Design and Construction Manual
for the

IMD Meter by kk7uq

Stand Alone IMD Measurements
for
PSK Modes

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About this revision:

Two resistor values were changed, to allow wider range of RF Field Strength without saturating RF amplifier. Resistor #8 was changed from 100 ohm to 47 ohm. This provides a 6 dB attenuation of the signal before the RF amplifier stage. Resistor #41 was changed from 255 ohm to 330 ohm. This increases the AGC control voltage, to ensure that the full attenuation is provided in the RF amplifier stage.

Mechanical changes were made in the assembly, to raise the 3 digit display to the level of the aluminum cover.

A new release of the cover and enclosure templates were also done, as well as the overlay used on the meter to match the changes in the cover plate. A red filter was added to cover the 3 digit display.

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1 Introduction

1.1 Intended Use - This design has been created for the amateur radio community to encourage more hams to enjoy the pleasures of the new sound card digital modes. This design is ideal for ham club construction projects and for the individual ham who likes to build his own equipment. The end result is an instrument used to measure the signal quality of BPSK and QPSK transmissions, allowing optimum setting of the audio drive level to the transceiver during operations in these modes.

1.2 Scope - This manual describes the design and assembly of an IMD Meter instrument used to monitor the quality of the transmission of data using the BPSK31 (Binary Phase Shift Keying 31 Baud) mode, the QPSK31 mode and the BPSK63 mode. Included in this manual are descriptions of the circuits used, material list, assembly procedures, and system setup and testing for the IMD Meter.

1.3 Features - This manual describes the ***IMD Meter by kk7uq***. This is a stand alone device. It picks up the locally transmitted RF signal on a small antenna built into the instrument; amplifies the signal with an AGC controlled, wide band RF amplifier; uses a diode detector to convert the received RF wave form to a continuous low frequency function; and then feeds this function to a micro controller A/D converter. The micro controller analyzes the signal wave form and provides a digital display of the equivalent IMD of the signal being transmitted.

Features of the IMD Meter are:

- Provided in kit form, all parts necessary to build the meter are provided.
- Requires an external +12.5 to +16 volt at 100 ma. power supply. (Not provided in kit). Average power required is 40 ma.
- Three digit, Red LED display used to display the equivalent IMD.
- An audio tone generator sends a Morse "H" when the IMD goes above -20db. When the signal has been adjusted and goes below -24 db, it sends a Morse "I". The "H" signal is sent once every 10 cycles. The "I" signal is sent once.
- Two LED, Green and Red, provide a summary view of Good or Bad signal quality.
- A mode control switch to select one of three modes: equivalent IMD measurement - with display of IMD on the Digit Display, and summary Red / Green LED display; Display Off - where the digit display is turned off, and audible alarms disabled; and Field Strength - measures relative field strength to aid in selecting best setting of whip antenna, and meter placement.
- Packaged in a small 4.125"w x 2.7"h x 1.55"d plastic box, with aluminum cover plate and photo quality legend overlay.
- Built in whip antenna, adjustable from 6" to 20".
- Wide band RF amplifier, AGC controlled. 50 dB max gain, AGC attenuation 0 to -40 dB.
- 20 MHz PIC micro controller and firmware does AGC level setting, A/D conversion, wave form analysis, and display control.
- Built in self test verifies operation of control panel display and mode functions.
- Stand alone device, does not require a connection to your PC for operation.
- Gives equivalent IMD reading when transmit is in Idle mode (no typing, empty buffer), or while transmitting data (typing).
- Used for BPSK31, QPSK31, and BPSK63 operating modes.
- Operates from 160 meters to 10 meters, no band select required.
- Wide dynamic range, measures signals at QRP to high power levels.
- Accurate to ± 1db of IMD for measurements -23 dB and higher. At -24 and lower, reading accuracy is from +0 to +5 db of actual - intentionally set to give conservative readings in this "good" range. Lowest reading for the meter is -34 dB. Highest reading is -10 dB.

2 What You Will Need to Build the IMD Meter

2.1 Skills - This design can be done as a home brew project that requires basic skills in electronic and mechanical assembly. To be successful at building this project, you must be able to:

- Identify basic electronic parts
- Check values of the resistors by reading color codes, or using a multi-meter
- Install the parts in a printed circuit board
- Solder parts to a printed circuit board
- Operate an electric hand drill
- Drill holes in an aluminum plate and in the enclosure using supplied templates.
- Cut and trim holes using a drill and file or a “nibbling” tool
- Cut and trim overlays and glue them onto the panel

To simplify the assembly process: templates are provided for drilling the enclosure and the cover plate; a four layer, plated through hole printed circuit board with solder mask and parts identification silk screen is provided to aid in mounting all electronic parts; printed overlays are provided for the panel and enclosure; and a complete assembly manual is provided.

2.2 Tools and Materials - You will need the following tools and materials

- Needle nose pliers
- Side cutter
- Phillips screw driver
- Small blade screw driver
- Soldering iron and good quality rosin core solder
- 1/4” electric drill, with bits of 1/16, 5/32, 3/16, 7/32, 1/4, 5/16 inch
- 1/2” counter sink drill bit
- Exacto knife with a new, pointed blade
- Electronic board cleaner
- Multi-meter
- Scissors
- Small flat file
- Nibbling tool (optional)

3 Description of Circuits

3.1 PSK31 Operation - The use of a PC sound card to modulate the audio of a SSB rig has seen explosive growth in the last few years. In particular, the PSK31 (Phase Shift Keyed, 31 Baud) has changed the nature of communications over ham radio and attracted thousands of hams to use this as their main mode of operation. PSK31 is extremely efficient of operating bandwidth use; typically requiring about 60 Hz for the signal. Signal separation of 100 Hz without interference is common practice. The nature of the PSK31 modulation system is such that it is effectively a two-tone modulation system. Because of this, good linearity must be provided throughout the audio path to prevent unwanted side bands from being created by the system. The IMD Meter is used to help set the correct audio drive level to prevent unwanted side bands.

