The RF Deck

Gordon Anderson

November 2, 2001

The RF Deck is the most complex electronics design challenge in the development of a RC transmitter. Even if you decide to build a crystal controlled RF deck it will be a challenge to find crystals in small quantities at the frequencies you will need. The synthesized RF deck I designed for the MicroStar takes advantage of the phase lock loop (PLL) technology developed to support the cell phone explosion. I will assume for this discussion that you have a schematic and I will be referring to component designators through out this paper. When ordering parts it is a good idea to get a few extra capacitors for the purpose of tuning. I can't predict the output tuning circuit without knowing the details of each installation. Please note that C17 and C18 are actually two capacitors in each case, a 100pF and 47pF in parallel. They are soldered on top of each other.

Narrow band!

What is narrow band? It means that 20 KHz off center frequency the signals from the RF deck must be 55 dB down measured with a spectrum analyzer using a 3KHz resolution bandwidth. This is not a simple task! This RF deck design meets these requirements.

This RF deck has the following features:

- AM or FM operation.
- RF ON/Lock LED.
- 53Mhz or 50Mhz options (only requires different tuning).
- 72MHz is technically possible but not FCC type approved.
- Positive or Negative shift selectable.
- All parts available from common suppliers. All but the J-FET is available from Mouser and DigiKey.

This RF deck can be built in two forms, standalone, or for connection to a MicroStar encoder. The PLL (a national semiconductor LMX2306) is a programmable device, the counters and modes of the PLL must be configured on power up. In the standalone mode a small PIC microcontroller is used to read the position of BCD switches and configure the RF deck. In the encoder mode the MicroStar encoder will configure the RF deck when the system is started. This is a powerful feature of the MicroStar, in this mode you can configure different aircraft with different channels and you can start the transmitter with the RF off.

The RF deck consists of the following major sections:

Modulation Integrator

> This section, consisting of T1 and IC1 plus the necessary discreet components, takes the incoming digital levels and transforms the square modulation pulses into a trapezoidal waveform. This is necessary to achieve the 20KHz narrow band

operation. This can be done a number of ways and as simply as using a single transistor, I decided to use a op-amp integrator.

VCO

The VCO is a voltage-controlled oscillator. This is made up of T6 and the related discreet components. This is a Colpitts type oscillator and D2 is a voltage variable capacitance diode, this diode allows the PLL to control the VCOs frequency. D2 has a small capacitance and thus a small tuning range on the VCO. This helps to minimize the non-linear effects of the RF signal on the diode junction.

PLL

The phase lock loop (PLL) is the heart of this design, I use a National Semiconductor LMX2306. The PLL uses a reference oscillator to develop a control voltage that is sent to the VCO. An array of programmable dividers in the PLL allows virtually any frequency to be generated, or synthesized. The PLL's dividers must be configured every time the power is applied. This can be done using a dedicated controller or by connection to the MicroStar encoder.

Reference oscillator

The reference oscillator is used by the PLL to control the frequency of the VCO and to give the VCO the same stability of the reference. I use a crystal controlled voltage variable oscillator as a reference. The control voltage can only change the frequency a small amount. This voltage control input is the modulation signal from the encoder, after shaping by the modulation integrator. Pots are provided to adjust the center frequency and the modulation depth.

Power amplifier

The power amplifier amplifies the signal from the VCO, after it is buffered by T7 and T8. The signal is amplified and impedance matched to the antenna by the dual PI matching network consisting of L3, L4, C17, C18, and C19. The final amplifier, T5, is driven by T4, T4's power can be controlled in AM mode and the PLL can turn this stage off if the PLL is not in a lock condition. T9 and T2 are the lock detect and power control for the exciter stage, T4.

Control processor

If the RF deck is to be used in the standalone mode then the control processor IC3 must be programmed and installed as well as a few additional components. I will program the PIC for you, the only cost to you is the shipping. The controller processor reads the selected channel from SW1 and SW2. SW1 is the least significant digit. Channels 00 through 09 are on the 50MHz band. The 53MHz frequencies (53.1 through 53.8) are selected using channel 91 through 98. The rest of the numbers are reserved for the 72MHz band, but are not enabled due to licensing issues. If you are building a 50MHz version you can omit SW2, if it is not installed the control processor will read it as 0.

The RF deck is designed to operate using a 8 cell NiCad battery pack with a nominal voltage of 9.6 volts. An on board 5 volt regulator will provided regulated voltage to the low voltage part of the circuit. When used with the MicroStar encoder this regulator can be omitted and jumper JM3 installed. The encoder will provide the regulated 5 volts.

Fabrication of an RF deck

This is not a simple task! I expect the builder to have some skills in the electronics fabrication area. In this section I will outline the steps involved in building an RF deck. You will need the following items:

1.) A good soldering iron with a very small tip.
2.) Solder paste, what I'm talking about is flux, not the solder/flux mix that is used for surface mount fabrication.
3.) Tweezers, or small pliers
4.) Magnifying glass, very important!
5.) Very small diameter solder
6.) Some kind of de-fluxing cleaner
7.) The PCB load maps, these are the drawings that show the locations of the parts.
8.) A small variable power supply would be nice, but you can live without it.

