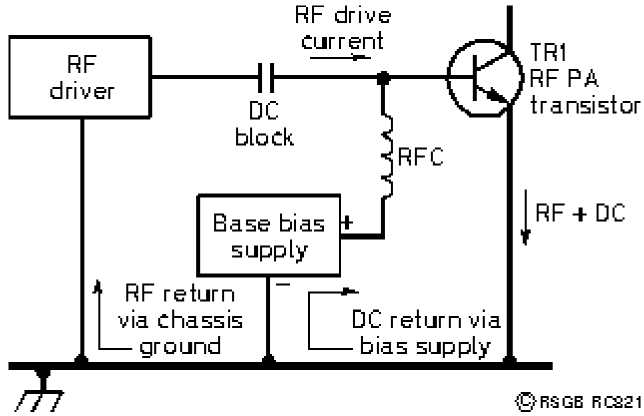
Two-Transistor Bias Circuit



In this circuit, RF drive turns on TR1 and makes it draw both base and collector current. The RF return path is via TR1 emitter and chassis ground - but the DC return path is through the bias bias supply. This means that the bias supply must be capable of delivering the full DC base current at maximum RF drive.

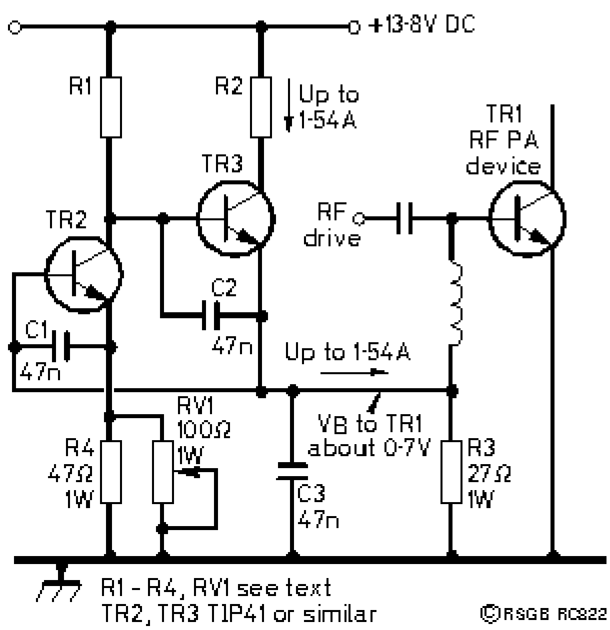
To provide an adjustable, precisely-regulated bias voltage to the base of the PA transistor. This voltage must remain constant in spite of the very large variations in base current caused by the RF drive.

Note the difference between the RF and DC current paths in the circuit above: it is the RF drive waveform that turns-on the transistor and makes it draw both base current and collector current, but the DC return path for the base current is through the base bias supply. This means that the bias supply must be capable of delivering **the full-drive base current**, and not just the small current required to bias the transistor to its idling current of about l00mA.

Another requirement for the base bias supply is a small negative temperature coefficient to help avoid thermal runaway caused by the decrease in base-emitter voltage drop of TR1 with increasing temperature.

The Bias Circuit

Here is the classic two-transistor bias circuit (RF components not shown):



http://www.ifwtech.co.uk/g3sek/tr-bias/tr-bias1.htm#3.

How It Works

To understand how this or any other voltage regulator circuit works, there's a standard technique to apply: imagine that the output voltage falls for some reason (e.g., because more current is drawn by the load) and work out what happens to compensate for it.

If the output voltage Vb falls for some reason, then TR2 will draw less current. That will reduce the voltage drop across R1, making the voltage rise at the connection between the collector of TR2 and the base of TR3. TR3 is an emitter-follower which delivers the output voltage with a high current capability. As its base voltage rises, so too will its emitter voltage, compensating for the fall in output voltage that we imagined at the start of this paragraph. If the output voltage were to try and rise for some reason, it's equally easy to work out that TR3 would deliver less current and thus make the voltage tend to fall back to its original value.

Similar reasoning explains the negative temperature coefficient of this circuit. TR2 is the temperature-sensing transistor bolted to the heatsink close to the RF power transistor TR1. An increase in temperature will cause a decrease in the base-emitter voltage drop of TR2, and a corresponding increase in the collector current drawn. This will increase the voltage drop across R1 and lower the base voltage of TR3, whose emitter-follower action will lower the output voltage. Thus the response to the temperature increase is a reduction in bias voltage supplied to TR1.

Design Procedure

As you read this, refer to the circuit above.

1. Estimate currents and voltages

How much collector current will TR1 draw at full RF output? Say you're designing for a 100W PA powered from 13.8V, which will be reduced to about 13.0V by the time it reaches the TR1 collector. Assuming an efficiency of 50% - it's best to err on the low side when making this estimate - the peak DC input will be (100W divided by 50%) = 200W, which at 13.0V represents 15.4A. Assuming that the current gain of TR1 falls as low as 10 at maximum collector current, that's 1.54A of base current to be supplied to TR1 through TR3.

