MMIC Preamp for "DC to Daylight"

*Edited from an original article in **QST November 1997**, by William A. Parmley, KR8L.*

DO YOU NEED a pre-amp for 28MHz, or maybe 432MHz? This one covers both bands -and then some.

I have heard it said that "The future is *up*, in direction and frequency". Those of use who are active in the amateur satellite program certainly agree with the "direction" part of this statement. Given the steady progress of commercial communication services into the gigahertz bands, it would be difficult for anyone to argue with the "frequency" part. If, like me, you have a growing curiosity about the higher frequencies and perhaps a desire to operate there someday, I have a little project that you may want to try. Besides learning about the construction techniques that are used in the microwave region (at and beyond 1GHz), you will end up with a neat little "dc to daylight" pre-amplifier that will have many uses around your shack, not the least of which is monitoring the downlinks from amateur radio satellites.

The subject of this article is a preamplifier that I recently built using the MAR-6 Monolithic Microwave Integrated Circuit (MMIC) manufactured by Mini-Circuits Labs [1]. The MAR-6 is a four terminal, Surface Mount Device (SMD) with an operating frequency range of DC to 2000MHz (2GHz), a noise figure of 3dB, a gain of up to 20dB, and input and output impedances of 50Ω. The most amazing feature of MMIC devices like the MAR-6 is that of the four terminals, two are for ground, and only three or four external components are required to make them work! The basic concept for the pre-amplifier and the construction techniques that I used to build it were gleaned from *The ARRL UHF/Microwave Experimenter's Manual* [2]. The parts and PCB material in this project are readily available from sources such as Ocean State Electronics [3]

CIRCUIT DESCRIPTION

YOUR FIRST REACTION to a four-terminal device with two grounds may be something like this: "Let's see, ground, ground, signal in, signal out . . . Hey! Where does V_{cc} go?" Take a look at **Fig 1**, which is the schematic for the preamplifier. C1 and C2 are simply dc blocking capacitors. V_{cc} connects to the device through the output lead via a resistor and RF choke (R1 and L1). The only other components are the bypass capacitors on the V_{cc} lead.

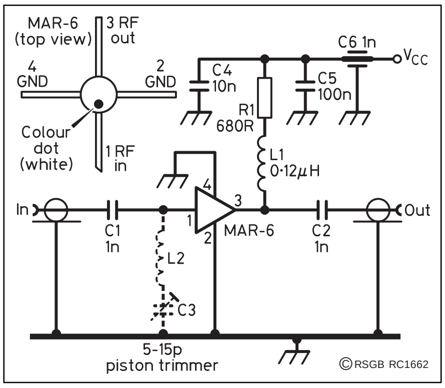

Fig 1: The DC to daylight Preamp. The dotted components are only employed if the preamp is being de-sensitised by a nearby transmitter.

Let's take a look at each of the components and discuss how I selected the values.

C1 and C2 should present a low impedance at the lowest signal frequency of interest. For example, I originally constructed my preamplifier for use at 432MHz, which is a downlink frequency for many amateur satellites. So, I selected a couple of 220 pF disc ceramic capacitors (X_c = 1.6Ω at 435MHz) from my junk box. I subsequently decided to use the preamplifier at 29MHz for downlink signals from Russians RS-series satellites. So I replaced C1 and C2 with 1nF disc ceramic capacitors (X_c = 5.5Ω at 29MHz).

The power supply voltage determines R1's value. The MAR-6 draws about 16mA, and needs a V_{cc} of about 3.5V. Use Ohm's Law to calculate the necessary voltage drop from your power supply, down to 3.5V. The power supply I use provides about 14.6V, so I ended up with a 680Ω, ½W resistor. It's tempting to use a 3.5V power supply and omit R1. Don't! R1 isolates the power supply from the MMIC output. Since the MMIC output impedance is 50Ω, R1's resistance should be considerably greater than 50Ω. L1 is listed as optional on the data sheet; it helps isolate the MMIC and power supply. The recommended combined impedance of L1 and R1 is at least 500Ω. I selected a value of about 0.12mH for L1 (X_L = 328Ω at 435MHz). The inductor is 8 turns of 28SWG enamelled wire around the shank of a 3/16 inch drill bit, spaced for a total length of 0.3 inches. (Remove the drill bit, or course; it's only a winding mandrel!) I left this value of L1 in place even though eventually I decided to use the preamplifier at lower frequencies.

The remaining three essential parts are bypass capacitors. Because capacitors have self-resonant frequencies (resulting from unavoidable inductances in the devices and their leads), it is a common practice to use capacitors of several different values. My design uses a 1nF feedthrough capacitor that passes through the circuit board ground plane. The 10nF and 100nF capacitors (C4 and C5) are disc ceramics. L2 and C3 are optional components that are describe under the title, "Preventing Desensitisation".

