The Encoder
A Technical Discussion
And Fabrication Notes
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September 6, 2001

This paper will introduce the Encoder electronics from the hardware design standpoint. I will reference the component designators on the schematic and I assume you have a hardcopy of the schematic for reference.

This Encoder is designed around the MicroChip PIC17C766 micocontroller. The electronics design is very simple because most of the functions needed and IO needed are built into this chip. On the schematic the PIC is divided into three parts call IC1-A, IC1-B, and IC1-C. I did this to make it easier to draw the schematic, but this is one 84-pin PLCC part. I have socked this part so it can be removed for erasing and programming. This part has EPROM memory of 16K and 902 bytes of RAM. The airplane and system configuration memory is stored in a 2K X 8 serial EPROM, IC2. This allows 8 model configurations to be saved. A module can be plugged into J5 and allow additional model memory, the software for this is not yet developed.

J1 is the power plug; this Encoder was designed to run on an 8-cell nicad battery pack. I have added a small fuse to prevent the short circuit radio burn up problem. I would recommend using socket pins for this fuse to make it easy to replace. The Encoder has a 5-volt regulator for its logic, this supply is also sent to the RF Deck.

IC4 is a TTL to RS232 level converted that supports two serial ports. One of the ports allows you to connect the MicroStar to a host PC for setup configuration. The second RS232 port is used for the buddy box system. You do not need any additional electronics to connect to your PC, just a cable. J7 contains the RS232 lines as well as the PPM modulation signal.

Connector J6 is the interface to my sensitized RF deck and can also interface to your MP8000 RF deck. The first 3 pins contain the same signals as the 3-pin deans connector on your MP8000.

J3 is the interface to a LCD display. I used a 2 line by 16 character on glass display from Digikey. Most of the LCD displays have a very similar interface and it is easy to change the code to support other displays.

JM1 is a jumper block used to enable the sensitized RF Deck interface. Install a jumper from pin 1 to 2 for 53Mhz, and a jumper from 3 to 4 for 50MHz support.

LED1 is used as an overrun indicator, mostly for software development reasons. This LED will come on if the software does not have time to finish all its calculations before its time to output servo position data. This will not cause the system to fail, it will just use

the last set of position data. I have never seen this LED light, but I wanted a way to test for this possibility. The calculations performed are a very interesting subject and I will write this up in detail later. All of the math is done using 8, 16 and 24 bit integers. No floating-point calculations, to avoid floating point calculation, all values were first scaled up to avoid any round off or truncation errors. This is a very interesting part of the software design

LED2 is a stack overflow indicator. The PIC only has a 16 level deep stack. I monitor the stack in software and light this LED if it overflows. Again, this is a software debug function. You will see this LED light depending on how you use the radio in configuration mode. You can exit the configuration mode using the locking switch like the MP8000. If you exit in the middle of a function the system will jump back to the main loop. There is no stack reset function, so this will cause a stack overflow, no big deal I just want you to be aware of the details.

The rest of the electronics is pretty standard and I will let you ask me for more details and I'll keep this document up to date.

J2 is the interface to the pots and switches in your radio. I organized the connector pins so I could use connectors to interface each pot or switch to the Encoder. This costs a little more but its easier to work on the system. I have also sent a ground to each function. The way the MP8000 is wired is they dasy-chain one ground from switch to switch, nothing wrong with this but I wanted to wire my radio differently. I twist a pair of wires together (signal and ground) and connect them to a two pin connector and plug it into the Encoder. This allows me to move switches and trims around anyway I like. Remember I did all of this inside a Proline case, this case is smaller than the MP8000. The signals should be pretty clear but I need to explain why R24 through R31 are used. The Proline uses wheel trims, these trims use the full range of the pots, this is different that the gimbals and CH6 and CH7. These channels are like all of the channels on the MP8000, only a small fraction of the pot motion is used. R24 through R31 allow me to change the voltage range of the trim pots on my Proline. These resistors can all be reduced to very small values (100 ohms) or shorted out on a MP8000. I will need to make a small software change for the MP8000, no big deal. I have also added R41 through R44 to allow you to reduce the range of the pots used for the four main functions. Most of the time this will not be necessary and these values can be kept small, 100 ohms. R40 or R21 need to be installed, but NOT BOTH. Using R40 applies regulated 5 volts to the pots, using R21 applies battery voltage to the pots. The software is designed to support using R21. I have added this options of using regulated 5 volts to cover nonstandard radio instalation.

The Transmitter wiring diagram shows the interconnection of all components that makeup the transmitter. The Details drawing shows all of the interconnection cables needed to install the encoder in your transmitter.

