Chapter 13

Monolithic Microwave Integrated Circuits

Monolithic microwave integrated circuits (MMICs) and similar devices are used in a wide variety of receivers. These devices may be very wideband or relatively narrowband. Very wideband amplifiers have a bandpass (frequency response) of several hundred megahertz or more, typically ranging from sub-VLF to the low end of the microwave spectrum. An example might be a range of 100 kHz to 1000 MHz (i.e., 1 GHz), although somewhat narrower ranges are more common. These circuits have a variety of practical uses: receiver preamplifiers, signal generator output amplifiers, buffer amplifiers in RF instrument circuits, cable television line amplifiers, and many others in communications and instrumentation.

One reason why very wideband amplifiers are rarer than narrowband amplifier circuits is that they were difficult to design and build until the advent of monolithic microwave integrated circuit devices. Several factors contribute to the difficulty of designing and building very wideband amplifiers. For example, too many stray capacitances and inductances are in a typical circuit layout, and these form resonances and filters that distort the frequency response characteristic. Also, circuit resistances combine with the capacitances to effectively form low-pass filters that roll off the frequency response at higher frequencies, sometimes drastically. If the RC phase shift of the circuit resistances and capacitances is 180° at a frequency where the amplifier gain is ≥1 (and in very wideband circuits that is likely) and the amplifier is an inverting type (producing an inherent 180° phase shift), then the total end-to-end phase shift is 360°—the criteria for self-oscillation.

If you have ever tried to build a very wideband amplifier, it likely was a very frustrating experience. Until now. New, low-cost devices, called *silicon MMICs*, make it possible to design and build amplifiers that cover the spectrum from near DC to about 2000 MHz, using seven or fewer components. These devices offer 13–30 dB of gain (see Table 13.1) and produce output power levels up to 40 mW (+16 dBm). Noise figures range from 3.5 to 7 dB. In this chapter, we use the MAR-X series of MMICs by Mini-Circuits Laboratories as representative.

Table 13.1 The MAR-X Series of MMICs by Mini-Circuits Laboratories

Type Number	*Color Dot*	*Gain @ 500 MHz (dB)*	*Maximum Frequency*
MAR-1	Brown	17.5	1000 MHz
MAR-2	Red	12.8	2000 MHz
MAR-3	Orange	12.8	2000 MHz
MAR-4	Yellow	8.2	1000 MHz
MAR-6	White	19.0	2000 MHz
MAR-7	Violet	13.1	2000 MHz
MAR-8	Blue	28.0	1000 MHz

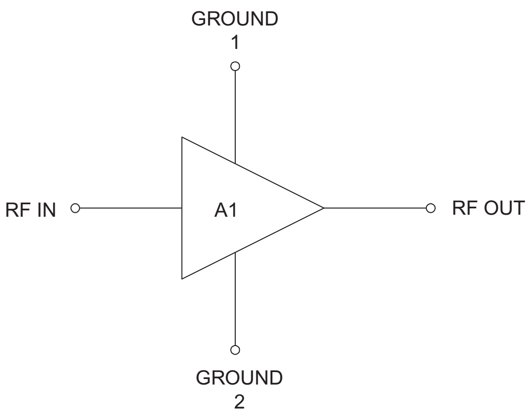

Fig. 13.1 *MAR-X circuit diagram.*

Figure 13.1 shows the circuit symbol for the MAR-X devices. Note that it is a very simple device. The only connections are RF input, RF output, and two ground connections. The use of dual ground connections distributes the grounding, reducing overall inductance and thereby improving the ground connection. Direct current power is applied to the output terminal through an external network. But more on that shortly.

The package for the MAR-X device is shown in Figure 13.2. Although an IC, the device looks very much like a small UHF/microwave transistor. The body is made of plastic and the leads are wide metal strips (rather than wire) to reduce the stray inductance that narrower wire leads would exhibit. These devices are small enough that handling can be difficult; I found that hand forceps (tweezers) were necessary to position the device on a prototype printed circuit board. A magnifying glass or jeweler's eye loupe is not out of order for those with poor close-in eyesight. A color dot and a beveled tip on one lead are the keys that identify pin 1 (the RF input connection). When viewed from above, pin numbering (1, 2, 3, 4) proceeds counterclockwise from the keyed pin.