3.1.1 Bandwidth - To realize this low bandwidth and close signal separation, some care must be taken in adjustment of the audio drive of the transmitter from the PC, and particular attention must be paid to minimizing stray signal pickup from sources such as the RF field of the transmitter, AC power lines and other sources. It is the job of the interface system to provide clean signals to the transmitter in this potentially hostile environment.

The basic concept is very straight forward. During transmit, audio output from the PC sound card is provided at the microphone (or accessory connector) of the SSB rig. The SSB rig is keyed using the PTT input to the rig. Data input from the operator is provided by the keyboard to the sound card software. The sound card software converts it to the modulation format and uses the sound card to create the modulated audio output for the SSB rig.

During receive, the audio from the SSB rig is connected to the audio input of the PC sound card, and the sound card software decodes the audio signal and provides text output on the screen.

3.1.2 Other Documents - See the website http://kk7uq.hfradio.org/index.htm for documents related to the IMD Meter.

- Operation Manual - IMD Meter by kk7uq
- Design and Construction Manual - kk7uq interface, Model II

3.2 Description of the IMD Meter - The schematic diagram for the instrument is shown in figure 3.1 below.

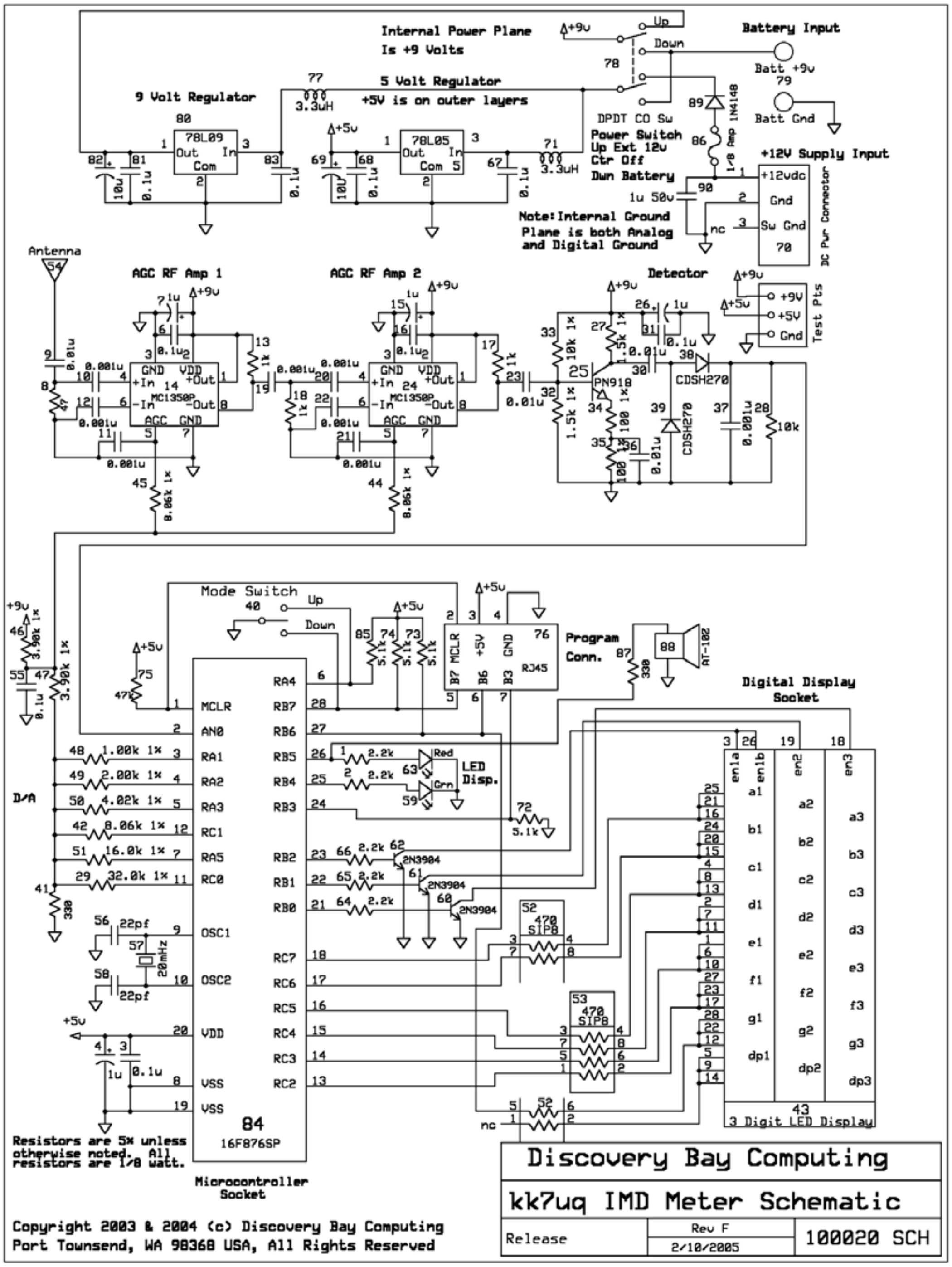


Figure 3.1 kk7uq IMD Meter Schematic Diagram

3.2.1 Power Supply Section - At the top of the page, is the power supply section of the IMD Meter. The power switch is set up to allow power to be supplied by an external 100 ma., +12.5v to +16v DC supply. Provision is made to take the power from a +9volt battery. Initial tests show that the battery drops below 9v after about 20 minutes of operation, which causes problems in the calibration of the RF amplifier section. Battery operation is considered experimental, and is not part of the specification for the kit.