This is just a general outline of how I built my systems, the experienced builder is free to ignore these recommendations. The component side, or top side, of the PC board is the side that has the text "GAA 2001" and "RF Deck 3.0" written in copper.

Never drill out any of the holes, the PC boards are through hole plated and drilling will destroy the board.

Before you start you must decide weather you are going to build a standalone version of the RF deck or the version used with my Encoder. If you are going to build the version using the MicroStar encoder, do not install the following components:

C3,C6,C43,C46
R40,R39,R38
RN1
SW1, SW2
IC2 (Note! Needed if you do not have a power supply for testing)
IC3
JM4

If you decide to build a standalone version of the RF Deck you will need a programmed PIC processor. There are two different PIC mircocontrollers that you can use, the PIC-16C622-04/SO-ND or the PIC-16F628-201/SO-ND. The 16C622 was specified in the original parts list and can still be used but can only be programmed one time. If you used the 16F628 it can be reprogrammed if new firmware versions are released. Rev 3.0 of the RF Deck allows the PIC to be programmed in place using the ICP module I have designed. The ICP operation with the RF Deck has net yet been tested and the ICP PC software needs to be updated. I expect to finish this work before the end of 2001.

Steps:

1.) Install all of the surface mount resistors. I like to do this first so that none of the big parts are in the way. The way I like to do this is, use a Q-tip to put a little solder paste (not much!) on the pads, then use the tweezers to hold the part in place. I then get a little molten solder on the tip of my iron and touch it to the resistor and the pad. The solder paste will make it suck the solder off the tip and wick under the part. If this is done right you will never even pickup your roll of solder!
2.) Use the same idea as in step 1, but this time install all of the surface mount caps. C48 is installed on top of R23.
3.) Install all of the surface mount transistors and diodes.
4.) Install IC4, paying attention to pin 1. This is the most difficult part to install, the lead pitch on this part is .025". Take your time and make sure you use a small soldering iron and a good magnifying glass. Inspect your solder job carefully.
5.) Install the three pots.
6.) Now install all remaining ICs, again paying attention to pin 1.
7.) Install all inductors, fixed and variable. L1, L3, L4, and L5 are in metal cans, these cans are not connected to ground on the PCB. To improve performance please install jumpers on the solder side of the PCB to at lease one of each inductors can pins to ground, for each inductor.
8.) Install the output power transistor, T5.
9.) Install all connectors and jumpers.
10.) On the solder side of the PC board are a couple of large square pads, these are designed to accept the mounting standoffs. The Standoffs specified are tin plated brass and can be soldered to the square pads on the PC board. To do this, first tin the pads then heat up and tin one end of the standoff. You may need to sand the standoff a little to clean it up. After you have the standoff hot and you have a little molten solder on it, set it on the tined pad on the PC board.
11.) Install the lock LED. Install the long lead in the round pad, this is the LED's positive lead. You should install this LED on the solder side of the PC board, this will allow you to drill a small hold in the transmitter case behind the RF deck so you can see the lock LED.
12.) If you are building the standalone version, install SW1 and SW2 on the solder side of the board. This will allow you to drill a couple of holes in the transmitter case to access the switches. These switches can only be installed on the solder side!
13.) Inspect everything using your magnifying glass.
14.) Clean the board with some kind of flux remover.

RF Deck Setup:

Weather you are building a standalone version of the RF deck or the version designed to work with my Encoder you should build the test cable shown on the RF Deck Accessories drawing. This cable will allow you to connect the RF Deck to a power supply and the parallel port on your PC. The MicroStar CD contains a National folder in the Data sheets folder. This National folder contains a setup program for National Semiconductors PLL Code Loader software. This software will allow you to test the

RF Deck. I strongly recommend you install this software and follow the test and alignment procedure given below.

A power supply is very useful for checkout but you can do the checkout using an 8 cell NiCad pack. If you do not have a power supply and intend to build a RF Deck to be used with my Encoder, I would recommend you install IC2. IC2 is the 5 volt regulator used in the standalone version. If you install this part then you will only need to apply the 8 cell battery pack to the encoder for checkout. If you have a power supply with a 5 volt and 10 volt output then you will not need IC2.

Checkout will be greatly aided by a scope, a frequency counter and a spectrum analyzer. Many of you will have access to a scope and a frequency counter, but a spectrum analyzer is a bit less likely. This alignment procedure assumes you can measure frequency, but you can checkout the RF deck without doing the center frequency adjustment.

