I now use what I think is a better method.

First the board is cleaned. One way is to use steel wool. Then a sheet of adhesive plastic is pressed onto it. This must be large enough to cover the whole board. The plastic is normally available at stationery or hardware stores and the type I use is sold under the name "Contact."

The required pattern is copied onto the plastic using a felt pen, carbon paper, or whatever is available. Cut along these lines using a single edge razor blade or sharp knife.

The plastic covering the copper which needs to be etched can now be removed. The plastic which remains must be pressed down firmly to ensure there are no air bubbles and that it has not moved out of place.

The board is etched in the usual way and the etchant will work faster if it is warmed during etching.

(From Mr T. Van Slageran, North Geelong, Victoria)

Soldering Hint

I have found it very difficult soldering transistors and small diodes salvaged from printed circuit boards. Usually the leads are so short that damage by the hot solder is almost inevitable.

I have solved this by applying a drop of water, either with the end of the finger or from a wet cotton bud, immediately after soldering. This quickly cools the lead and joint to a safe temperature. This has enabled me to re-use small solid state devices over and over, without damage.

(From Mr B. Jones, Towong, Victoria.)

Editorial comment: A variation on this idea might be useful in some cases. Where there may be a risk of damage to other components by using water, methylated spirit may be substituted. This also has the advantage of providing better cooling by reason of its rapid evaporation.

Awkward Nut

How often do you spend half an hour trying to get a nut into an inaccessible corner? It is quite easy when you know how. Simply tap the end of a length of solder into the thread of the nut, bend the solder to suit, then twist the whole assembly until the thread of the nut grips the screw. Complete the job by griping the nut with long nose pliers.

(From Mr B. Pettingill, Warrnambool, Victoria.)

Multivibrators . . . Cont.

necessary in this case is for the free running frequency of the multivibrator to be slightly slower than the pulse frequency. Each pulse then triggers the multivibrator earlier than it would have switched naturally.

A typical application for this arrangement would be in some of the simpler types of TV synchronising circuits. The horizontal and vertical synchronising pulses which form part of the transmitted TV signal are separated from the video signal, and from each other, and may then be used to trigger multivibrators running slightly slower than the sync pulse frequency. For example, the vertical sync pulses occur at 50Hz, so a multivibrator normally running at 47 or 48Hz would lock in and run at 50Hz.

This ends our theoretical discussion on the basic types of multivibrators. Next month, we will present some practical circuits which will put the various types of multivibrators to work for you.