CHOOSING A REPLACEMENT TRANSISTOR

When you're servicing a piece of faulty electronic equipment, the problem can easily involve a transistor that has shorted, gone open circuit or developed low gain and/or high leakage. Tracking down the dud may not be too hard, but finding a suitable replacement can pose problems — especially for newcomers.

Clearly the ideal replacement for any transistor is a new one of exactly the same type. But let's face it: there have been around 200,000 different transistor types produced so far over the years, many of them almost impossible to get nowadays.

So what do you do if the exact type is impossible to obtain?

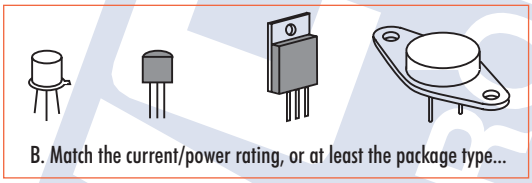
As it happens, many circuits are really quite tolerant of transistor parameters, and because many transistors are very similar in terms of their main parameters, you can often substitute any of a number of transistors and still achieve normal circuit operation or very close to it. But you do need to know what you're doing, in selecting a substitute device...

The first step is to identify the faulty transistor. Preferably, look it up in one of the many excellent Transistor Data Books or Comparison Tables that are available (Jaycar stocks some very good examples of these — see the current Catalogue).

Basic info & parameters

Now make a note of its basic information: whether it's germanium (Ge) or silicon (Si); NPN or PNP; high power or low power; designed for linear amplification or switching; and low noise or not. Also note its main performance parameters: voltage breakdown rating (usually V_{cemax} or BV_{ceo}); current gain (β or h_{FE}) at the likely collector current; and upper frequency limit (f_T or F_{max}).

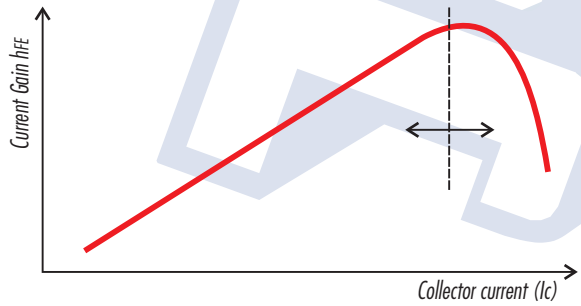
What if you can't even find it in the data books? Perhaps you can find out at least some basic information about it from the circuit schematic for the equipment — if you have access to it. For example this will tell you if it's a PNP or an NPN; and if the base-emitter voltage is shown, this will tell you if it's germanium (0.25V) or silicon (0.6V). Of course if it's reasonably new equipment, you can probably assume it's silicon anyway.



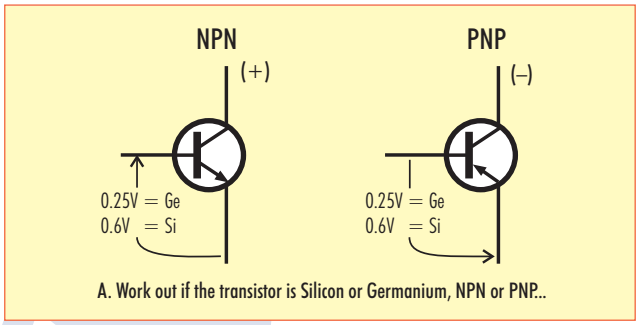
B. Match the current/power rating, or at least the package type...

You'll probably also be able to get a good idea of whether it's being used for switching or amplification, the supply voltage, the approximate collector current/power level (from the supply voltage divided by load impedance/resistance) and perhaps the operating frequency. If it's being used in the first stage of a preamp or high-gain amplifier, you can reasonably assume that it's a low-power, low noise type.

If you don't even have a schematic, it would be a good idea to trace out the circuit in the immediate vicinity of the transistor



C. Match the operating point on the Current Gain vs. Collector Current curve...



A. Work out if the transistor is Silicon or Germanium, NPN or PNP...

in question. This probably won't take long, and should let you work out at least the basics: whether it's an NPN (collector connected to the positive rail) or a PNP (collector to the negative rail), and what kind of resistance/impedance is limiting the collector-emitter current.