Jumpers:

All of the jumper blocks on the RF deck are design to accept standard shorting jumpers. Each jumper's function is defined below:

JM1, Shift
: This jumper allows you to set the modulation shift for Normal (short pins 2 to 3) or Invert (short pins 1 to 2). Please install this jumper in the Normal position if you are using this with my Encoder.

JM2, Modulation
: AM or FM modulation is supported. Short pins 1 to 2 for AM and short pins 2 to 3 for FM.

JM3, Ext Vcc
: Install this jumper if IC2 is not installed and you indent to provide power from an external source through J1.

JM4, 72MHz enable
: Install this jumper if you are building a standalone version of the RF Deck and you wish to enable 72 MHz operation. This option is not supported because you would need FCC type acceptance to operate on this band. Also, several component values would need to be changed for operation on this band.

Initial Tests:

1.) Build the parallel interface between your PC's parallel printer port and the RF Deck. Please refer to the RF Deck Accessories drawing for the details on building this test cable.
2.) Install the national Instruments PLL code loader utility. You will find the install program in the \Mstar\DataSheets\National folder of the CD. This test procedure is based on the code loader utility.

3.) While monitoring the current apply power. If you are using a power supply with both 10 and 5 volt supplies, apply only the 5 volt suppy. If you are using a 8 cell NiCad battery pack, add some resistance in series with the pack (50 ohms) to limit the current. Remember, if you are using a battery pack you will need to install the 5 volt regulator on the RF deck, IC2.

4.) Setup the PLL code loader as shown on the following pages. The first test you should do is the 5 volt power test. Use a voltmeter to insure that regulated 5 volts is applied to the analog and digital circuitry on the RF deck. Next use the code loader to toggle the FoLD signal between Active High and Active Low. This should cause the red LED on the RF deck to toggle on and off. When this test passes it will indicate the connection between the PC and the PLL is correct.

5.) If you have a scope, check if XTL1 is oscillating, also check if the VCO is oscillating.

6.) Use the code loader utility to set the RF Deck frequency. Adjust L5 until the lock LED comes on. You may have to cycle power and try re-sending the configuration information from your PC.

7.) Tuning the RF deck output using L1, L3, and L4 requires some way of measuring the output of the RF deck. This can be done with a field strength meter or some kind of RF power meter. You should have the RF deck connected to an antenna or a dummy load. Adjust the inductors L2, L3, and L4 for maximum RF output. These coils will interact with one another, so you will need to repeat these adjustments until you have maximized the output RF level.

8.) You need to use a frequency counter to set the output frequency. First determine weather you are building an AM or FM version of the RF deck. The two adjustment options are given below:

AM

Install a shorting jumper between pins 1 and 2 on JM2. Set the RF deck frequency to the center of the band you are working on. Use the code loader to set the frequency and insure the lock LED is on. Measure the output frequency and adjust R29 until the frequency is correct.

FM

Install a shorting jumper between pins 2 and 3 on JM2. Make sure no modulation signal is applied to the RF deck. Install a shorting jumper between pins 2 and 3 on JM1. Set the RF deck frequency to the center of the band you are working on. Use the code loader to set the frequency and insure the lock LED is on. Measure the output frequency and adjust R29 until the frequency is correct. Now move the shorting jumper on JM1 from pins 2 and 3 to pins 1 and 2. Adjust R28 until the output frequency is 1000 Hz higher that the requested frequency. R29 and R28 will interact so you will need to repeat these adjustments until you achieve the desired results.

9.) If you built a standalone version of the RF deck you should be able to remove the test cable and apply 10 volts to the J1 and use the BCD switches to select the frequency. Test the output frequency and the lock LED to insure everything is working properly.

This will complete the initial testing of the RF deck. You should now install the RF deck in your transmitter and connect it to the encoder before final tuning and testing can be performed.

Installation:

Install the RF deck using the two 2-56 threaded standoff that were soldered to the solder side of the RF deck during the assembly phase. Install the RF deck so that the RF output connector is close to the antenna. Make sure the RF deck is connected to the transmitter case and makes good electrical contact. If you are installing in a plastic cased transmitter you should plan on making a shielded box around the RF deck.

Build a cable to connect the RF deck to the MicroStar Encoder or a cable to connect to your encoder. The RF deck expects the modulation signal to be un-shaped.

Final tuning:

Final tuning is best done using a scope, a field strength meter, and a spectrum analyzer. Use the following procedure to perform the final adjustments:

1.) Using a scope monitor the signal on JM2 pin 2. Apply the modulation signal and adjust R3 to achieve a pulse that is 300 uS wide at the base and 100 uS wide at the peak. The base may be at 0 volts or 5 volts depending on the jumper JM1.
2.) Use your field strength meter to adjust L1, L3 and L4 for maximum output RF signal.
3.) You should use a spectrum analyzer to insure that the RF deck is within specifications. Make sure to test this the emissions are 55 db down 20 KHz off center frequency (3KHz RBW). Also check the second harmonic at twice the RF decks frequency.