Two voltages are produced by the section: +9volts, and +5volts. Three terminal regulators of the 78L09 and 78L05 are used.

The ground and the +9v is distributed to the board on the inner layers of the PCB. The 9 volt supply is controlled to be in the range of 8.9 to 9.25 volts. The +5v is distributed on the outer surface of the board.

The external connector providing +12.5 to +16 volts is a 5.5mm x 2.1 mm DC power connector. A diode and a 125 ma. pico fuse are provided in series with the +12.5 volts going to the power switch. This provides protection in case a center negative power connection is used instead of the expected center positive. The fuse provides protection to excessive current being drawn in case there is a short on the board, or a failed component.

Decoupling of RF picked up by the power cable is done with a 1 uFD ceramic capacitor in location 90, and RF chokes in location 71 and 77.

3.2.2 Wide Band RF Amplifier - The RF signal is picked up by a small extendible whip antenna. The antenna feeds a set of cascaded MC1350 AGC amplifiers. Since this is a wide band RF amplifier, no tuned circuits are used in the inter-stage design. A high pass filter (Resistor #8, Capacitor #9) is provided at the point where the antenna feeds the first stage, to reject 60 Hz signals.

The MC1350 output of the second stage is about 1 volt p-p, which is too low to feed the detector circuit and get a reasonable signal swing on the output. It is amplified in the Detector stage.

The gain of the RF Amplifiers is controlled by the signals into pin 5 (AGC). The increasing the current into pin 5, reduces the gain of the amplifier. The gain of the amplifier pair will vary from about 50 dB down to about 10 dB.

3.2.3 Detector An additional stage of amplification is provided by the circuit with the PN918 NPN transistor. This stage brings the output feeding the detector to about 2 volt p-p. The detector is done with the pair of CDSH270 diodes. These are Schottky diodes, which have similar performance to a Germanium diode, but are manufactured with modern diode techniques.

The positive going signal from the PN918 stage feeds through diode #38 to capacitor #37 and resistor #28. The capacitor stores the peak signal seen on each high frequency cycle, the resistor slowly bleeds off the signal when the input drops below the capacitor value. The values of R and C are chosen to have a decay time constant between the period of the modulation frequency (16 ms for the 62.5 Hz of PSK63) and the lowest RF frequency being modulated (0.55 µsec for 1.8 MHz). The values of 0.01 µfd and 1k give a time constant of 10 µ second Another way to think of this is that the RC components create a low pass filter with a corner frequency of about 100 kHz.

The second diode of the detector is placed there to remove the negative half of the wave form. The output of the detector should look like it is a positive half cycle of a sine wave, with a peak between 1 and 2 volts. This is the signal fed to the A/D converter of the micro controller. If the wave form being monitored is over driven, the signal will look like a sine wave that has been "flat topped".

3.2.4 AGC Control - the AGC inputs of the RF Amplifiers are fed by a D/A converter controlled by the micro controller. The six resistors 29, 42, 48 - 51 are driven from 6 bits of output of the micro controller. They are arranged such that one end of each resistor is either taken to a logic high, or a logic low. The other ends of the resistors are tied together. This forms a fairly linear D/A converter whose output goes from 0 to about 1.7 volts. Resistor 41 is tied to ground, which limits the upper limit of the D/A.

The voltage swing is scaled up to a range of about 4.65 volts, the desired value to feed into the AGC circuit. A capacitor (#55) is placed here to reduce any noise which might be present on the line. This creates a settling delay of about 2.5 msec. This is accounted for in the firmware of the micro controller.

The two resistors, #44 and #45 convert the voltage to a current of about 0.2ma to 0.1ma into the MC1350 components.

While the AGC is being adjusted, the display to the 3 digit LED display is turned off by the firmware, to remove current transients from interfering with the measurement of signals from the detector.

3.2.5 Digital Display - a three digit LED display is provided to indicate the values measured by the meter. These are seven segment displays, with decimal point. The decimal point is not used in this application.

The display is operated in a multiplexed mode, where each digit is displayed for 1 ms, then the next digit is displayed for 1 ms and then the next for 1 ms, and then the cycle is repeated. This method reduces the number of segment drivers needed for the instrument to seven (RB6 and RC2 - RC7). The digits are selected by three bits and then buffered through three 2N3904 transistors which in turn drive the enable controls of the display. The buffering is provided since the current required can reach 75 ma if all seven segments are on (the digit “8”). The average current will be much less, since the most significant digit is used for the minus sign (one digit) and the value -88 dB does not occur. Typical average current is on the order of 40 ma.

The current through the display is limited by the resistors in SIP #52 and #53. Each segment has a 470 ohm resistor in series. Peak current per segment is limited to about 10 ma.

3.2.6 Red / Green LED Display - two LED, one green and one red are used as summary indicators. When the green LED is on by itself, it means that the equivalent IMD is -24 dB or below. When the red LED is on by itself, it means that the equivalent IMD is -20 dB or higher. If they are both on, the IMD is between -21dB and -24 dB inclusive. These LED are driven by two outputs of the micro controller, (RB4 - green, and RB5 - red). The current through the LED are limited to about 2 ma. each by 2.2 k ohm resistors #1 and #2.