Another interesting part of the software design is the user interface. There is more code involved in interfacing with the user that any other part of the system!

Fabrication of an Encoder

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 Encoder. 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.
9.) PLCC extraction tool, Radio Shack sells one of these.

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 "Encoder Rev 3.0" written in white lettering.

Never drill out any of the holes, the PC boards are through hole plated and drilling will destroy the board. The big connector, J2 is tight but if you wiggle it back and forth a bit it will go in.

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, only a few of these to do. The caps on the osc circuit are very small, you will need your magnifying glass!
3.) Install IC2 and IC4. Pay attention to pin 1, it's the square PCB pad. IC2 does not have pin 1 marked very well. The side of the chip that has pins 1 through 4 has a 45 degree bevel on the plastic case, also you can tell where pin one is by reading the part number on the chip. Place the chip in front of you with the leads running from left to right, when you orient the chip so you can read the part number, from left to right, then pin one is in the lower left corner of the chip.
4.) Install the LEDs, the long lead goes in the round pad, this is the LED's positive lead.

5.) Install the resistor SIPs, RN1 and RN2. These parts must be installed with the lead, marked by the black dot, into the square hole on the PCB.
6.) Install all of the through hole components. Pay attention to the polarity of the caps. The square holes are for the positive leads.
7.) You do not need to install SW1, this is a processor reset switch, its useful for development but not needed in the final systems. This part is listed as optional on the parts list.
8.) Install the connectors, and IC1's socket. Pay attention to pin 1, it is in the center of the top row of pins.
9.) Install the buzzer, it is polarized, the + lead goes in the square hole. The buzzer may come with a piece of tape over the hole on the top. Leave this tape on even after you wash the PC board, remove it only after its in the radio and the job is finished. I have added a jumper, JM2, to allow you to disable the buzzer. Install a shoring plug on JM2 to enable the buzzer.
10.)   You do not need to install a heat sink on IC3, but make sure the tab on the regulator does not make electrical contact with any traces on the PCB. The regulator on the parts list has an insulated body and is ideal in this application. Bend the leads down about 1/8" past where they exit from the plastic body of the regulator, make sure the flat bottom surface of the regulator is facing the PCB. I like to put a small piece of thick double sticky tape between it and the PCB, or you can use a small dot of RTV. You will want to do this after the board has been cleaned.
11.)   Inspect everything very closely, use you magnifying glass!
12.)   Clean the board with de-flux solution. I used something called Flux-Off from Chemtronics.
13.)   You need to install R15 or R39, but not both. Install R39 if you are using the on glass display (Digikey 73-1177-ND), most of the other displays will need R15 installed. I have tested with the two most popular displays. Please contact me if you have a strange display you would like supported. This is pretty easy but its not possible for me to buy one of every display. You will need to send me your encoder and display for me to test and change the software to support your custom display. The 4 line display from Earth Computer Technologies are supported and the wiring details are in another application note. They are a very good deal, and you do not need R15, R39, or R14, R14 is a spendy part, in fact the display costs less than R14.
14.)   Install R21, DO NOT INSTALL R40.
15.)   Inspect it again!

The parts list will list parts as a series of designators, like R1,R2,R3 or a range of designators, like R1-R4. R1-R4 means R1 through R4 and it represents 4 resistors. You will find the parts list contains a mix of these representations.

Pre-powerup tests:

1.) Use an ohm meter and check the input power line to make sure you do not have any shorts.

2.) You will need to build your display interface cable before you can test your system. Refer to the transmitter wiring diagram and the details diagrams for the cable details. You will also need a few test switches and cables. Here is what I use for PCB testing:
- LCD display
- Switches connected Run/Cal, Auto Trim, Preset and Option.
- Two 5K or 10K pots with connectors so you can test each channel.
3.) Prepare a power source. If you have a power supply, great! If not get 5 AA dry cells and series them up. This will give you around 7.5 volts. Put a 10 ohm resistor in series with this source to limit the current. The PCB and display will only draw about 20 milliamps and this resistor will limit the current in the case of an error!
4.) Now you need your PIC programmed. You have a couple of options. You can send it to me, I will program it and return it, or you can build the programming accessory and the program I provide to program it yourself. The advantage to programming it your self is, you can do your own upgrading and software development.