If the transistor seems to be being used for switching, you'll hopefully also be able to get an idea of the base drive current available to switch it on. This will let you make a rough calculation of the minimum current gain needed, simply by dividing the approximate collector current when it's 'on' (assuming it will then have very little voltage drop — say 200mV), by the estimated base drive current.

The dud transistor's own package, and whether or not it's fitted with a heatsink, will give you a pretty good idea of its power rating. For example if it's in a metal T0-18 or plastic TO-92 package, the odds are it has a power rating below 500mW. If it's in a TO-126 or TO-220 package with a small heatsink, it's probably a medium-power device; and if it's in an SOT-93 or TO-3 package bolted to a large heatsink, it's clearly a high-power device.

How about transistors in RF or IF amplifier stages, or in oscillator circuits? Here you'll probably have a very good idea of the frequency it is working at, and if so, you can use this to estimate its F_{max} or f_T. A safe guess in most cases is to multiply the working frequency by a factor of 10.

Picking a substitute

At this stage you've hopefully found or worked out the basic information and parameters for the dud transistor. Now it's a matter of looking through the data for the new transistors you *can* obtain, and choosing one that seems closest to it. This is basically just a process of progressive elimination:

1. First off, is it **NPN or PNP**? This narrows the field by 50% straight away, and the same applies for **Si** or **Ge**. Needless to say your substitute generally has to have the same polarity and semiconductor material, so this narrows your selection down quite a bit already.

2. Now, is it **high** or **low power**? You should try to match this reasonably carefully, or at the very least go for a device in the same or a very similar type of package to the original.

3. How about the **voltage rating**? You'll need to find a device with either the same or a higher voltage rating, to make sure it doesn't break down in operation.

4. Now we come to **maximum current rating**, and here you have to be a bit more careful — especially with silicon transistors. The current gain of these devices is roughly proportional to collector current level, but reaches a peak and then drops again at higher current levels. Where this peak occurs depends on the transistor's construction, but it can

have an important effect on how the transistor behaves in your circuit. That's why a transistor with much higher current rating may not work properly in your circuit, because its gain might actually be quite low at low working current levels; conversely a transistor with too low a current rating might be driven past its peak, where it will again have low gain.

This can be very important in switching circuits, because if the working gain is low, there might not be enough base current drive to switch the transistor properly on, and it could be damaged due to abnormally high power dissipation. Switching transistors spend most of the time either turned off or 'hard on' (saturated) — both conditions where there's a relatively low power dissipation. So it's important to match the maximum current rating fairly closely, to ensure that the transistor is going to be switched on and off properly.

5. You should now have narrowed the field down quite a lot, and be more or less at the fine-tuning level. Here's where you need to look at things like matching the original transistor's **current gain h_{FE}** and its **maximum frequency f_T**. In many cases it won't matter much if you go for a device which is even better than the original in both these respects, as most circuits are designed to cope with a reasonably wide range in these parameters anyway.

Summary

Hopefully you'll find this rough guide to choosing a replacement transistor useful. The basic steps we've covered should generally allow you to find a reasonable substitute for most transistors in *typical* circuit applications, assuming the exact type simply isn't available.

Note, however, that there will be specific cases where you'll need to be particularly cautious in choosing a replacement transistor, either because the device concerned is very special or the circuit itself is more critical of device parameters. For example horizontal output transistors in TV sets and monitors can be especially tricky, as they frequently have very fast **charge-storage** and **turn-off characteristics**, and may also have an inbuilt protective or booster diode. Be very careful about choosing a substitute for these, and also for transistors in DC-DC converters, motor control circuits, regulated power supplies and so on.

Watch out also for **Darlington** or 'compound' transistors, which will generally need to be replaced with a similar type. And of course for SCRs and triacs, which may physically look like a transistor — but definitely aren't!

Finally, be very careful with RF power transistors, especially those designed for use at VHF and UHF. Here a replacement will generally need to be in exactly the same specialised RF package, and a very close match in terms of inter-lead and internal capacitances, etc.

Note that Jaycar Electronics cannot accept responsibility for the outcome of any transistor substitution made on the basis of the above advice.