3.2.7 Audio Transducer - an audio transducer is available to provide audible tones when the measurements are out of limits. A Morse “H” (dit dit dit dit) will be produced when the equivalent IMD drops below -20 dB. When the value is adjusted back to -24 dB or less, Morse “I” (dit dit) will be sounded.   The transducer is an electro mechanical transducer with a resonant frequency of 2048 Hz. This frequency is used for the code tones, since it produces the strongest sound. Resistor #87 limits the current to the transducer to about 10 ma. The transducer is an AT-10Z, #88. The output RB5 is used to provide square wave signals to the transducer. This output is shared with the red LED driver, so you will see the red LED pulse while the Morse is sent.

3.2.8 Mode Switch - A three position mode switch is provided to control the display presentation. It is a SPDT Center Off toggle switch. **Up** means that the display will show the equivalent IMD for PSK63 operation. **Center** means that the display will show the equivalent IMD for PSK31 opertion. **Down** means that the display will show a value related to the signal strength seen by the instrument. Pull up resistors #85 and #74 establish the value at a logic high level when the switch is open.

3.2.9 External Programming Connector - the micro controller can be programmed while in circuit. The connector for the external programming connection is shown as an RJ45 connector, #76. This connector is only used for development, not for the production release of the kit. Pull up resistors #73 and pull down resistor #72 are provided for the external function. The production kit does not have the RJ45 installed in location #76. The resistors associated with the connector are stuffed in the production version of the kit, however.

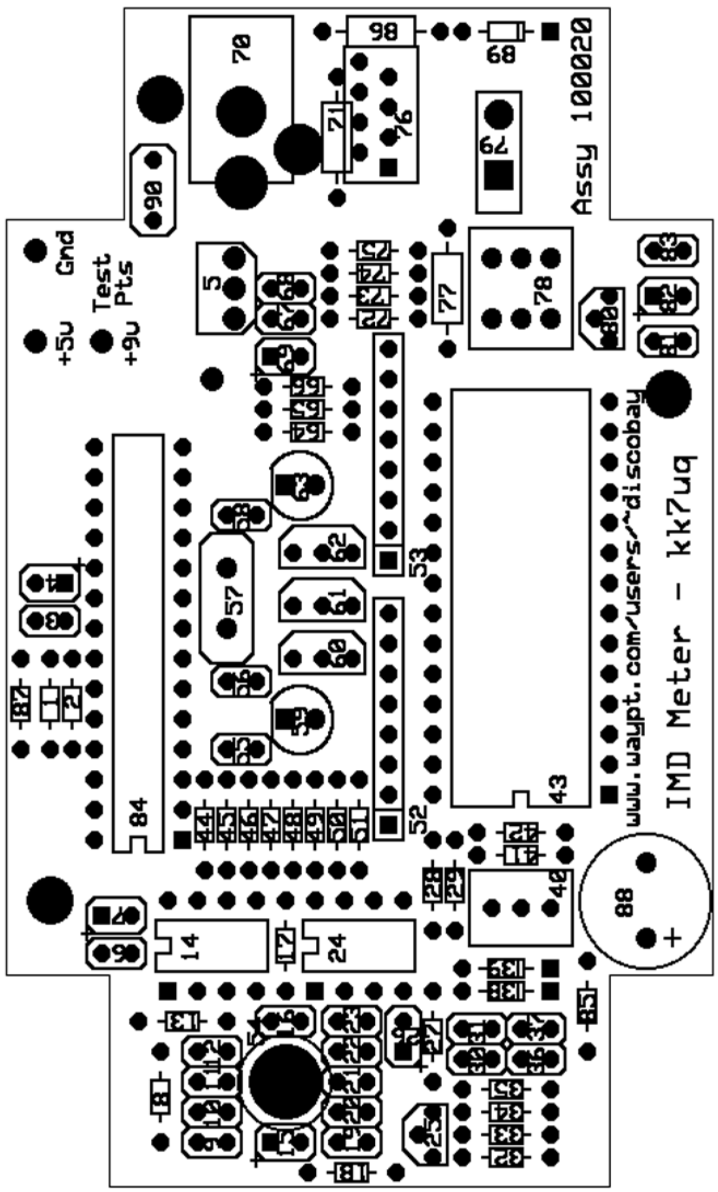
3.2.10 Oscillator - the operating clock for the micro controller is 20 MHz. Crystal #57 and capacitors #56 and #58 provide the external components of the oscillator.

3.2.11 Micro Controller - the micro controller for the instrument is a PIC 16F876SP. This is a 28 pin slim package. A socket is provided for this part. Master Clear for the micro controller is provided by resistor #47, pulled to +5 volts.

4. Assembly of the Kit

The assembly drawing of the PCB assembly is shown in figure 4.1 below. This view has been magnified to make it easier to read the number designators of the parts on the board. The numbers on the board silk screen on the board are clear and distinct.

Figure 4.1 PCB Assembly - Expanded View



4.1 Assembly of Parts on the Printed Circuit Board

Parts should be installed on the circuit board in the order shown in figure 4.3 below. Parts are grouped into assembly steps shown on the figure. Mount the parts in one assembly step onto the board, then inspect, solder and trim as a group.

Parts which are polarized or have special mounting instructions are marked in RED**.** **Three items have particular mounting needs:** the **DC power connector**, the **switches**, and the two **LED**.

The DC power connector is mounted on the bottom of the board. It must be installed and soldered (step 9) before the RF choke (step 10).

The two switches should be fully inserted onto the board. Be sure that the switches are perpendicular to the board surface.

