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Whether we are brave enough to admit it or not, we all suffer varying degrees of paranoia when it comes to the doors in our life. Was that someone sneaking in the front door? Did we leave the back door open? Where’s the padlock on the shed door? Should we have a mortise or a night latch?

The list goes on and on... There isn’t a day goes by when we don’t suffer some stress event associated with a door! Perhaps the circuit described here might help put some of those fears at rest. The Door Defender is a simple circuit intended to monitor the opening and closing of a single door, but it could easily be expanded into a comprehensive system.

It can be used with any type of internal or external opening, and consumes very low current in standby. For instance, the long battery life would make it ideal for protecting a garden shed. On the other hand, its small size could allow it to be a portable unit for protection when travelling.

**DESIGN OVERVIEW**

It was decided to create a door monitoring circuit based on the reliable reed switch and magnet method. This would feed information into a circuit designed to indicate whether the door was open or shut. An “arming” sequence would begin with the door closed i.e. you’re getting ready to leave, followed by a turn of a keyswitch to apply power to the circuit. The unit would signal that it had entered the arming sequence which prompts you to open the door and leave, closing it behind you.

The action of opening and shutting the door would be detected by the circuit which would then move into an “armed” mode. The next time the door was opened, the system would immediately turn on and latch the alarm. This would only be cleared by switching off the unit with the keyswitch, even if the door was closed again.

**CIRCUIT DESCRIPTION**

The complete circuit diagram for the Door Defender is shown in Fig.1. Power for the circuit comes from a 9V alkaline battery, which is ideal to supply the CMOS i.c.s that control the alarm process. As mentioned earlier, a reed switch, S2, is used to detect the opening and closing of the door. These items are standard in most burglar alarm systems and are usually employed to monitor the entry/exit route.

They consist of two main components – the reed switch and a magnet. When the two are positioned adjacent and “in-line” i.e. when the door is properly closed, the reed switch physically aligns itself with the lines of flux from the magnet, causing the contacts to close. They are generally good enough to detect a door even slightly ajar. Unfortunately, like all switches, the reed type is liable to “bounce” when closing. In other words, the contacts do not necessarily come together cleanly, and for a very brief fraction of a second, they may open again one or more times before they finally settle. The bounce may appear to us to be over very quickly, but in logic terms, it is a lifetime, and the circuit will detect every “bounce” as an opening and closing of the door! The ideal recipe for a very confused circuit!

Components R2, C1 and IC1b come to the rescue here, forming a “debounce” circuit. Basically we are using an RC slow-down network to drive the Schmitt trigger gate IC1b. The low-pass filter formed by resistor R2 and capacitor C1 smooths out the bounces of the switch contacts so that IC1b makes only one transition. A time constant of 10ms to 25ms is generally enough.

**ON GUARD**

Now that we have a clean reliable signal telling us what the door is doing, we can...
start doing something useful with that information.

When we look carefully at the design concept, it becomes clear that we need to produce a circuit that remembers the sequence of door movements so that we can correctly control the alarm operation. In a more complicated system we might use a microcontroller, but here the sequence is so simple we can use a couple of bistables, or flip-flops.

These circuit blocks are characterised by the fact that they are stable in one of two logic states (as opposed to monostables, which are stable in only one state, and astables, which continually oscillate between the two). The condition they adopt is dependent on changes of logic state at two or more inputs.

The type of flip-flop used here is a D-type (Data type), which is designed for data-related applications where it is desirable to “remember” the state of an input at a point in time defined by a clock signal. In this circuit it is actually wired as a T-type (Toggle-type), which results in the Q output “toggling” (switching to the opposite logic state) every time there is a rising edge at the clock input.

Since the flip-flops can adopt either state at power-up, it is important to perform a reset operation every time at switch on. Components C2 and R3 form a rather unorthodox yet effective reset circuit. When power is applied, the “hot” end of resistor R3 initially goes high (about 9V), but this voltage drains away very quickly down to zero. Despite this voltage fall, it is high for long enough to put the two flip-flops into the desired states – IC2a has its Q output forced high, whereas the Q pin on IC2b is forced low. So we know we are starting from the same point every time.

