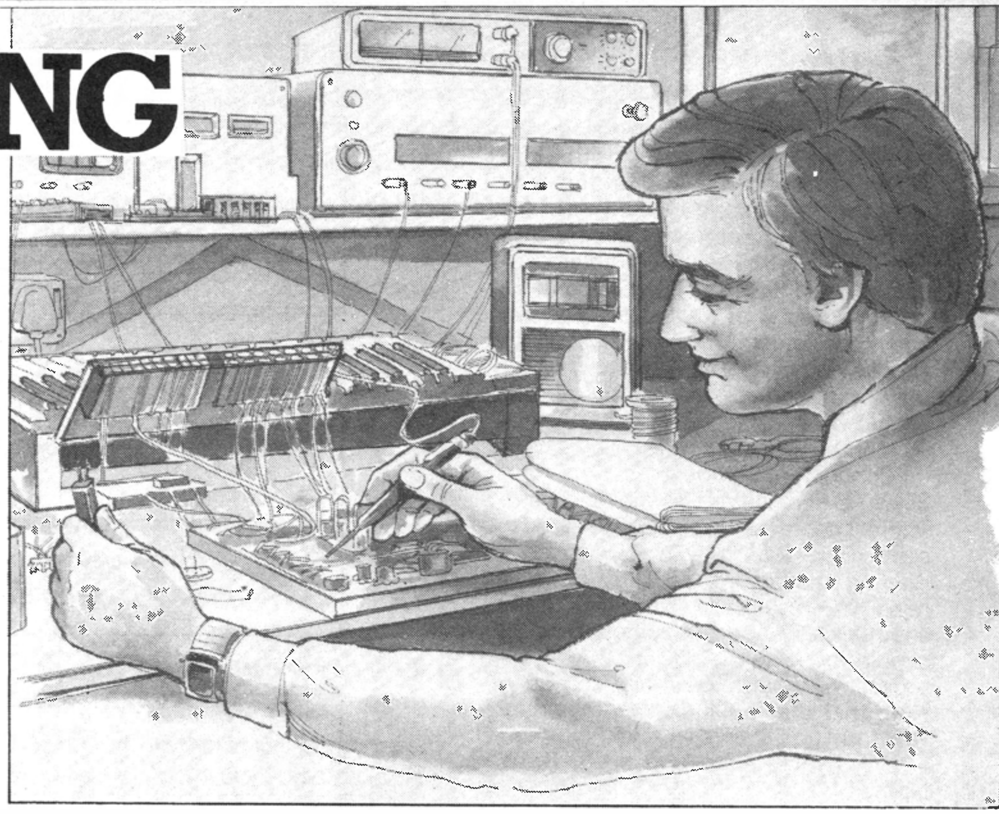
STARTING POINT



by R. Penfold

Introducing the fundamentals of electronics for the constructor.

UJTs, FETs and SCRs

In this final article in the "Starting Point" series we will consider some of the semiconductor devices which have not been covered by previous articles in the series. The devices that will be discussed here are unijunction transistors (UJTs), junction field effect transistors (Jfets), VMOS transistors, and silicon controlled rectifiers (SCRs).

UJTs

Unijunction transistors used to be quite popular, but are not often used in new designs due to the availability of inexpensive integrated circuits such as the 555 timer device which give more predictable results and greater versatility. Unlike other forms of transistor a UJT cannot be used as an amplifier, and these devices are in fact normally only used as the basis of relaxation oscillators. A UJT is analogous to two resistors and a silicon diode connected in the manner shown in Figure 1. The total resistance through the resistors is several kilohms and the upper resistor is normally somewhat lower in value than the lower one.

A UJT is used in the oscillator configuration shown in Figure 2, and this provides three output waveforms (which are shown in the diagram). A UJT is a three terminal device like ordinary bipolar types, but the terminals have different names, these being base 1, base 2 and emitter. In the circuit of Figure 2 there is initially an extremely high input impedance at the emitter of Tr1 as there is effectively a reverse biased silicon diode here, and C1 is therefore free to charge by way of R1. When the charge on C1 reaches something in the region of 65 to 90% of the supply voltage (depending on the particular device used), the voltage at the emitter becomes slightly higher than the voltage at the junction of the two resistances within the UJT, and the silicon diode then becomes forward biased.