CIRCUIT CONSTRUCTION

IT IS CERTAINLY possible to build this circuit using conventional construction techniques, even "dead bug" style. Such a circuit might perform satisfactorily up through the 432MHz band. However, since one of the reasons for undertaking this project was to study and practice microwave construction techniques, that is the approach I used and will describe here. I'll explain what I did and why I did it. For a deeper understanding, you may want to study *The ARRL UHF/Microwave Experimenter's Manual.*

Fig 2 shows the circuit-board layout. The material is a double-sided, glass-epoxy board with a thickness of 0.0625 inches, known as FR-4 or G-10. This is the least expensive board material suited for microwave use. (The board I used is a product of GC Electronics in Rockford, Illinois). Notice that most of the top of the board, and all the bottom of the board, serve as circuit ground.

The signal-conducting part of the circuit is a 'microstrip'. (That is a strip-type transmission line: a conductor above or between extended conducting surfaces. - Ed). The line width, board thickness and board dielectric constant determine the microstrip's characteristic impedance. A 0.1-inch-wide line and the ground plane on 0.0625-inch-thick G-10 form a 50Ω transmission line, which matches the MMIC's input and output impedance.

I fabricated my board by laying-out the traces with a machinist's rule. Then I cut through the copper foil with a knife and lifted off the unwanted copper areas while heating them with a 100W soldering gun. You could etch the board if you prefer, or use any other method you like. The single mounting pad was "etched"

4540 S.Ammon Rd, Idaho Falls, Idaho 83406, USA.
e-mail kr8l@amsat.org.

by grinding away the copper around it with a hand-held grinder.

The MMIC is tiny. Connect it to the traces with the shortest possible distances between the traces and the body. (I managed to achieve about 0.03 inch). Also, the device leads are very delicate; if possible, do not bend them at all. To fit the MMIC leads flat on the PC-board traces without bending, I ground a small depression in the board dielectric for the MMIC body. Alternatively you could drill a hole completely through the board, but I believe my method provides better mechanical support for the device. Remember that the coloured dot (white on the MAR-6) on the body marks pin 1, which is the input lead.

Mount the blocking capacitors as close to the board as possible. To do this, I cut the capacitor leads to about 1/16 inch long. Then I tinned both the capacitor leads and the circuit traces and soldered the capacitors in place. This method of mounting minimises lead inductances.

Because I intend to use my preamplifier at UHF, I installed N connectors. To achieve a zero lead length, I notched the ends of my board to suit the profile of the connectors, then installed the connectors directly onto the board. I laid the centre pin on top of the microstrip and soldered it, then soldered the connector body to the ground foil in four places (two on the top of the board and two on the bottom). An alternative very good technique for fitting the connectors is to drill a hole in the microstrip and insert the centre pin from the bottom of the board. The centre pin is then soldered to the microstrip and the body soldered to the ground foil or mounted with machine screws. (If you do this, be sure to remove a little foil from around the hole on the bottom of the voard, so the centre pin doesn't short to ground). The latter approach is much better if you want to mount the preamplifier into a box, as you can mount the board on the inside of the lid with the connectors projecting through.

It is important that all portions of the ground foil be at equal potential, particularly near the MMIC and the board edges. To achieve this, I wrapped the long edges of the board with pieces of thin brass and soldered them on both top and bottom. I also drilled two small holes on either side of each MMIC ground lead, installed a small 'Z wire' in each hole and soldered them to each side of the board. (A 'Z wire' is a short, small-gauge, solid copper wire, bent at 90°, inserted through the hole and then bent at 90° again).

I mounted inductor L1 for minimum lead length. One lead connects to the microstrip and the other to the square pad. The resistor connects from the pad to the feedthrough capacitor, and the other two bypass capacitors connect from the feed-through to the ground foil.

HOOKUP AND OPERATION

FOR THE BASIC pre-amplifier design there is nothing to align or adjust. Simply connect it between your antenna and receiver, then apply power. If you connect the pre-amp to a transceiver, take precautions to prevent transmitting through it! I think you will find this pre-amplifier very handy for many uses: adding gain to an older 28MHz receiver or scanner, boosting signal-generator output, or for casual monitoring of the amateur radio satellites on 29, 144 and 432MHz. I leave the choice of cabinetry up to you. A commercial metal box, home-made printed circuit board or thin sheetmetal boxes are suitable.