The two LED should be mounted so that the top of the shoulder of the LED is 0.4 inches above the top of the board. Use the drawing in figure 4.2 below to pre-cut the LED short lead to aid in positioning the LED to the correct height. The cut lead should be inserted so that the lead is flush with the bottom of the board. Solder the cut lead in place, then adjust the LED so it is perpendicular to the board. Then trim the other lead. When the PCB is assembled into the enclosure, there are two LED mounting clips used as a bezel. If the LED are too high, they will interfere with these clips.

Figure 4.2 LED Lead Trimming

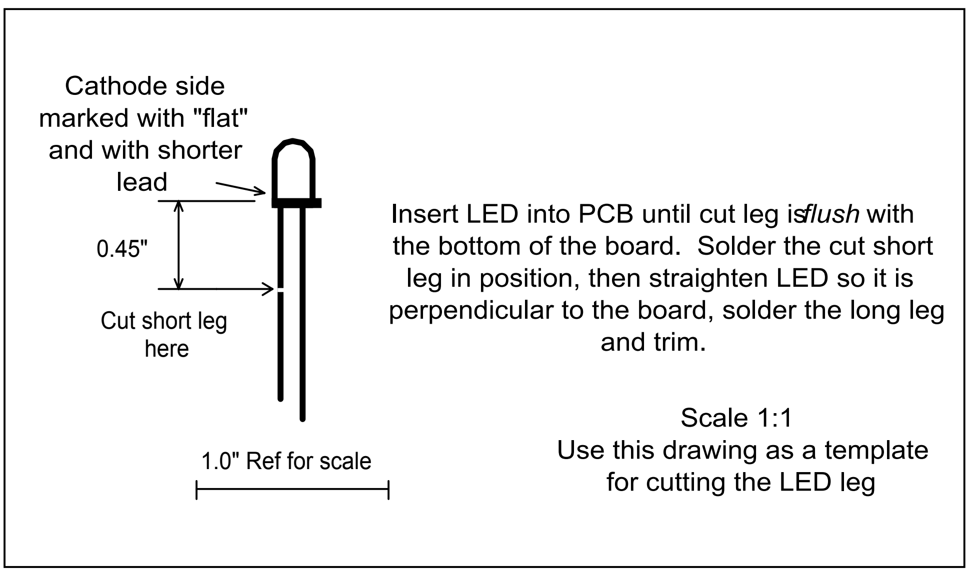


Figure 4.3 PC Board Bill of Materials, Sorted By Assembly Step

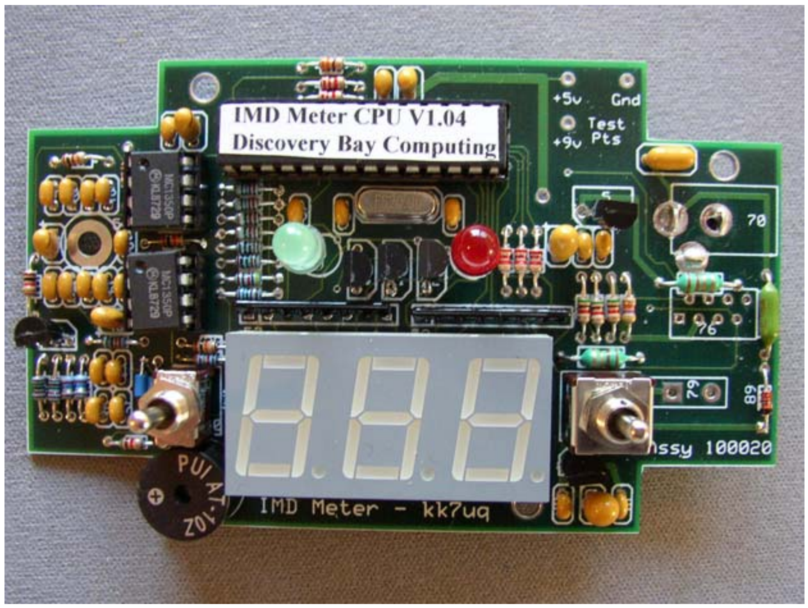
Ref	Type	Value	Qty	Mouser PN	Step	Identifier / Code
0	PCB	Custom	1	Discovery Bay Bd 100021E	0	
	Step 1 - 1% Resistors have 0.3 inch lead spacing					
34,35	Res 1% 1/8w	97.6	2	270-97.6	1	Wh,Vi,Bu,Gd,Br
48	Res 1% 1/8w	1.00k	1	270-1k	1	Br,Bk,Bk,Br,Br
27,32	Res 1% 1/8w	1.5k	2	270-1.5k	1	Br,Gn,Bk,Br,Br
49	Res 1% 1/8w	2.00k	1	270-2k	1	Rd,Bk,Bk,Br,Br
46,47	Res 1% 1/8w	3.9k	2	270-3.9k	1	Or,Wh,Bk,Br,Br
50	Res 1% 1/8w	4.02k	1	270-4.02k	1	Yw,Bk,Rd,Br,Br
42,44,45	Res 1% 1/8w	8.06k	3	270-8.06k	1	Gy,Bk,Bu,Br,Br
33	Res 1% 1/8w	10k	1	270-10k	1	Br,Bk,Bk,Rd,Br
51	Res 1% 1/8w	16.00k	1	270-16k	1	Br,Bu,Bk,Rd,Br
29	Res 1% 1/8w	32.4k	1	270-32.4k	1	Or,Rd,Yw,Rd,Br
	Step 2 - 5% Resistors have 0.3 inch lead spacing					
8	Res 5% 1/8w	47	1	299-47	2	Yw,Vi,Bk
41, 87	Res 5% 1/8w	330	2	299-330	2	Or,Or,Br
13,17,18	Res 5% 1/8w	1k	3	299-1k	2	Br,Bk,Rd
1,2,64,65,66	Res 5% 1/8w	2.2k	5	299-2.2k	2	Rd,Rd,Rd
72,73,74,85	Res 5% 1/8w	5.1k	4	299-5.1k	2	Gn,Br,Rd
28	Res 5% 1/8w	10k	1	299-10k	2	Br,Bk,Or
75	Res 5% 1/8w	47k	1	299-47k	2	Yw,Vi,Or
	Step 3 - Ceramic capacitors are not polarized					
56,58	Cap, cer, radial	22 pf	2	80-C315C220J1G	3	220
10,11,12,19 20,21,22,37	Cap, cer, radial	1000 pF	8	80-C315C102K5R	3	102
9,23,30,36	Cap, cer, radial	0.01 uF	4	80-C315C103K5R	3	103
3,6,16,31,55 67,68,81,83	Cap, cer, radial	0.1 uF	9	80-C320C104K5R	3	104
90	Cap, cer, radial	1 uF	1	80-C330C105M5U5CA	3	105
	Step 4 - Tantalum capacitors are marked with PLUS side. Match to silk screen + on PCB. The plus side on the PCB also has a square pad to help identify the plus side.					
4,7,15,26	Cap, tant. 25v	1 uF	4	80-T350A105K025	4	105
69,82	Cap, tant. 20v	10 uF	2	80-T350E106K020	4	106
	Step 5 - Resistor SIP marked with Pin 1 as Square Pad on silk screen					
52,53	Resistor SIP	4x-470	2	71-CSC08A03-470	5	470
	Step 6 - Diodes have 0.3 inch lead spacing match cathode bar to silk screen					
89	Diode	1N4148	1	512-1N4148	6	Clear Glass Diode
38,39	Diode	CDSH270	2	610-CDSH270	6	Blue CDSH270
	Step 6 - Pico Fuse has 0.4 inch lead spacing					
86	Picofuse	1/8 amp	1	5761-52125	6	LF 1/8 Radial lead