ARMED GUARD

At power-up, we want to enter the “Arming” mode because we are getting ready to leave the room, and the circuit signals the presence of an intruder by flashing a l.e.d. Therefore, in this enabled oscillation process – the l.e.d. D1 will only respond to rising edges, and the Door Defender now settles into “Monitoring” mode – both the l.e.d.s are off, and it continues to flash until you open the door in preparation for departure.

Reed switch S2 detects the opening of the door causing the voltage at the junction of resistors R1 and R2 to fall to 0V. The input conditioning at IC1b converts this to a logic level change that is fed into the clock input pin 3 of IC2a. The arrival of a rising edge (a change of state from low to high logic level) toggles the flip-flop and the Q output goes low, switching off “Arming” I.e.d. D1. Although the clock input to IC2b at pin 11 is connected to the Q output of IC2a, there is no change to its state, as it sees a falling edge.

ABSOlUTE MAYHEM

The closing of the door causes no further changes to the circuit, apart from the flip-flop outputs as their clock inputs only respond to rising edges, and the Door Defender now settles into “Monitoring” mode – both the I.e.d.s are off, and it continues for some time, but very little current is drawn, so the battery is kept fresh for Alarm action.

Everything happens when the door reopens! – breaking the magnet/reed switch “influence”. A rising edge into the clock input of IC2a at pin 3 toggles the state of its outputs – the Q output moves from low to high and which is a rising edge. This logic change is also seen at the clock input to IC2b (pin 11) causing it, too, to toggle the state of its outputs, since it is also wired as a T-type. The change in the state of IC2b sounds the alarm!

Using IC1a as a buffer to drive transistors TR1, TR2, the low output from pin 12 of IC1b brings on the Alarm I.e.d. D2 and also “fires” the warning Alarm sounder WD1. You may also note that the Arming I.e.d. starts flashing too! Absolute mayhem – just what we want!

### Components

- **Resistors**
  - R1, R2 100k (2 off)
  - R3, R5, R7 10k (3 off)
  - R4 20k
  - R6, R8 470Ω (2 off)
  - All 0-6W 10% carbon film

- **Capacitors**
  - C1 100n disc ceramic
  - C2 10n disc ceramic
  - C3 47μf min. radial elect. 16V

- **Semiconductors**
  - D1, D2 5mm l.e.d. red (2 off)
  - TR1, TR2 BC108 npn low power transistor (2 off)
  - IC1 4093 CMOS quad 2-input NAND Schmitt trigger
  - IC2 4013 CMOS dual D-type flip-flop

- **Miscellaneous**
  - S1 single-pole make/break miniature round key-operated switch
  - S2 2-piece plastic moulded reed switch, with magnet
  - WD1 4V to 9V min. buzzer
  - B1 9V alkaline battery (PP3 type), with clips

Stripboard, size 21 holes x 23 strips; plastic handheld box, with battery compartment, size 105mm x 62mm x 28mm approx; 14-pin d.i.l. socket (2 off); multi-strand connecting wire; wire links; solder pins; solder etc.

Approx. Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripboard</td>
<td>£16.50 excl. batt.</td>
</tr>
</tbody>
</table>
Now, the design requirement is that the Alarm shall continue to sound even when the door is shut again – in other words it “latches” until the authorised keyholder turns the power off. This is where the connection between IC2b pin 12 and IC1b input pin 5 comes in to play.

At switch-on, the reset circuit ensures that this line is high, and this allows the reed switch signals through to IC2a. We already know that IC2b toggles when the circuit goes into Alarm mode. This immediately changes the signal to IC1b and disables the gate, preventing further door signals being processed.

As long as pin 5 (IC1b) is low, the output of the gate can never go high and create a rising edge – the circuit is “latched” in the Alarm mode, and continues to sound no matter how many times you open and close the door! A turn of the keyswitch S1 is the only way.

**CONSTRUCTION**

The original concept was that the finished unit could be easily fixed to a bedroom or workshop door. The chosen enclosure results in a very compact fit but produces a handy little “Defender”. There’s no reason why it could not be housed in a larger box, especially if you’re thinking of expanding the circuit to create a full blown intruder detection system.

Construction should commence by preparing the case to accept the off-board components. A general layout guide can be seen in the accompanying photographs. Note the cutouts in the stripboard.