At this point a current flows into the emitter of the device, and a regeneraive action within the UJT causes the input impedance to the emitter to fall to a very low level. At the same time the resistance between the base 1 and base 2 terminals falls substantially. C1 largely and rapidly discharges into the emitter of Tr1 until the charge voltage is no longer high enough to sustain the regenerative action, and the device then reverts to its original state. C1 then starts to charge again, and this process continues with a nonlinear sawtooth waveform being produced across C1. This signal is at a fairly high impedance, especially if R1 has a high value. As C1 discharges, positive pulses are produced at the base 1 terminal and negative pulses are generated at the base 2 terminal. These are both at a low impedance.

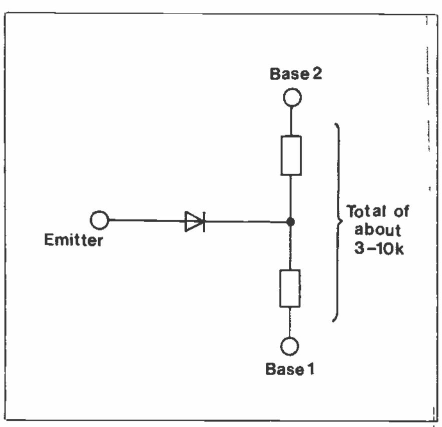


Figure 1. A UJT is analagous to this circuit.

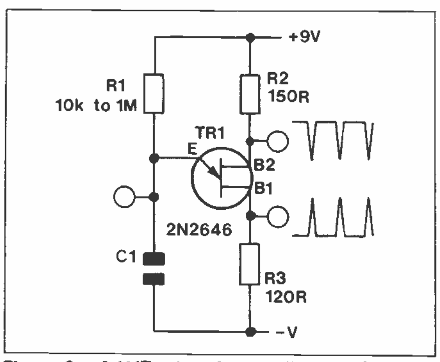


Figure 2. A UJT relaxation oscillator and output waveforms.

It is important to realise that you cannot produce a UJT by simply connecting two resistors and a diode in the configuration shown in Figure 1. A UJT actually consists of a bar of silicon which forms the two resistances, with a single semiconductor junction on the bar to form the diode. It is from this single junction that the name unijunction is obtained. Two resistors and a diode connected in the manner shown in Figure 1 will not produce the regenerative action required to trigger the UJT to the on state.

R1 should not have a value of less than about 10k or it will supply enough current to hold Tr1 in the on state and oscillation will be blocked. Similarly, if R1 is made more than about 1 megohm in value it will not supply enough current to trigger Tr1 properly, and oscillation will not take place. Another point to bear in mind is that R2 and R3 must be very low in value or they will prevent the circuit from operating.

Jfets

The three terminals of a Jfet are called the gate, drain, and source, and these roughly correspond to the base, collector, and emitter of bipolar transistors. Jfets are depletion mode devices, and they require bias circuits that are subsequently different to those employed with bipolar transistors. However, like bipolar transistors they can be used in three amplifying modes which are the common source, common drain (or source follower), and common gate modes. The equivalent bipolar configurations are the common emitter, common collector (or emitter follower), and common base modes respectively.

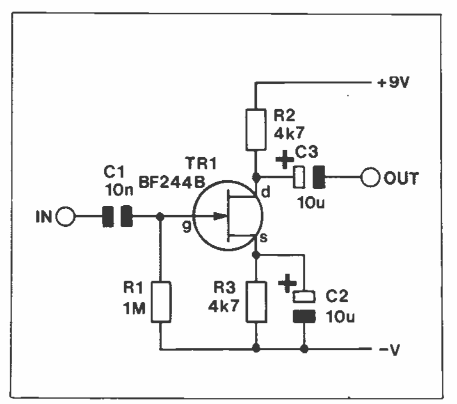
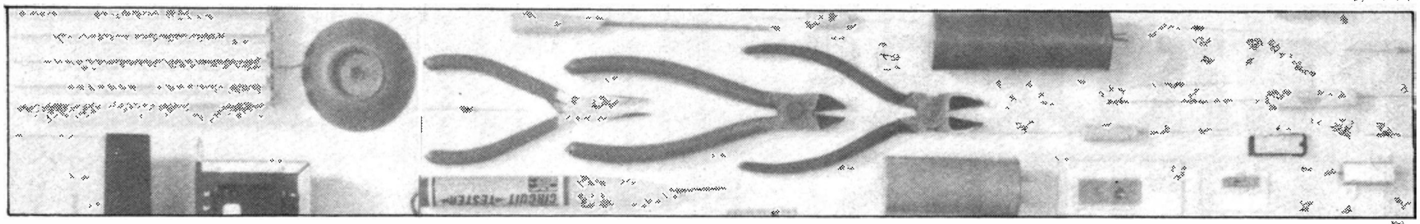


Figure 3. A simple JFET common source amplifier.

