QRV July, 2000

As I'm writing this month's column, I'm riding in the back seat of a BMW on the German Autobahn, cruising along at about 200kilometers per hour. What's that got to do with QRP? Well, the "I" in ARCI reminds me that we are an *international* group, and that no matter where I go in the world, I've got my QRP friends. Although this business trip is way, way too short (I've been here two days and have to go home tomorrow), I have thoroughly enjoyed being here and the welcome that I have received. I look forward to coming back, meeting a few German ARCI members and maybe even operating as a /DL.

In the past month, I've had a blast, operating at QRPp (<1W power) in the "QRP To The Field," May "Spartan Sprint" and the Knightlights' "SMiTe Hunt." In these friendly contests, I used 2 different QRPp kit rigs, the Knightlights' SMiTe and the Norcal SMK-1, each running about 300mW. Both rigs use Surface Mount Technology (SMT), difficult, but incredibly fun, to build. I don't recommend either for the first time kit builder, but SMT is definitely within the capabilities of the reasonably experienced builder. For those of you that are just getting into construction, try a few other projects first, but don't be intimidated by SMT. All it really takes is a reasonably steady hand, a fine soldering iron, fine solder, a magnifying lens (with built-in light is helpful) and a lot of patience!

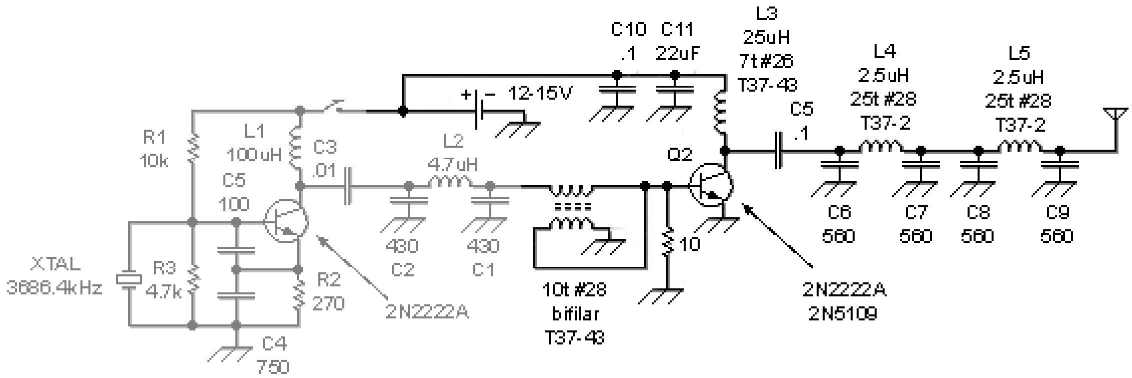
At about 300mW, on 40 and 80 meters, I've worked 8 different states (GA, AL, SC, NC, KY, LA, and WI), and achieved 100 miles per watt several times. In the last column, I talked about the NOGAnaut transmitter, which will put out anywhere from about 30 mW up to about 220 mW or so (depending on the power supply voltage). My favorite was the 2xQRP QSO with Jim, N5IB, between Smyrna, GA, and Baton Rouge, LA, that resulted in 229 reports from both stations. At the time, I was running 13.8V into my SMiTe , and measured about 360mW out. There was a lot of noise and static on the band that night, and given that the QRN tends to increase on the lower bands in the summer months, it might be difficult making a DX QSO using the NOGAnaut, at least for the next few months.

Which brings me to the topic of this month's column—amplifiers. Amplifiers are at the core of just about everything we build in amateur radio. As I showed last time, even the basic oscillator is made using an amplifier. And as Doug DeMaw said, they are so easy to build that there's really no reason to build a transmitter with just an oscillator.

Bipolar transistors have the interesting property that when a small amount of current flows between the base and the emitter, a large amount of current flows between the collector and the emitter. The condition where a small amount of current flows between base and emitter is called *forward bias*. We can *amplify* a signal, by applying it to the base of the transistor. A small variation in the base current (that is, the bias, plus the *signal*) will cause a larger variable current to flow through the collector and emitter and through the load, causing a *gain* in the signal power (current times potential).

Most amplifier design is related to controlling the base-emitter and collector-emitter currents, by establishing the proper amount of forward bias. Remember from Ohm's Law that a certain potential (measured in Volts) will cause a certain current (measured in Amperes) to flow through a certain resistance (measured in Ohms). Ohm's Law becomes very important in establishing the forward bias of an amplifier.

The schematic below shows a simple "class C" amplifier for the NOGAnaut transmitter. Initially, I built this circuit using the same 2N2222A transistor as I used in the original NOGAnaut. I tried several different transistors, but decided finally to use the 2N5109, which is a relative inexpensive transistor, generally available, and rated at up to 2.5 Watts output. Using this transistor, I managed to amplify my 220 mW NOGAnaut signal to 720mW, or about 10 dB (dB gain = 20*log(power1/power2)). Now that will really punch through the QRM!