Start by preparing the stripboard to the suggested shape, the layout will be dictated by the off-board components used, particularly the clearance required for the keyswitch S1. Once you have cut the board to the desired shape, temporarily place it in the base of the case and check for a satisfactory fit.

When you’re happy, remove it and begin to make the breaks in the copper tracks – there are 24 in all. A small handheld twist-drill or a dedicated stripboard cutter tool will do the trick. Examine the board carefully after each cut to make sure that the break is clean and complete – a magnifying glass will help here.

The stripboard topside component layout and details of breaks required in the underside copper tracks are shown in Fig.2. The interwiring details to the off-board components are also shown in this diagram. The reed switch housing is bolted on one of the outside case panels – see photograph.

Fit all the lead-off solder pins and wire links – quite a tedious job but it helps define the layout. Again, keep checking against the layout drawing at every opportunity. Once all the links are in place, solder in the two 14-pin IC sockets, making sure that they’re the right way round. Don’t fit the chips yet.

Next, the resistors can now be added. Most lie flush to the board, but a few stand almost vertical. Then it’s on to the capacitors – C3 is polarity conscious so check that the positive (+) lead is in the right hole.

The final components are the two transistors. Again, have a careful look at Fig.2 to be sure that you’ve identified their pins correctly and then solder them in position.

Before continuing, take time to check the circuit board just one more time. It is not only a case of confirming that all the components are in the right place but also that there are no solder splashes, bridges, etc. on the copper side.

**BOARD CHECK**

The next job is to do some basic checks on the circuit board. Set your multimeter to the lowest resistance scale and measure across the +V and 0V terminals. What you

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are looking for here is any short circuit between the rails, i.e. less than one or two ohms.

Once the multimeter is giving good news, attach a 9V battery across the same terminals. Check that there is a nice steady voltage across pin 7 and pin 14 of the i.c. sockets. If everything is okay go ahead and finish the installation.

**FINAL ASSEMBLY**

Start by taking the reed switch and attaching two lengths of wire to the internal terminals – measure the resistance across them. In isolation, the reading should be open circuit but if you bring the magnet alongside the reed switch there’s a point where the contacts close. This is a good test to see if you’ve wired it up correctly and that the switch responds to the presence of the magnet. Make sure that the contacts open again when the magnet is removed.

The reed switch module can now be securely attached to the case side panel and the circuit board screwed securely in place. Now it’s just a matter of doing the wiring-up – connecting the led’s, reed switch, buzzer, keyswitch, and battery clip as shown in Fig.2.

Finish by doing another multimeter check to confirm that no short circuits have crept in, and that the keyswitch S1 is working correctly. If everything looks good, insert the battery, and temporarily tape the magnet block in line with the reed switch S2. Now turn the key to apply power to the circuit. Neither of the led’s should be lit and the buzzer WD1 should be silent.

Now detach the magnet, moving it well away from the reed switch. The “Arming” led D1 should begin flashing, indicating that the circuit has detected that the contacts have opened. Now bring the magnet back in-line with the reed switch. The Arming led D1 should go out.

Finally, remove the magnet again. This time, both led’s (D1, D2) should light and buzzer WD1 sound. Replacing the magnet will have no effect and the only way to reset the system is by turning the keyswitch. If all is well, the box can be screwed together and the system is ready for use!

**IN USE**

The Door Defender will be found useful in all sorts of applications, although it should not be used in an unattended public position as it does not have an automatic cut-off time-out for the alarm sounder. Installation requirements are not critical, simply that the magnet and reed switch parts are consistently aligned when the door/window is shut. Also, there is no reason why the reed switch needs to be mounted on the box – you could locate the alarm unit remotely and run a cable to the sensor (reed/magnet). The intruder would be unaware of the setup.

You could pack it in your suitcase and use it to protect a hotel door or monitor movements in and out of the workshop. Perhaps it might work as a child alarm, warning you if Junior has found their way into your den or wandered from their bedroom/playroom? What about using it to protect your toolbox from prying little hands?! Whatever the need, it can be quickly set up and provide sterling service.

If you’re feeling adventurous, why not expand the basic system to create something more comprehensive? Further switches could be added (normally closed types wired in series) to monitor windows and other doors, while the led’s could be replaced with relays or opto-isolators to drive flood-lamps, strobes, or sirens. There’s nothing like going over the top!
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**BRIGHT BARGAIN PACKS**

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PAKOLON PANEL. Approximately 12in. x 12in. Order Ref: 1033.