Figure 4.3 PC Board Bill of Materials, Sorted By Assembly Step (Cont'd)

Ref	Type	Value	Qty	Mouser PN	Step	Identifier
	Step 7 - Crystal can be mounted in either direction - not polarized					
57	Crystal	20mHz	1	520-HCU2000-S	7	S200ECSL
	Step 8 - Mount TO92 parts with flat side as shown on silk screen					
5	Reg. TO92 5V	78L05	1	511-L78L05ABZ	7	78L05
80	Reg. TO92 9V	78L09	1	513-NJM78L09A	7	78L09
60,61,62	NPN TO92	2N3904	3	512-2N3904-D81Z	7	2N3904
25	NPN TO92	PN918	1	512-PN918	7	PN918
	Step 9 - Sockets have a dimple on Pin 1 end, match to silk screen					
84	Socket	28 pin slim	1	571-3902619	8	
43	Socket	28 pin wide	1	571-3902622	8	
14,24	Socket	8 pin DIP	2	571-3902612	8	
	Step 9 - Audio transducer is marked with (+), match polarity to silk screen					
88	Audio Trans	AT-10Z	1	665-AT-10Z	9	AT-10Z
	Step 9 - Power connector is mounted on bottom side of PCB					
70	DC Pwr Jack	2.1x5.5mm	1	163-5004	9	
	Step 9 - Switches should be fully inserted on the board. Check that the switch is perpendicular to the PC board					
78	Switch	DPDT	1	10TC418	9	
40	Switch	SPDT	1	10TC412	9	
	Step 10 - LED are mounted with flat side (cathode) match to silk screen and are mounted 0.4 inch above board at top of shoulder on LED					
59	LED	Grn	1	512-HLMP4740	10	Flat side cathode
63	LED	Red	1	512-HLMP4700	10	Flat side cathode
	Step 10 - RF Choke has 0.4 inch lead spacing					
71,77	RF Choke	3.3uH	2	542-78F3R3	10	Or,Gold,Or,Gold
	Step 11 - Insert parts into sockets after full inspection of the board assembly and after initial DC power testing has been done. Pin 1 ends are marked with a dimple					
14a,24a	AGC Amplifier	MC1350P or NTE746	2	MC1350P or 526-NTE746	11	Insert into socket
84a	CPU	16F876SP	1	579-PIC16F87620SP	11	Insert into socket
	Step 11 - Mount LED Display with decimal points toward the bottom of the board					
43a	LED	3 Digit LED Display	1	604-BC56-11EWA	11	Insert into socket

4.2 Final Inspection and Cleaning - After the assembly of parts onto the printed circuit board, inspect all connections to be sure they are soldered, and that there are no solder splashes between adjacent pins or components. Clean the bottom of the board with a board cleaner such as "Tronic Kleen" from Radio Shack. Let dry. Your completed board will look like the photo in Figure 4.4 below. The board is now ready for testing.

Figure 4.4 - Completed IMD Meter PCB Assembly



5 Testing the Board

5.1 Initial testing - Initial testing is done before the integrated circuits and the LED display are installed into their sockets. At this time, the board should not be mounted into the case. Check the resistance of the +9v and +5v supplies to ground, before applying power. This can be done at the test points on the upper right hand area of the board. The resistance should measure more than 1 k ohm. If the resistance below that number, check for solder splashes and shorts between pins before applying power.