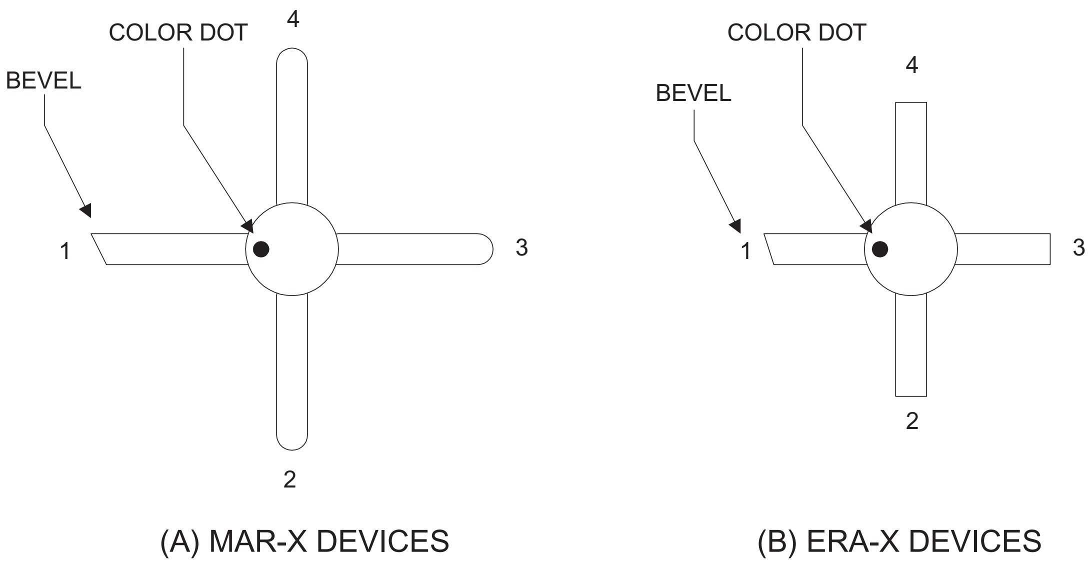

Fig. 13.2 *MAR-X and ERA-X device packages.*

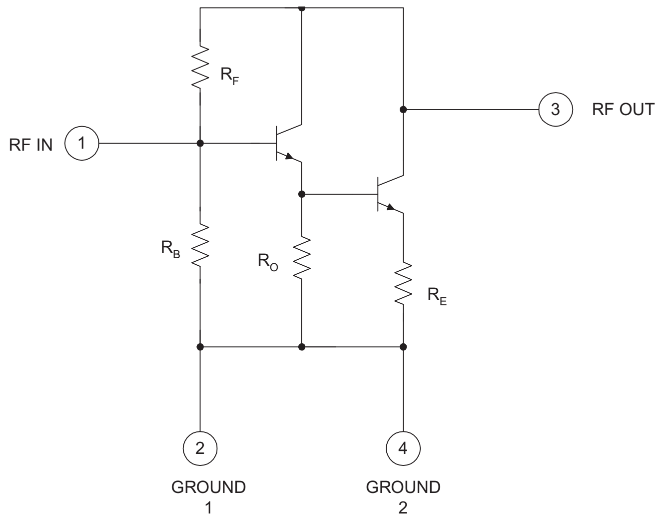

Fig. 13.3
MAR-X internal circuitry.

INTERNAL CIRCUITRY

The MAR-X series of devices inherently matches 50 Ω input and output impedances without external impedance transformation circuitry, making it an excellent choice for general RF applications. Figure 13.3 shows the internal circuitry for the MAR-X devices. These devices are silicon bipolar monolithic ICs in a two-transistor Darlington amplifier configuration. Because of the Darlington connection, the MAR-X devices act like transistors with very high gain. Because the transistors are biased internal to the MAR-X package, the overall gains typically are 13–33 dB, depending on the device selected and operating frequency. No external bias or emitter bias resistors are needed, although a collector load resistor to V+ is used.

The good match to 50 Ω for both input and output impedances (*R*), from the circuit configuration, is approximately

$$R = \sqrt{R_F R_E} \tag{13.1}$$

If R_F is about 500 Ω and R_E is about 5 Ω, then the square root of their product is the desired 50 Ω.

BASIC CIRCUIT

The basic circuit for a wideband amplifier project based on the MAR-X device is shown in Figure 13.4. The RF in and RF out terminals are protected by DC blocking capacitors *C*1 and *C*2. For VLF and MW applications, use 0.01 µF disk ceramic capacitors, and for HF through the lower VHF (≤100 MHz) use 0.001 µF disk ceramic capacitors. But, if the project must work well into the high-VHF through low-microwave region (>100–1000 MHz or so), then opt for 0.001 µF (1000 pF) “chip” capacitors. If there is no requirement for lower frequencies, then chip capacitors in the 33–100 pF range can be used.

The capacitors for *C*1 and *C*2 should be chip capacitors in all but low-frequency (<100 MHz) circuits. Chip capacitors can be a bit bothersome to use, but their use pays ever greater dividends as operating frequency increases.

Capacitor *C*3 is used for two purposes. It prevents signals from *A*1 from being coupled to the DC power supply and from there to other circuits. It also prevents higher-frequency signals and noise spikes from outside sources affecting the amplifier circuit. In some cases, a 0.001 µF chip capacitor is used at *C*3, but for the most part, a 0.01 µF disk ceramic capacitor suffices.

The other capacitor at the DC power supply is a 1 µF tantalum electrolytic, which decouples low-frequency signals and smoothes out short-duration fluctuations in the DC supply voltage. Values higher than 1 µF may be