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CLOCKWORK MOTOR with 15A changeover contacts. Order Ref: 1086.

**OVER 1,000 PACKS**

Ref: 811.

**12V-0V-12V, 6W. ORDER**

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**WHITE PROJECT BOX,** Ref: 685.

**100M COIL OF CONNECTING WIRE.** Order Ref: D86.

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**HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, thin am- plitude to be at least 25A, pack of 2. Order Ref: 7FC47.

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**HALL EFFECT DEVICES, mounted on small heatsink, pack of 2. Order Ref: 1022.

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10mm, changeover contacts, pack of 2. Order Ref: 826.

**BEND 1A SOLAR CELL. Best type, has bubble lens on face. £1 each. Order Ref: 3P92.**

**2.5P34.**

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**CLOCKWORK MOTOR.** Suitable for up to 6 hours continuous. Order Ref: 1038.

**HIGH CURRENT RELAY, 12V d.c. or 24V a.c.,**

**OPERATES CHANGEOVER CONTACTS.** Order Ref: 1026.

**CLOCKWORK MOTOR.** Suitable for up to 6 hours continuous. Order Ref: 1038.

**HIGH CURRENT RELAY, 12V d.c. or 24V a.c.,**

**OPERATES CHANGEOVER CONTACTS.** Order Ref: 1026.
ALTERNATIVE USES FOR TRANSISTORS

NED STEPHENS

A look at the other uses to which transistors can be applied

TRANSISTORS have many uses which are well known, such as amplifiers, oscillators and switches, but have many further uses, some of which are not as well known. A knowledge of these other uses can be helpful when a particular component is not immediately available but is required for gadgeteering or experimentation.

For instance, if a Zener diode of a particular voltage is needed for a constructional project, but is not available in the spares box, then it may be possible to use a transistor instead. Transistors may also be used in place of signal diodes, rectifier diodes, varicap diodes, tunnel diodes, constant current sources, and even solar cells.

In some cases, a transistor pressed into such service may be superior to a purpose made part and may reduce the circuit’s total parts count.

SIGNAL DIODES

When a current is passed through a diode in the forward direction, the diode acts as a non-linear resistor, such that the effective resistance is large at small voltages, but reduces as the voltage increases. This has the effect that there is no appreciable current flow through the diode until the voltage across it has risen above a certain value. In the case of a germanium diode this is approximately 0.3 volts, and in the case of a silicon diode it is about 0.7 volts.

If you wish to detect a small r.f. voltage in a crystal set, for instance, then it is better to use a diode with the lowest possible voltage drop, i.e. a germanium one.

So much for standard practice – results are better if we use a transistor instead. A transistor, measured with an ohmmeter appears to be two diodes, one connected from base to emitter and the other between base and collector. Either of these apparent diodes may be used as real diodes, the third connection of the transistor being left open circuit.

We can, however, do better than this by connecting the base of the transistor to the collector and using that common connection as one diode connection, whilst the other diode connection goes to the transistor emitter, making a so-called “superdiode”. Which of these connections is the diode anode (a) and which is the cathode (k) depends on whether you are using a pnp or an npn transistor.

Due to the amplifying action of the transistor, the effective resistance of this new superdiode is as low as, or lower than, that of a purpose built diode, so that its use in signal circuits will enable the detection of smaller r.f. voltages. Table 1 shows forward voltage drops of base-emitter junctions and superdides, and the drops of germanium and silicon purpose built diodes for comparison.

We see that this trick of connecting a transistor as a superdiode is much more successful with germanium transistors than with silicon. With germanium the forward voltage drop may be more than halved, but for all the many different types of silicon transistor that were tried the forward voltage was only reduced by about 10 per cent or so.

It is apparent that a germanium transistor connected as a superdiode, i.e. with the base connected to the collector, begins to conduct in the forward direction with much smaller applied voltages. In order to check out the characteristics of this new device the circuit of Fig.1 may be used.

Sample curves of an OC72 germanium transistor used in this fashion are shown in Fig.2, along with the curve of a germanium diode type OA91 for comparison. Practical tests with a standard crystal set circuit show that a germanium diode is indeed better than one made of silicon, but a germanium r.f. transistor in the superdiode configuration is best of all.