5.2 DC Power - Connect +12.5V DC power to the board and put the power switch #78 in the UP position. Check for hot spots by lightly touching the regulator TO92 parts. They may be slightly warm but should not be hot. Check the DC voltages with a multi-meter by the test points in the upper right hand corner of the board.

1. Check the +5 V to GND voltage on the test points in the upper right corner of the board. The reading should be 5V ± 0.1 volts.

2. Check the +9V to GND on the test points in the upper right corner of the board. The reading should be 9V ± 0.25V.

3. **Turn off the power switch, and remove DC power.**

5.3 Install components in sockets - Install the CPU into socket #84, the two AGC amplifiers into sockets #14 and #24, and install the LED display into socket #43. The decimal points on the LED display should point toward the bottom of the board. The pin 1 end of the sockets should match the pin 1 dot on each part. The PIC should have pin 1 on the left side, the AGC amplifiers at the top side, and the LED display at the left side. Inspect to be sure that all pins go into the socket, and are not bent over. Apply power to the board, and turn the switch on. Repeat the DC power check done in the previous step.

5.4 Self Test - The board has a self test mode which checks that the CPU is running, and that the displays and the audio transducer are functional. Turn power off. Put the mode switch #40 into the DOWN position. Turn power back on again - this performs a master reset on the CPU. You should see the following:

1. There should be a single BEEP from the Audio Transducer, and the Red LED should briefly pulse.
2. The LED digit displays should be showing a digit pattern, starting with the sequence 000 to 009. Then the sequence should be 000 to 090, incrementing only the center position. Then the last sequence should be 000 to 900, incrementing only the left hand digit position. The display then goes off.
3. Next the Green and Red LED should be activated, showing alternate Green then Red 5 times.
4. Next, a three digit number will be displayed. This represents the firmware revision number.
5. Next the audio transducer will sound with Morse “FB” repeated once. The tone frequency should be 2048 Hz.
6. The initial test is now complete, and the board begins operation with the Field Strength display. You should now see a number, probably 000 on the display. At this point, turn off power, and remove the DC power from the board.

5.5 First Operations - Temporarily install the whip antenna directly onto the board on pad #54 (the large pad in the upper left hand corner. Hand tighten the nut on the bottom. (This antenna will be removed later on and installed into the case.)

Connect DC power again, put the Mode switch into the DOWN (FS) position, and reapply power. The board will repeat the self test again, and then begin display of signal Field Strength. With no signal present, you should see the number 000 on the digit display. If it is reading another number, be sure that the board is not near a CRT display, or other RF generating source.

Now, generate some RF energy by turning on your transmitter with an idling BPSK31 signal. Go to 20 meters, (or some other favorite band) and set your transceiver frequency just above the normal PSK area, at 14.073, with an audio offset of 1000 Hz. Be sure that there is no station on the air at the frequency chosen. Put the word TEST into the CALL field of your PC software, and then use your Call macro to send the message TEST TEST TEST de (Your Callsign). This identifies who you are, and what you are doing. Repeat this every few minutes. Now go into IDLE mode by clicking on TX on the PC. The station should now be transmitting BPSK31. Keep the power down during this step, about 1 to 10 watts.

The meter display should now change to a number greater than 005. The number may be as high as 045. The number displayed is the amount of attenuation being applied to the AGC of the RF amplifier stage in the IMD Meter. The higher the number the more attenuation, hence the stronger the signal.

If the number is low, pull out the antenna and the number should increase. If it is high, push the antenna in a bit. Signal strength is also sensitive to location. Remember that you are in the near field of your antenna, and moving the antenna a few feet can significantly change the received power. You should end up with an operating FS of between 25 and 45.

At this point, you have an operational IMD Meter. You can now check your signal by moving the mode switch to the PSK31 position (Center). You should see negative numbers displayed representing your transmitted IMD. You will see some delay between digits displayed. The IMD Meter may take a second or two to begin displaying IMD numbers. This is because the meter must first set the AGC level of the signal. The IMD Meter micro controller turns off the digit display when it is measuring, because the display is a source of local RF noise. After the initial delay, the display delay is normally about a second between samples, but may be slightly longer if you are transmitting data. If the display is blank, it may mean that you are not transmitting a BPSK31, or QPSK31 signal. Check to see that your transmitter is on and that one of those modes is in operation.

If the display is showing -24 or lower (more negative), then your audio level produces a clean signal. If it is between -20 and -23, you are close, but should reduce your audio drive level until you go to an IMD of -24 or below. If the display is from -10 to -19, your signal is wide, and you must adjust the drive level to improve the situation. More about this in the Operation Manual.

You will also see the Green or Red LED (or both) on. Green only means -24 or less, Green and Red means -20 to -23, and Red only means at -19 or higher.

Now move the Mode switch to the UP position. The meter should be blank. Change the operating mode to PSK63. The meter should now display valid IMD readings. The Red or Green LED should continue to display as above.

You have now completed testing of the unit, and it is ready to install into the case. If there are problems during the testing, refer to the troubleshooting section which follows.

5.6 Troubleshooting

In the trouble shooting steps below, there are many suggestions for finding and correcting a problem on the IMD Meter. If you reach a dead end, don't hesitate to ask for help from Discovery Bay. Send email to discobay@waypt.com with a Subject of "Service - IMD Meter" in the subject heading. Briefly describe the troubleshooting steps taken, and the results found.