Powerup tests:

1.) Do not install the PIC yet. Connect to your power source and powerup. Monitor the current, it should only draw a few milliamps. If this is not the case then something is install backwards or you have a short.
2.) Measure the plus 5 volt supply.
3.) Measure IC4 pin 6, it should be negative about 10V
4.) Measure IC4 pin 2, it should be positive about 10V
5.) The buzzer should be off and the LEDs should be off.
6.) Power down and install the PIC in its socket. This is not easy to do! Its very difficult to get it installed straight, use your magnifying glass to make sure the pins are touching the correct socket pins and are not shorting. You will need a tool to remove the PIC from its socket, do not try and pry it out! For this discussion I'm assuming the PIC is programmed.
7.) Put a piece of tape over the buzzer, you will be glad you did this, or remove the shoring plug from JM2.
8.) Make sure the display and switches are connected, do not connect the pots!
9.) Power it up! Holding the Preset and Option buttons.
10.) If all goes well, you will hear a short beep and the display will have the signon message. If this happens hold the buttons for a few seconds and then let go. The system will enter the IO test mode and the LCD will be displaying the IO ports bits, as 1s and 0s. At this point you can test all of the switches and make sure the bits change. Do not press the Option button, if you do you will advance to the ADC testing screen. The only pot on the Encoder is for the display contrast, adjust it as you like. So, if it does not work you will need to do more testing. Here are some ideas:
- The PIC is not installed correctly, very likely!
- You have a short some where. The best thing to do is to test with an ohm meter, the connections to the display. Make sure they are correct and not shorted to one another or ground.
- Test the OSC circuit for the correct values and no shorts

- If you have a scope then look at the OSC and make sure its working IC1 pin 63, it should be 8MHz.
- Look at the control signals going to the LCD display. If they are toggling (only just after powerup) then check to see if its miswired.

11.) The display will show ports C and D on the top line in binary format with the most significant bit to the left. You can use the schematic to determine what switch is what bit. The second line displays a couple of ports that will not change. A bit is 1 when the switch is open, or not pressed. Now press the Option button to advance to the ADC testing screen. Here is the assignment of the ADC channels:

Channel	Function	Range, in hex (approximate values)		
- 0	Vpos monitor	226		
- 1	Gnd	0		
- 2	CH7	6D (Up)	346	
- 3	CH6	72 (Up)	3AA	
- 4	Aileron	39 (Left)	164	258
- 5	Elevator	31 (Up)	144	282
- 6	Rudder	3F (Left)	13D	258
- 7	Throttle	04 (Low)	23C	
- 8	Aileron trim	11 (Left)	3FC	
- 9	Elevator trim	12 (Up)	3F5	
- A	Rudder trim	11 (Left)	39B	
- B	Throttle trim	13 (Low)	3FF	
- C	+5 volt monitor	201		

Each time you press the Option button you will advance to the next channel. After the last channel you will return to the IO test screen. Channels 2 through 11 can be tested with one of your pots. A word of caution here! One end of the pot connects to ground the other to the input supply voltage. The PIC input must never exceed 5 volts or it will draw lots of current and it can be damaged! The power supply voltage will need to increase to 10 volts. After these test are complete its time to bring it up!

12.) Power it off, Press the Preset and the Auto Trim buttons and power it up, after a few seconds (the display should show the signon message) let go of the buttons. It should now be running! Now its time to configure the system and this is best done after its installed in your radio. Pressing the Preset and Auto Trim tells the system to use default model settings, the serial eprom will not yet have valid data. This will be done during configuration after the encoder is in you radio

13.) Your finished!

Its now time to install the Encoder in your radio. There are lots of ways to do this and I have provided a set of drawings for how I did this in my Proline upgrade. Please take a look at this and decide how you would like to proceed.

If you are going to do the in circuit programming option you will need to read the paper describing this and you will need to build the in circuit programmer and use my PC program.

Refer to the programming manual for radio configuration and programming!

Installing the Encoder in your radio

This is a big project! I think its more work than building the Encoder. Please spend some time thinking about the details and study my transmitter and details diagrams as well as the pictures to get an idea of how I did the install. I have no mounting holes on the Encoder, because there are lots of options. Below are a few general comments about the installation:

1.) First determine where you are going to mount the encoder and how. I used a couple of small L brackets and drilled two mounting holes in the PCB. When I did this I made the electrical contact with the case, this is important and if your mounting insulates the encoder's ground from the case, you will need to add a ground wire from the case to the encoders circuit ground.