NOGAnaut Transmitter NOGAboots Power Amplifier

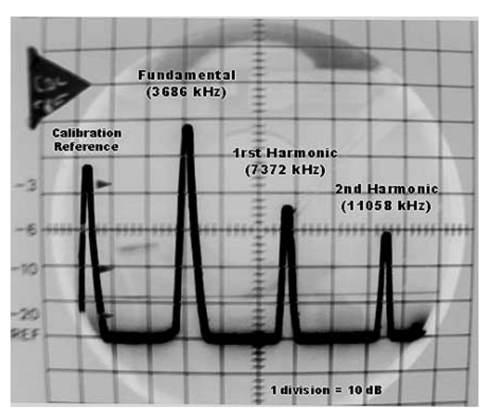
Here's how the circuit works. The input impedance of transistor Q2 is about 10-12 Ohms. The output impedance of the NOGAnaut pi filter is about 50 Ohms. Merely connecting the output of the NOGAnaut to the input of the amplifier would be a very bad impedance mismatch, and would cause significant degradation of the signal as it flowed between the two circuits. The transformer is used to make a 4:1 impedance match between the two circuits. 50 Ohms divided by 4 is 12.5 Ohms, so this establishes a much better match. This transformer is described in many construction books, sometimes being a called a "transmission line transformer" because the twisted wire actually behaves like a transmission line (you can measure the characteristic impedance of twisted pair wire just like you can coax), significantly shortened electrically by the permeability of the toroid.

The 10 Ohm resistor helps to "tame the beast"—that is it lowers the "Q" of the transistor base circuit, and helps reduce the potential for feedback causing the amplifier to oscillate (see last column on oscillators). L3, C10 and C11 help prevent oscillations as well, shunting any RF coming in from the power supply to ground or choking it with the RFC (L3).

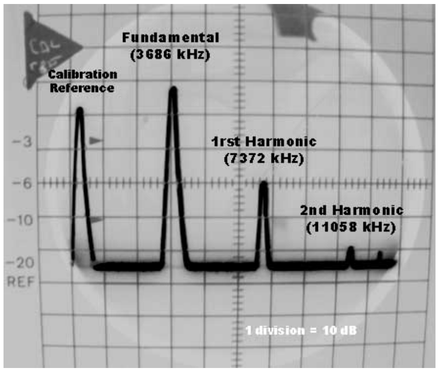
When a signal is applied to the base of Q2, through the matching transformer, it has a positive voltage, going from 0 to peak and back to 0, for half of the signal's cycle. This positive voltage causes a forward bias current to flow through the base-emitter resistance (there is a small resistance between base and emitter in every transistor), which in turn causes a larger current to flow between the collector and the emitter. Since this current must vary with the rise and fall of the bias, and since the current being supplied from the power supply doesn't change (there is a slight DC resistance from L3), the changing current must be supplied through capacitor C5.

The changing current through C5 appears at the output of the amplifier as a signal. It is important to note that this signal *is not* an exact replica of the input signal, since during part of the cycle, the input signal is negative and forward bias does not exist. This amplifier is not a *linear* amplifier. This means that it cannot be used for SSB and AM signals, because these signals would be distorted. For these cases, where the output signal must be an amplified replica of the input, a linear amplifier ("Class A" or "AB") must be used. However, Class C amplifiers work quite nicely for CW and FM signals, and can be extremely efficient.

The filter formed by C7 through C9, L4 and L5 is very important in this circuit. They form two pi filter sections and are necessary to ensure that the amplifier meets FCC "spectral purity" requirements. As I said in the last column, the simple pi filter in the NOGAnaut does not adequately attenuate its harmonics. Take a look at the next photo, taken of a spectrum analyzer looking at the output of the NOGAnaut with just the pi filter.



The spectrum analyzer effectively measures the level of the various components of the output signal. The horizontal axis represents frequency, increasing from left to right. The vertical axis represents signal strength, with a 10dB change per horizontal line. What this means is that the second harmonic is about 20dB lower than the fundamental. If your NOGAnaut is running at 200mW on 3686KHz, you're also transmitting a 20milliWatt signal on 7372KHz. Given that the 40M record is 452 miles at 221 *microWatts* (AA4XX-KA3WTF, 12/26/95), this could really be a problem! If this signal were amplified, you could be in real trouble (well, OK, your signal might not make that much difference against Radio Canada International at 7.3MHz, but *technically*, you are out of compliance with FCC regulations).



The NOGAboots Power Amplifier output filter is actually two pi filters, back-to-back. Notice that C6 and C7 could be replaced with a single 1120pF capacitor. Typically, this circuit is shown with a 1200pF capacitor (good enough, especially with 10% tolerance capacitors). In this circuit, I used two 560pF capacitors, because (1) they are easy to get and (2) it shows how the three-pole filter is actually just two half-wave pi filters. Now, however, the second harmonic is nearly 30dB down from the fundamental, as required by the FCC, and the third harmonic is nearly 50dB down! No more interference with Radio Canada International!

In the next issue, I'll talk about how transistors can be used as switches, and build a keying switch for the NOGAnaut (so that you can use your keyer with the transmitter). Finally, we'll put the transmitter into a case so that it looks nice, and then you'll be QRV—just in time for 80M to quiet back down for the winter.

72 de Mike, KO4WX