Figure 3 shows the circuit diagram of a simple common source amplifier which helps to highlight the difference between Jfet and bipolar devices. Whereas ordinary transistors are normally switched off and require a forward bias to enable them to be used as amplifiers, Jfets are normally in the on state and require a reverse bias in order to partially switch them off so that they can act as linear amplifiers. In Figure 3 the gate of Tr1 is biased to the negative supply potential by R1, while R2, the drain to source



resistance of Tr1, and R3 form a potential divider across the supply lines. The potential developed across R3 takes the source terminal of Tr1 about two or three volts positive, and the gate is therefore about two or three volts negative of the source and has the required reverse bias.

An important difference between bipolar a field effect devices is that the latter have a very high input impedance and consume very little input current. The input impedance of a Jfet is typically about one thousand megohms at low frequencies (the input capacitance gives reduced input impedance at high frequencies), and some field effect devices have an input impedance of over a million megohms. The gain of a field effect transistor is not therefore specified as a certain current gain since such a figure would be of little practical value, but instead it is the transconductance that is specified. This relates the

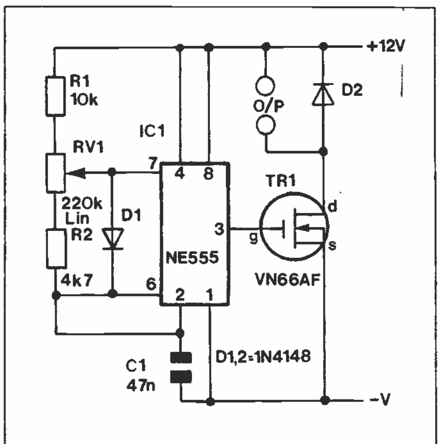


Figure 4. A motor speed controller using a VMOS transistor.

change in input voltage to the change in output current, and in data sheets "gm" is the abreviation often used for transconductance.

Transconductance is usually specified in milli-mhos, and this unit is equal to a one volt change in input potential giving a change in output current of 1 milliamp. Transconductance is equal to output current divided input voltage which is the opposite of the formula for finding resistance in ohms, and it is from this that the name 'mho" is derived. Milli-mho is sometimes abbreviated to m ℧. Transconductance is sometimes specified in micro-mhos, and this unit is simply a thousandth of a milli-mho. A Jfet has a gm of something in the region of 2 to 7 mhos.

The circuit of Figure 3 has a voltage gain of only about 20dB (ten times) which is only about a tenth of the voltage gain obtained using a high gain bipolar transistor. However, by making R1 high in value a high input impedance can be achieved with a figure of approximately 1 megohm being obtained in this case. This is about one hundred times higher than the input impedance achieved using a high gain bipolar transistor.

The BF244B is an N channel device which is comparable to an npn bipolar device. There are also P channel devices such as the 2N3820, and these have the same circuit symbol apart from the arrow in the gate part of the symbol, and this points in the opposite direction for a P channel type.

VMOS devices

Until recently there were no field effect power devices available to the amateur user, and there were in fact no really practical power f.e.t.s. at all. Power Jfets are now produced, but are difficult to use and are not available to amateur users. There are other types of power f.e.t. though, and the most common type is the VMOS transistor.

These are enhancement mode devices, and are similar to bipolar transistors in that the device is cut off with a gate bias voltage of zero, and does not begin to conduct until a gate potential of about 0.8 to 2 volts is reached. Like all field effect devices, the input impedance of VMOS transistors is very high and they are voltage rather than current operated. They have transconductance figures which are much higher than those of Jfets, and they obviously need to be since they are power devices which might need to control output currents of a few amps with an input voltage change of just a few volts. Most VMOS devices have a gm of about 250 mhos, which means that a 4 volt change in the input potential gives a 1 amp change in output current! High power types have gm values in excess of 1000.