2.) Next you need to decide if you are going to use connectors or just hardwire the encoder to the pots and switches in your radio. Actually you needed to make this decision as you are building the encoder, because if you are going to hardwire it you will not need, or want, to install J2. You will need J2 for the connectors, but you can use a right angle connector, or a straight one, it depends on the layout on your transmitter. I recommend you use connectors for at least the pots, you will likely need to make a few changes to these as you build the system. None of the connectors on the Encoder are keyed, the load maps will define pin 1, it's the square pin. I like to use different colors of heat-shrink tubing on the cable end of the connectors, I use red on pin one. It's a good idea for you to mark pin one on the encoder with a good marker.

3.) Connecting the switches and pots to the encoder, using connectors or not, can be done a couple of ways. The first radio I built used 26-gauge hook up wire that I twisted together then soldered to the pots or switches on one end and the connector on the other. I used heat shrink tubing on the connector end. I twisted these wires together using a drill, and I made different color codes for different signals. The way I wired this up is; I first connected the twisted wires to the switch or pot (two wires for a switch and 3 for a pot), and left them long enough to reach the encoder. I did not put the connectors on until all the switches and pots were routed to the encoder. I made the wires a bit longer that they needed to be and trimmed them to length after I had all of the cable routing figured out. This is a time consuming task! Another option you can consider is the way I wired the second transmitter. In this case I used multi-colored ribbon cable. I have listed the cable I used on the parts list. This option is a bit less expensive because you can buy this cable by the foot and you only need a few feet to do a transmitter. The cable I used has 25 conductors, if I wanted a pair of wires I would just strip off two of the conductors from the 25 conductor wide ribbon. This is pretty easy to do, use a pair of side cutters to separate the pair at one end, then carefully tear them apart. The rest of the process is the same. I intend to use this method from now on, it is much faster!

4.) I mentioned this earlier but I need to stress and elaborate this issue. The pots are used to tell the PIC the position of the sticks, this is done by putting ground on one end of the pot and the supply voltage on the other. The voltage on the wiper,

the center pin, of the pot sends a voltage to the ADC in the PIC. The voltage on the wiper must never be higher than 5 volts or damage to the PIC will happen. The reason the pots have the supply voltage on one end is to get the maximum voltage change on the wiper as the stick is moved. The best way to test this is to remove the PIC and, after the encoder is installed in the radio, apply power. Then measure the voltage on the PIC pin for each pot, adjust the pots position to get about 1.2 volts on the PIC pin. The pot directions are also important, make sure the voltage goes down when the sticks are moved to the left, or up, or low throttle. This has to be correct for the rest of the radio setup to proceed. If the direction is wrong on a pot, just reverse the two leads on the ends of the pot, if you reverse a pot you will need to readjust the center position. Spend some time on this step and make sure everything is correct before you proceed. When I say UP I mean up like up elevator, pulling back on the stick.

5.) Now you can test the digital inputs. The switches are connected to input ports on the encoder, each input port and a resistor pulling it up to 5 volts. The switches short this IO pin to ground. All switches act the same way, the push button switches are all normally open.

6.) After you are happy with the system tests, install the PIC (and test its alignment in the socket). Now apply power and hold Preset and Option buttons on power up to test all the digital and analog IO lines.

7.) Please refer to the programming manual for details on the setup of the encoder. The first thing you need to do is format the Sprom, when you startup the system without pressing any buttons, you should be prompted to format the Sprom, do so. Next you need to do the joy stick calibration, make sure you do not format after you do the joy stick calibration or any setup work. Formatting will erase all setup information you have entered.

If the radio you are installing the Encoder in does not support all channels or you are not going to use all of the trims, make sure you ground the unused pot wipers inputs. You can do this using shorting jumpers. For example short J2 pin 4 to pin 6 to disable the Ail Trim pot.

The Encoder silk-screened text labels J2 digital inputs with letter codes. The table below decodes these letter codes into their functions. This labeling was done to make it easier to determine witch pins to connect to witch switches!

Code	Function
A	Aileron dual rate
B	Elevator dual rate
C	Rudder dual rate
D	Preset
E	Mix 1
F	Mix 2
G	Mix 3
H	CH5
RC	Run/Cal

I	Auto Trim
OP	Option
JA	CH8 A
JC	CH8 C
K	Alt aircraft
L	Snap right
M	Snap left

That's pretty much it, now you can refer to the programming manual for more details on the features of the MicroStar. Please remember this is not a commercial product, its intended for the guy who likes to tinker a bit with RC radio equipment. Please forward bugs you find to me, I will update the PIC firmware as soon as I can. I would also like to hear about features you would like to see added to the radio. Ideas I like will be implemented as fast as I can write and debug the code. You are also welcome to change the software as you like to build your our custom radio, but please do not sell or claim this development as your own, I have lots of work invested in this project.