RECTIFIER DIODES

Large power transistors may be used as rectifiers in this fashion and, as above, germanium transistors used in the superdiode configuration at low currents show much more reduction of forward voltage drop than do silicon types. The list in Table 1, however, is for signal diodes and refers to only small diode currents. It should be noted that the voltage drop at higher currents will be less for silicon than for germanium, so that when substituting components germanium should be used for low currents and silicon for anything above about 10mA.

Table 1: Forward voltage drop comparisons

<table>
<thead>
<tr>
<th>Diode</th>
<th>Construction</th>
<th>Emitter-base junction at 100μA</th>
<th>Superdiode at 100μA</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA91</td>
<td>Germanium diode</td>
<td>0.184V</td>
<td>0.077V</td>
</tr>
<tr>
<td>1N914</td>
<td>Silicon diode</td>
<td>0.509V</td>
<td>0.046V</td>
</tr>
<tr>
<td>2N1307</td>
<td>Germanium transistor</td>
<td>0.137V</td>
<td>0.038V</td>
</tr>
<tr>
<td>AC128</td>
<td>Germanium transistor</td>
<td>0.105V</td>
<td>0.053V</td>
</tr>
<tr>
<td>OC71</td>
<td>Germanium transistor</td>
<td>0.105V</td>
<td>0.046V</td>
</tr>
<tr>
<td>BC107</td>
<td>Silicon transistor</td>
<td>0.511V</td>
<td>0.487V</td>
</tr>
<tr>
<td>BSY3</td>
<td>Silicon transistor</td>
<td>0.640V</td>
<td>0.627V</td>
</tr>
</tbody>
</table>

Fig.1. Test circuit for “transistor” superdiode and Zener diode.
It must be remembered that the current flow is through the base-emitter junction of the transistor, which is not its normal mode of operation. The author has been unable to find any data relating to the maximum permissible base currents. However, data books listing transistor saturation voltages quote the base current used, in the case of the BD239 this is 200mA and for a BUX98 it is 4.0 amps (Ref.1), with most silicon power transistors quoted as using base currents between these two figures. Using transistors in place of rectifier diodes at these current levels will be fine, but care should be taken if exceeding them by a large margin.

**ZENER DIODES**

If the superdiode connection is used in the reverse direction then it will be seen that the transistor now exhibits a Zener characteristic. Several different types of transistor were tested using the circuit in Fig.1 to see which Zener voltages were available. The results are shown in Table 2.

The same formula may be used except that the constant should be approximately doubled, i.e. to approx. 1.10((R1 + R2)/R2) volts. The methods of connecting these “Zeners” is shown in Fig.4.

**LOW LEAKAGE DIODES**

If a diode with infinitesimal reverse leakage current is required then one can be made from an ordinary n-channel f.e.t. By connecting the drain and source leads together and using this connection as the diode cathode and the f.e.t. gate as the anode then such a diode is obtained. These anode and cathode connections should be reversed if using a p-channel f.e.t.

Several species of f.e.t. were tested and all gave results within five per cent of each other. In addition to the use of a transistor in this fashion to obtain a fixed Zener voltage, we may connect one in a way that we are able to select our own Zener voltage. By connecting a transistor as shown in Fig.3, a “Zener” may be made with any desired Zener voltage by varying the ratio of the two resistors.

For instance, when using a BC109 at a current of 1mA flowing through the device, in some cases several diodes and transistors with the same type number were tested and all gave results within five per cent of each other.

In addition to the use of a transistor in this fashion to obtain a fixed Zener voltage, we may connect one in a way that we are able to select our own Zener voltage. By connecting a transistor as shown in Fig.3, a “Zener” may be made with any desired Zener voltage by varying the ratio of the two resistors.

For instance, when using a BC109 at a current of 1mA, the Zener voltage is given by 0.63 ((R1 + R2)/R2) volts. Examples of this method are: using R1 = R2 = 10kΩ the Zener voltage is 1.25V, and using R1 = 30kΩ, R2 = 10kΩ then we obtain 2.50V, both measured with a Zener current of 1mA.

Plotting the voltage/current curves of this connection shows that there is quite a high slope resistance, but this may be overcome by using a Darlington transistor, or two transistors wired as such, and with this lower slope resistance better voltage stabilization will result.

