Controlled-Q RF Technology-
What It Means, How It's Done

The difficult transfer of high frequency energy from a signal source to the control element of an RF power transistor is efficiently achieved by a new design philosophy. Both monolithic and hybrid IC techniques are used to include a matching network in the transistor package and overcome this tough design problem.

The insertion of a matching network into an RF power transistor package has cured many evils encountered in high frequency circuit design. Devices using such an internal impedance matching network have been dubbed Controlled Q because that is exactly what the added package circuitry does — it gives the power transistor a consistent and highly controlled electrical quality (Q) factor. In a nutshell controlled Q increases guaranteed gains from previously available 4 dB to 5 or 6 dB in the 470 MHz region at 12.5 V. The controlled Q means that these devices are easier to match into circuit networks, and offer better consistency of high frequency parameters than other, non-controlled Q RF power devices.

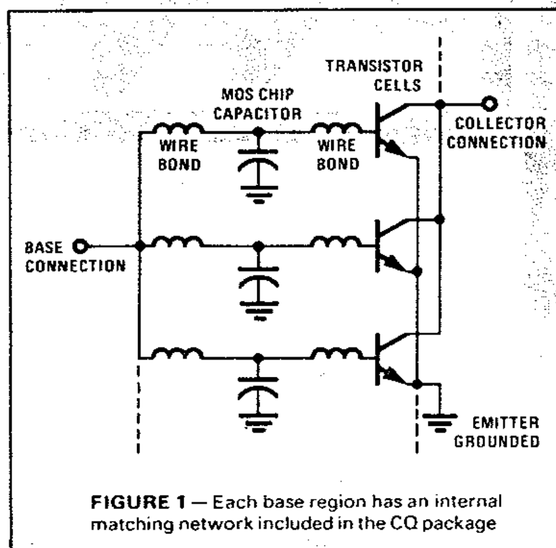

FIGURE 1 — Each base region has an internal matching network included in the CQ package

The Old and the New

There are no panaceas for the complexities of broadband RF circuit design. With or without controlled Q, circuit networks must be designed to impedance-match the different stages. Gain and power output has to be optimized for the particular application, while maintaining a specified overall circuit bandwidth.

With older RF power devices, such as the 2N6136, a complete interstage matching network had to be provided using discrete passive components external to the transistor package. Not only did the circuit take up a lot of space, but its overall series component reactance limited design capability — especially in bandwidth. In addition, parasitic elements caused by the extra components, and package geometries interfered with establishing a solid signal ground.

With newer controlled Q devices, "inside-the-package" construction of some of the network matching elements brings the network closer to the active transistor die. Not only does this eliminate the number of required external components, but it also means that a small amount of capacitance can minimize the imaginary part of the input impedance for maximum bandwidth. Internal construction techniques help establish a better signal ground by removing most parasitic reactance.

A Closer Look

Controlled Q transistors use both monolithic and hybrid techniques in their construction. The active transistor die is fabricated using monolithic integrated circuit methods. A small MOS chip capacitor is wire bonded to the active transistor die thus incorporating hybrid technology. The

resulting total transistor package can be thought of as an active transmission line element for high frequency (to 500 MHz) amplifier design. Figure 1 shows a portion of the device circuit.

To meet the high power handling requirements the controlled Q transistors are specially constructed with each of its multiple emitters having its own ballast resistor. These nichrome (NiCr) resistors, shown in the close-up of Figure 2, have different resistance values to compensate for thermal differences of various portions of the transistor chip. This prevents overloading of some emitters due to temperature difference. This Isothermal* resistor design technique assures balanced current distribution throughout the transistor for more consistent operation at various power levels.

Emitter inductance and its undesirable gain reducing negative feedback are minimized in controlled Q devices, by establishing a solid ground for the transistor emitters. This is accomplished by using the lead frame to extend the ground plane completely around the device. Emitter wires are then attached to this ground plane. Such an emitter bonding technique has been shown to contribute more than 50% of the gain increase of a controlled Q device in the 470 MHz region. Its total gain of 5.22 dB is significantly higher than a non-CQ device of the same 25 W version that gives around 4.0 dB gain.

Controlled Q transistors also have bonding wires extending from each transistor base region to the MOS capacitor chip and then out to the package base lead. These bonding wires and the MOS capacitor interconnect one half of an input impedance matching network as in Figure 3.

*Trademark of Motorola Inc.

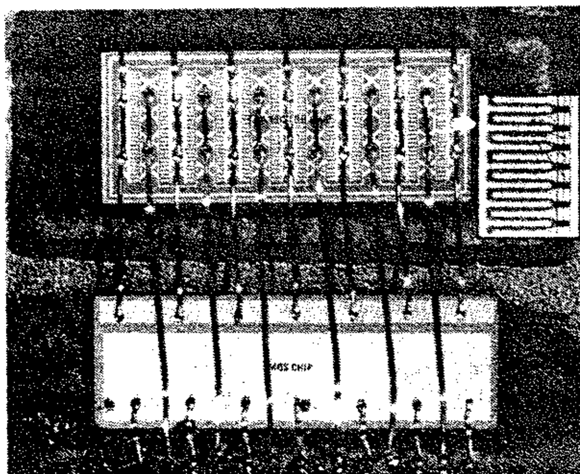

FIGURE 2 — A close-up view of the emitter ballasting resistors

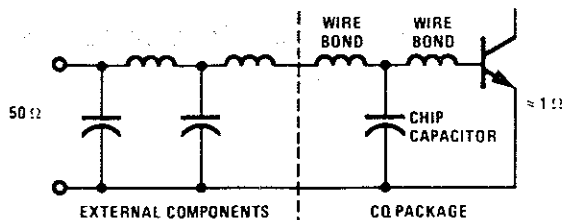

FIGURE 3 — Part of the transmission network inductance and capacitance is provided in CQ transistor packages.

Controlled Q production methods not only increase device yield, but also allow all final factory testing to be done in fixed-tuned test equipment. This means ease of final test for the semiconductor manufacturer, but more importantly, insures the consistency of controlled Q transistors from device to device. To the RF equipment manufacturer, this means that once a piece of communications gear has been designed, controlled Q devices can be dropped into amplifier modules with a minimum of circuit adjustment and tuning.

What's Available

Motorola's MRF series of high frequency power devices are available in stripline opposed emitter packages which offer excellent thermal characteristics along with controlled Q operation. Available in both 12.5 V and 28 V devices, these transistors listed in Table I are capable of operating at frequencies to 900 MHz with power outputs to 50 watts.

TABLE I — Controlled Q RF Power Transistors

Device	Operation Voltage	Output Power	Frequency	Comment
MFR243 MRF245	12.5 V	60 W 80 W	to 175 MHz	For VHF Large Signal Application
MRF 316 MRF317	28 V	80 W 100 W	to 200 MHz	For VHF MIL Aircraft and Mobile Operation
MRF641 MRF644 MRF646 MRF648	12.5 V	15 W 25 W 40 W 60 W	to 512 MHz	For UHF FM Mobile Applications
MRF321 MRF323 MRF325 MRF326 2N6439 MRF327	28 V	10 W 20 W 30 W 40 W 60 W 80 W	to 500 MHz	For 225-400 MHz Aircraft and Mobile Operation
MRF840 MRF842 MRF844** MRF846**		7 W 20 W 30 W 40 W	to 900 MHz	For 900 MHz Land Mobile

**To Be Introduced