Now let's look at the voltages. The base voltage of TR1 must be about the standard silicon Vbe value of +0.7V. This is also the emitter voltage of TR3, and the base of TR3 must therefore be another Vbe higher than its emitter, i.e. about +1.4V. R2 limits the amount of base current this circuit can deliver when TR3 is turned fully on. Allowing about 1.0V from emitter to collector of TR3 in this condition, the collector voltage would be 1.7V and the voltage drop across R2 would be (13.8 - 1.7) = 12.1V.

2. Select R2

The estimated peak base current of 1.54A must flow through R2, so its resistance must be 7.86 ohms and its wattage 18.63W. For practical purposes, choose a lower-resistance component with a higher wattage, i.e. a 6.8-ohm 20W resistor. At this point it's useful to note that unlike any of the 'passive' shunt regulators, which draw large currents all the time, this circuit draws very little standby current from the DC supply: R2 and TR3 only handle significant current at high levels of RF drive to TR1.

3. Semiconductors

TR3 gets its base current through R1, with relatively little going through TR2. At this point we have to decide what device to use for TR3, and TR2 can be the same. A good selection would be something like the TIP41A (cost about £0.50/$1). This has a flat TO-220 package suitable for tucking under the PC board as the temperature sensor TR2 (see next section) and also a 6A/65W rating which with heat-sinking will be ample to handle the power in the TR3 position. The TIP41A has a typical current gain of 50, so when the collector current is 1.54A the base current must be (1.54A divided by 50)A = 30mA. This current flows through R1 across a potential difference of (13.8 - 1.4)V, so the value of R1 required is 413 ohms - we'll call that 390 ohms as the next lower standard value. The power dissipated in R1 is less than 0.5W -work it out.

4. Other components

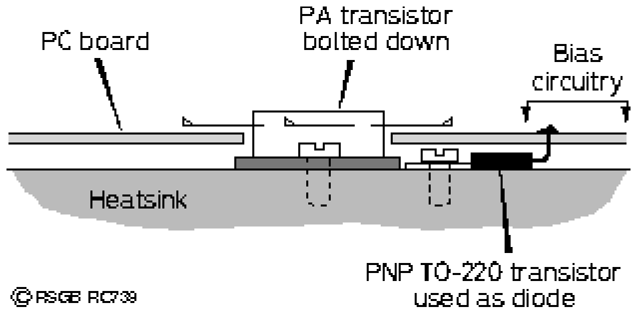
R3 is chosen so that TR3 is always passing a minimum of, say, 25mA to keep the system stable at low currents. That's (0.7V divided by 25mA) which is 27 ohms to the nearest standard value. You might imagine that this could be a low-wattage component, but if the bias supply fails (e.g. R2 goes open-circuit) the amplifier will revert to Class C and all the RF-driven base current to TR1 will go through R3, and if R3 then burns out you'll lose the expensive RF power transistor. For the sake of a few extra coppers, make R3 a 1W resistor.

The final two resistors in this circuit are RV1 which will set the required bias current through TR1, and R4 which is a safety resistor in case RV1 fails open-circuit. Initially, make RV1 a 100-ohm 1W trimpot, and R4 a 47-ohm 1W fixed resistor.

Garnish with 47nF capacitors to prevent the circuit being upset by stray RF, and it's ready to test.

Construction and Testing

Construction



TR2 acts as a temperature sensor, so the best place to track temperature variations is to bolt TR2 to the heatsink, very close to the flange of the PA transistor TR1.

TR2 is not grounded, so don't forget to use insulating hardware!

Testing

DO NOT test the bias circuit using TR1 as a guinea-pig! Big RF power transistors are too expensive to risk mistakes!

Initially, just check it without any load except R3, and confirm that RV1 will adjust the output voltage through the necessary 0.6-0.75V region. Hook up an NPN audio power transistor in place of TR1 and confirm that you can set the collector current to 100mA. Play a hot-air blower on the back of the heatsink where it will heat up TR2 by conduction, but won't affect your temporary test transistor, and confirm that the standing current in TR1 falls as TR2 heats up. Now you can feel reasonably confident to connect the real TR1.

Further checks

When the amplifier is working correctly, you can adjust a few component values to provide even greater long-term reliability.

R2 needs to be low enough to supply the maximum possible base current at full RF output, with something in reserve, but a much lower value would unnecessarily endanger the PA device under fault conditions. Check the voltage drops across R2 and TR3 under full-drive conditions, and review the value of R2.

RV1: If the slider of RV1 loses contact, the bias output could jump to a dangerously high value. You can do two things to reduce this risk. First, spend a little money on a new, good-quality cermet trimpot. For even greater reliability, after initial testing you could replace the 47-ohm resistor R4 with a lower preferred value that allows RV1 to be set close to its maximum resistance (while still leaving enough room for adjustment).