VMOS transistors can be used in the output stages of audio power amplifiers and other high power linear applications, and their freedom from secondary breakdown and thermal runaway plus their excellent high frequency response make them in many respects ideal for such applications. They are also useful for switching applications such as the simple pulse type motor speed controller circuit of Figure 4. VMOS transistor Tr1 can be driven direct from the output of the 555 timer I.C. without the need for any current limiting resistor since Tr1 is

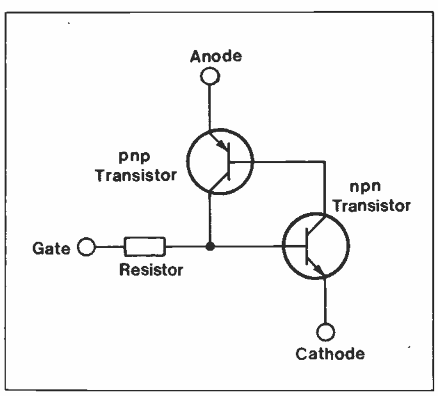


Figure 5. An SCR is analagous to this circuit.

voltage and not current operated. For the same reason there is no need to have a low impedance drive circuit capable of supplying a few hundred milliamps, and although the VN66AF can handle drain currents of up to two amps it can be driven from a fairly high impedance source (such as a CMOS logic device) unless the input frequency is quite high. The input capacitance of most VMOS transistors is only about 50pF and it is really only at radio frequencies that the input impedance of these devices falls to a fairly low level.

VMOS transistors are susceptible to damage by high static voltages and many types (including the VN66AF) have a 15 volt zener protection diode connected between the gate and source terminals. Obviously the gate potential should not be allowed to exceed 15 volts or a high input current could flow with the device being damaged in consequence.

Power MOSFETs are another type of high power field effect devices. They are primarily intended for use in very high quality audio power amplifiers, and designs of this type have been featured in previous issues of this magazine.

S.C.R.s

Silicon controlled rectifiers or "thyristors" as they are popularly known, are switching devices and cannot be used for linear amplification. These are analogous to the circuit shown in Figure 4.

Initially both transistors will not receive any base current and will be switched off, but if a forward bias of about 0.6 volts is applied to the gate terminal the npn transistor will begin to conduct and supply a base current to the pnp transistor. This device then supplies a base current to the npn transistor, and a regenerative action results in both transistors switching hard on. They

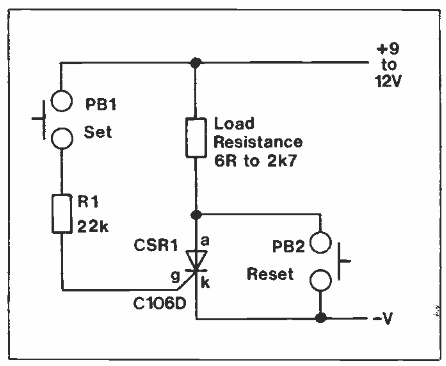


Figure 6. A simple bistable circuit using an SCR.

remain in this state even if the forward gate bias is removed, and the device conducts between the anode and cathode terminals with a voltage drop of about one volt or so between the two.

The simple bistable circuit of Figure 6 demonstrates the basic properties of an S.C.R. Power will not be supplied to the load until PB1 is operated and a gate current is fed to CSR1 through current limiting resistor R1. The C106D device specified for CSR1 is a sensitive device which requires a gate trigger current of no more than 0.2mA, but most thyristors require a trigger current of as much as 20 or 30mA. When PB1 is released CSR1 remains switched on provided the current through the load is high enough, and the hold-on current for the C106D is no more than 3mA. Again this is lower than the figure for most types, and a hold-on current of about 20 to 35mA. is more common. Apart from a few special types it is not possible to switch off a thyristor by reverse biasing the gate, and the only way to switch off the device is to take the anode to cathode current below the hold-on level. In this circuit this is achieved by momentarily operating PB2 so that the current flow is briefly diverted from CSR1.

A triac is similar to a thyristor, but it will operate with gate and load voltages of either polarity (they can even be of opposite polarity). Triacs are mainly used to control A.C. loads in applications such as lamp dimmers and drill speed controllers.