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### Table 2: Transistors as Zener diodes

<table>
<thead>
<tr>
<th>Transistor</th>
<th>Voltage</th>
<th>Transistor</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N3553</td>
<td>5.57</td>
<td>BFY18</td>
<td>8.11</td>
</tr>
<tr>
<td>2N3703</td>
<td>6.06</td>
<td>BSY26</td>
<td>8.15</td>
</tr>
<tr>
<td>2N2846</td>
<td>6.18</td>
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<td>8.22</td>
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<tr>
<td>2N4047</td>
<td>6.35</td>
<td>BC148</td>
<td>8.38</td>
</tr>
<tr>
<td>BFZ29</td>
<td>6.40</td>
<td>BFX85</td>
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<td>7.16</td>
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<td>7.38</td>
<td>BC639</td>
<td>8.83</td>
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<td>BC109</td>
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<td>2N969</td>
<td>9.21</td>
</tr>
<tr>
<td>2N1613</td>
<td>8.08</td>
<td>BSY95</td>
<td>9.43</td>
</tr>
</tbody>
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*Fig.2. Forward biased germanium junctions.*

These were all measured with a current of 1mA flowing through the device. In some cases several different silicon transistors with the same type number were tested and all gave results within five per cent of each other.

*Fig.3. Circuit for selecting the Zener voltage by varying the ratio of R1, R2.*

beginning when biased by around 600mV. This again is not the normal f.e.t. mode of operation and care should be taken that the f.e.t. is not overloaded, as the manufacturers have not designed the device with gate current in mind.

**VARICAP DIODES**

Diodes used in the reverse bias mode giving capacitance between the anode and cathode connection, the capacitance decreasing as the applied voltage is increased. Diodes used in this fashion are known as varicap diodes, and are specially made so that this characteristic is exhibited to a greater extent than in normal silicon diodes.

Varicaps are commonly used in tuned circuits in the r.f. stages of TVs and car radios to enable them to be tuned electronically with no moving parts. Radio amateurs have for many years used cheap general purpose diodes in place of the more expensive varicap diodes, but it is unusual to use a transistor instead, even though it is simple to achieve results with them.

The test circuit of Fig.5 was built and the frequency measured with different values of tuning capacitor to enable the stray capacitance to be calculated. The oscillator frequency was then set at precisely 6.0MHz and the transistor under test was connected. The resulting oscillator frequency was measured at different tuning voltages to enable the capacitance swing to be calculated.

The results are shown in Table 3 for various types of transistor, the maximum frequency and minimum capacitance figures refer to a tuning voltage of 12V, whilst the minimum frequency and maximum capacitance figures refer to zero tuning voltage.
Whilst it is easy to tune an oscillator in this fashion, the use of tuning transistors in the signal circuits of radios may lead to disappointment as, although the transistor used has a large capacitance swing, it may have a low Q. Because of their relatively large leakage currents, germanium transistors will be worse in this respect than will silicon transistors.

Due to the need to keep the transistor “diodes” reverse biased, only npn transistors have been used with this test circuit, although it would be possible to use npn types if the polarity of the tuning voltage rail were changed.

**CONSTANT CURRENT SOURCES**

Constant current sources, whilst not seen very often, are very useful field effect devices which over a large voltage range will keep the current through the device at a given value. Motorola have a range 1N5283 to 1N5314, which have preset currents between 0-22mA and 4-70mA (Ref.2). Siliconix have a similar range which has device numbers easier to understand, i.e. CR390 has a constant current of 3-9mA and CR470 has a constant current of 4-7mA. These devices may be easily made from f.e.t.s (field effect transistors) by connecting them as shown in Fig.6a.

Looking at $I_{ds}$ in transistor characteristic tables gives some idea of the constant current that can be obtained, but this will only be approximate because the spread in characteristics of f.e.t.s is quite wide. For example, the 2N3823 is quoted with a figure between 4mA and 20mA, and the 2N4391 between 50mA and 150mA (Ref.1). We can, however, obtain any current value less than $I_{ds}$ by inserting a resistor in the source lead of our chosen f.e.t., as in Fig.6b.