Encoder Display Options

There has been lots of confusion about the LCD display options for the MicroStar. In this section I will outline what needs to be done to use one of the three supported options. These options should cover most of the displays you will find.

No matter what type of display you use, you will need to build a cable that goes from J3 on the Encoder to the LCD display. Each of the displays I will discuss has a different type of connector and will require different cables to be built and different options on witch parts are installed on the Encoder.

The parts list shows three options and shows you the parts you will need for each of the display options supported.

Optrex DMC-50747NF

　　This is the display used on the original MicroStar (DigiKey 73-1177-ND. I have referred to this as the "on glass" display. That is because it is built on a piece of glass and its only 2mm thick. This display uses a SED1230 controller. Listed below are the steps you need to do in order to use this display:

　　1.) Build cable detail B shown on the cable details drawing.
　　2.) Build the on-glass display interface board.
　　3.) You will need to order items 33,34,36,44 and 49.
　　4.) Install the following parts on the encoder; R14 and R39 but do not install R15.

　　Use SED1230.HEX or SED1230P.HEX (for Proline option) to program the PIC17C766.

LCD52, LCD64

　　This is the display purchased from Allelectronics. This display uses the HD44780 controller, this is the most common control in use today. I show connection details for a similar display I bought from Allelectronics, I one I used is no longer available. The LCD52 is identical except the display has 16 pins instead of 14, to use this display just ignore the last two pins and wire it using cable detail B, the one for the LCD52. This option also supports the Mouser 628-L167200J display. Listed below are the steps you need to do in order to use this display:

　　1.) Build cable detail B (LCD52) shown on the cable details drawing.
　　2.) You will need to order items 32,35 and 36.
　　3.) Install the following parts on the encoder; R14 and R15 but do not install R39.

　　Use LCD52.HEX or LCD52P.HEX (for Proline option) to program the PIC17C766.

ECM-A1010

This is the 4 line, 12 characters per line, display purchased from Earth Computer Technologies. This is a surplus display originally used in cell phones. The astrictive thing about this display is the price, they are only 3 bucks in quantities of ten. I have a special version of code to support this display but I have not fully exploited all four lines. The details of using this display are described in the file ECMA1010.ppt, this is a PowerPoint file that defines how to modify the display for use on the MicroStar. Listed below are the steps you need to do in order to use this display:

1.) Build the cable detail shown in the PowerPoint document, ECMA1010. This document also defines how the display's cable need to be modified to fit in the connector.
2.) Install a 100K, 805 size, surface mount resistor on the display in the position show in the PowerPoint document.
3.) Do not install any of the following parts in the Encoder; R14, R15, and R39.
4.) You will need to order the following items; 36,45,46 and the display, 50. You can order from Earth Tech or I will provide them and buy in quantities high enough to get the good price.

Use ECMA1010.HEX or ECMA1010P.HEX (for Proline option) to program the PIC17C766.

Mouser 628-L167200J

The Mouser display is a 2 line by 16 character per line unit. This display uses the HD44780 controller, this is the most common control in use today. Listed below are the steps you need to do in order to use this display:

1.) Build cable detail B (LCD52) shown on the cable details drawing.
2.) You will need to order items 32,35 and 36.
3.) Install the following parts on the encoder; R14 and R15 but do not install R39.

This display has a funny pinout, so make sure and pay attention to the details drawing. This drawing shows the connection details for this display.

Use LCD52.HEX or LCD52P.HEX (for Proline option) to program the PIC17C766.

Switch ID Names

One of the new features of the MicroStar is the switch programming. You can assign most any function to any switch, with a few exceptions. For example the Option switch can't be changed. The power up options are always using the default switch options. The table below will define the switch ID to the default switch name. This default switch name is what you will find on the schematic. When you start working with the MicroStar do not mess with the switch settings, first get use to programming the radio. The switch programming is very powerful but you can confuse yourself with the feature!

Default Name	Switch ID	Type
Ail DR	SWA	ON/OFF
Ele DR	SWB	ON/OFF
Rud DR	SWC	ON/OFF
Preset	SWD	PRESS/RELEASE
Mixer 1	SWE	ON/OFF
Mixer 2	SWF	ON/OFF
Mixer 3	SWG	ON/OFF
CH5	SWH	ON/OFF
Auto Trim	SWI	PRESS/RELEASE
CH8	SWJ	A/B/C
Alt Aircraft	SWK	ON/OFF
Snap right	SWL	PRESS/RELEASE
Snap left	SWM	PRESS/RELEASE