Armed with the experience gained from this project, a copy of *The ARRL UHF/Microwave Experimenter's Manual* and perhaps a copy of *The ARRL UHF/Microwave Projects Manual* [4], you will be ready to continue your journey to 1GHz and beyond.

PREVENTING DESENSITISATION

THE ORIGINAL GOALS for this project were very modest: (1) develop a simple, low cost pre-amplifier that could be easily constructed for anyone interested in casual monitoring of amateur radio satellites using simple antennas; and (2) educate myself and others in circuit construction techniques for 1GHz and beyond.

I fully anticipated that this simple pre-amplifier would not function in the presence of my 100W, 144MHz uplink signal for Mode A and Mode J satellites. I also realised that the Noise Figure of 3dB is far from optimum, but I assumed that it would not be a problem at 28MHz, where natural and man-made noise is fairly strong. It would also be acceptable at 432MHz, because the FO-20, FO-29 and AO-27 downlinks are relatively strong and I only have 35ft of Flexi 4XL coax between my antenna and rig.

A quick test of the pre-amplifier on RS-15's 29MHz downlink confirmed very good receive performance. I was pleased to find that my uplink signal did not effect it, probably because there is about 40ft between my 144 and 28MHz antennas.

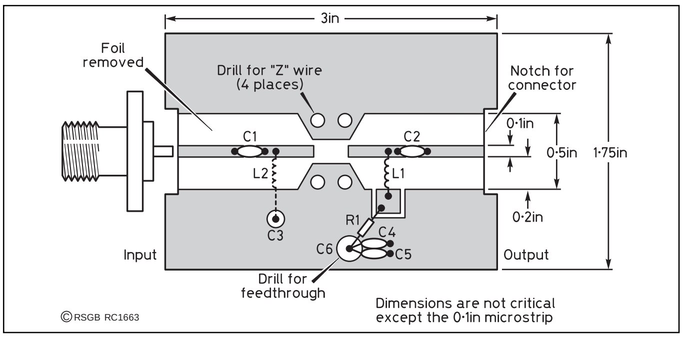

Fig 2: Physical layout (on double sided PCB). Note the location of the holes for the 'Z wires', which are used to link the upper and lower ground planes together.

The situation on Mode J was quite different, however. My 144 and 432MHz antennas are only about 8ft apart, and the 144MHz signal completely blocked the pre-amplifier, just as I anticipated. Out of curiosity, one evening I installed a series-resonant circuit (L2 and C3 on the schematic) on the pre-amplifier's input. I drilled a hole in the board and mounted a 5-15 pF piston trimmer capacitor, then wound another inductor identical to L1. I installed these parts on the board and connected the amplifier between my 432MHz antenna and my rig. To adjust the tuned circuit, I used the local oscillator of my scanner to generate a signal on 435.850MHz. This signal registered about S5 on my S meter, and disappeared completely into the noise when I keyed my 144MHz Tx. As I tweaked the trimmer capacitor, I was pleasantly surprised to hear the receiver noise decrease and the signal from the scanner's local oscillator become audible and return to its former S5 level.

Even with this modification, I found that the pre-amplifier is not yet entirely suitable for full-duplex operation on Mode J. Some combinations of uplink and downlink frequencies are entirely clear. Others suffer from interference to varying degrees, which appears to be mixing products - probably generated in the MAR-6 - in the presence of my uplink signal. Although this use is beyond my original intent for this pre-amplifier, I plan to continue experimenting with additional filters to see if I can make the pre-amp usable for full-duplex operation. The series tuned circuit makes the pre-amplifier unusable for AO-10's Mode-B 2metre downlink. In my case this is not a problem, since I already have a commercial preamplifier for that band.

NOTES

[1] Mini-Circuits Laboratory, PO Box 350166, Brooklyn, NY 11235-0003. Data sheets for the MAR-6 and countless other MCL products are available at http://www.mini-circuits.com.

[2] The ARRL UHF/Microwave Experimenter's Manual (Newington: ARRL, 1990) is ARRL order No 3126. ARRL publications are available from your local ARRL dealer or directly from ARRL. Mail orders to Pub Sales Dept, ARRL, 225 Main St, Newington, CT 06111-1494. You can call us toll-free at 1-800-277-5289; fax your order to 860-594-0303; or send e-mail to pubsales@arrl.org. Check out the full ARRL publications line on the World Wide Web at http://www.arrl.org/catalog.

[3] Ocean State Electronics, PO Box 1458, Westerly, RI 02891l; information 401-596-3080, orders 800-866-6626.

[4] The ARRL UHF/Microwave Projects Manual (Newington: ARRL, 1994-96) is ARRL Order No 4491. See Note 2 for purchasing information. ♦