A sample of 2N3819 that was tested with no source resistor gave a constant current of 12mA. When 100 ohms was inserted, the current was 9mA, 7.5mA with 200 ohms and 11mA when used with 100, 200 and 300 ohms respectively. The only things to bear in mind when using f.e.t.s as constant current sources is that the maximum permitted voltage across the device is around 30V and the dissipated power should not exceed the device rating.

**SOLAR CELLS**

Back in the dim distant past of transistors, their cases were constructed of glass, which was painted black on the outside to stop light affecting the inners. One of the common transistors then available, an OC71, a pnp germanium a.f. transistor, was also made in another version, OC71A, which in effect had a hole in the paint so that it could be used as a phototransistor.

What the manufacturers did not tell us, however, is that if all the black paint was scraped off an OC71, or any other glass transistor of similar construction, then it could be used as a photovoltaic cell to generate electricity. Brightly lit it will produce up to 300mV when not driving a load, although this drops off sharply when a load is applied.

As an experiment, the author cut the top off a BC109 and the voltage in full sunlight was measured. An output of 400mV was obtained when measured on a digital voltmeter. However, when loaded with a moving coil meter it gave no discernible output.

**NEGATIVE RESISTANCE DEVICES**

Tunnel diodes are rare but useful two terminal devices which exhibit a region of “negative resistance” over a small applied voltage range, enabling amplifiers and oscillators to be easily built. Silicon tunnel diodes show this effect when biased between 65mV and 420mV, gallium arsenide between 150mV and 500mV, and germanium from 55mV to 320mV (Ref.3). They were more popular in years gone past, though, and are now difficult to obtain.

Table 3: Transistors as varicap diodes

<table>
<thead>
<tr>
<th>Transistor</th>
<th>Measured Frequency</th>
<th>Calculated Capacitance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min MHz</td>
<td>Max MHz</td>
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<tr>
<td>2N1132</td>
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<td>5-81</td>
<td>5-76</td>
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<tr>
<td>OC201</td>
<td>5-76</td>
<td>5-52</td>
</tr>
</tbody>
</table>

Fig.5. Test circuit for using transistors as varicap diodes.

Fig.6. Constant current source using f.e.t.s.

Fig.7. Using n and p-channel f.e.t.s in a lambda configuration to produce a “tunnel diode” effect oscillator circuit.

By using an n-channel f.e.t. in connection with a p-channel f.e.t. the same negative resistance effect may be obtained cheaply and simply, although in this case the applied bias is somewhat higher. This combination of two different types of f.e.t. is called a lambda circuit, one of which was constructed from a 2N3819 n-channel f.e.t. and a 2N5460 p-channel f.e.t., connected to an old 10-7MHz i.f. transformer, as shown in Fig.7.

The power supply voltage was varied and it was found that the circuit oscillated with bias voltages between 2-7V and 6-5V, although it was found impossible to measure these values precisely due to the circuit suddenly jumping from one current value to another as the supply voltage was increased. Nevertheless, the circuit oscillated well at the 10-7MHz test frequency used. This really is a simple and easy little oscillator circuit and deserves to be more widely known.

**CONNECTING IT ALL TOGETHER**

Having explored a constant current source and a constant voltage source, the
two can now be connected together to form a low current stabilised power supply which may be used to supply the lambda circuit. The tuned circuit attached to the lambda circuit can be tuned by a npn transistor taking the place of a varicap diode pair (Fig.8).

The total circuit for a simple oscillator circuit thus consists of five transistors, two resistors, a fixed capacitor and a tuned circuit. This may be reduced even further if the “varicap” part of the circuit is not required.

You may well be asking whether this unlikely looking circuit does actually work: after an initial 30 minutes wait for the circuit to achieve thermal equilibrium (during which time the frequency drifted by 113Hz), the oscillator output frequency was measured with different supply voltages. The results are shown in Fig.9, which shows that for best results the supply voltage should be kept within the range 6V to 18V, the output frequency varying by only 26Hz between these voltage limits.

Varying the tuning voltage from zero to 10V reduced the output frequency by 550kHz. The circuit of this oscillator shows that transistor substitution is well worth doing as the component count is very small and the only component selection required is that the transistor acting as a Zener should have its “Zener” voltage within the negative resistance range of the lambda circuit, i.e. between 2.7V and 6.5V.

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