5.6.1 First Steps - Check the Power - if the unit doesn't seem to be working at all, check the input power supplied to the board. Verify +12.5 to +18 volts supplied to the DC connector - measure on the top of the board between the two large pads on #70 that are side by side. + pin is to the left, - pin to the right. Next verify that the voltage gets through the fuse #86 and the diode # 89. Measure at the bottom of #86 to ground, then from #89 to ground. The diode is there to protect the board in case the input power is reversed, so if you get reading at the bottom of the fuse, but not at the bottom of the diode, then the input power is backwards - fix it. The board expects the + voltage to be on the center of the connector and the - connection on the outer part of the plug. Then check for +5 Volts and +9 Volts when the Power Switch is in the UP position., as described above.

5.6.2 Self Test - if there are problems encountered during the self test, it usually means that a connection is unsoldered, or else there is a solder splash between connections. The first step is to do a thorough visual inspection of solder connections. The first step of the self test beeps the audio transducer and blinks the Red LED; the next test which displays digits segment displays - successfully performing these steps indicates that the PIC micro controller is running, as well as that the transducer and the LED display are functional.

5.6.3 Micro Controller Running? - First, determine that the PIC micro controller, IC #84, is running and functional. If you hear a beep, or see any indication of digits on the display, then the CPU is running.

If you don't get to the point where you hear the beep, or that anything is displayed on the digit panel or the LED, then the problem is either in the PIC or in the power to the PIC. First, be sure that the PIC is not installed backwards - the dot on pin 1 should be on the left side of the socket. Then look at the IC in the socket, and be sure that no pins are bent under, or have gone on the outside of the socket. Check voltage to the chip and be sure that you have about +5V at pin 20.

Check the voltage at pin 28 - it should be at 0 volts. This is determined by the mode switch being in the down position. If the voltage is not at ground, then the self test will not be performed on power up. Check the soldering connections on the switch. Then check pin 1 (MCLR) it should be at +4.75 Volts. If not, check the soldering on the pull up resistor #47. Pin 24 should be at about 0 V. If not, then check the soldering at the resistor #72. Then visually check the crystal soldering, and the soldering on the two 22 pf capacitors (#56, 58). Voltage at pin 9 should be about 0.7volts, and the voltage at pin 10 should be about 1.7 volts. If you still have no indication that the PIC is running, by either getting a beep or Red LED display on, when the power switch is first turned on, then turn off power, disconnect the DC power, and remove the PIC from the socket. Check for bent under pins. Look into the socket and look for wide socket pins (bad socket). Look again at the soldering on the socket and look for a pin from the socket that did not come through the bottom side and is bent over under the socket. If none of this trouble shooting gets you to the point where the PIC is running, then ask for help from Discovery Bay.

5.6.4 Don't get the initial beep - If you see indication that the PIC is running because there are digits being displayed on the display, but no tone - but you did see a short pulse on the Red LED just after power on, it means that the signal is being generated to sound the tone, but no tone is being created. The problem is in the transducer #88, or the limiting resistor #87. Check that the Audio Transducer has been installed with the correct polarity. The + should be on the left hand side. Check the solder connections on the transducer #88, and the connections on resistor #87 (at the top of the board). The resistor value should be 330 ohms (Org, Org, Brn). If none of the above find the problem, you probably have a defective transducer. Ask for help from Discovery Bay.

5.6.5 Get the initial beep, but don't see all digits on the display or some segments are wrong - The digit display test is intended to verify that all segments of the display are active, and that the digit drivers are all working. If you get display on some digit positions, but not all, check the soldering on transistors #60, 61 & 62 and on resistors #64, 65 & 66. Also check the soldering on socket #43 and look at the pins on the digit display inserted into #43. If you get all digits, but some segments are missing, or stuck on, check the soldering on SIP #52 & 53. The segment drives are common to all three digits, so the same ones should be affected on each digit if there is a problem here. If none of the above find the problem, you probably have a defective LED display. Ask Discovery Bay for help.

5.6.6 Green or Red LED are not showing on the self test - if either of the digits are not showing on the self test, then check for soldering / shorts on LED #59 & 63, and resistors #1 & 2. If none of the above find the problem, you probably have a defective LED. Ask Discovery Bay for help.

5.6.7 Don't get the beep tone, or the morse "FB" or else tone frequency is very low - the beep tone was tested earlier right after power on, in self test mode. See the write up there for trouble shooting. The tone is 2048 Hz, if it sounds low, then the PIC clock is running much slower than it should be. Check the solder around the crystal #57, and the capacitors # 56 & 58. Ask Discovery Bay for help.

5.6.8 Self test runs OK, but don't get the 000 digits on the display afterwards - you should expect to get digit display 000 indicating that the AGC RF amplifier is running at maximum gain. If there are no sources of RF present, that is what you should see. But, if the unit is near a source such as a CRT display, or if there is a transmitter on, the display may be higher than 000. See the section on First Operation again. If you remove the antenna from the board, and the display returns to 000, there is probably RF present. If the display shows a small amount of RF present, with displays 001 or 002, you should be able to use the IMD meter successfully. Anything larger indicates an interference problem or else a problem in the RF section of the meter. Check the solder connection in the RF section on the left hand side of the board. Also verify that the +9V supply is working. Measure +9V at pin 2 of ICs #14 & 24. Should read between 9V and 9.25V. If you can't resolve the issue, ask Discovery Bay for help.

5.6.9 Self test runs, and get the 000 Field Strength signals OK, but don't get any FS readings when transmitting BPSK31 - With the Mode switch #40 in the DOWN position, you should be seeing signal strength readings on the meter above 000. If it stays at 000, then the problem is most likely in the Detector circuit. Check the diodes #38 & 39. They should be Blue in color, and the black bands should be pointing down. Check the soldering around the diodes and in the area around the lower part of the right hand side of the board. Check position of transistor #25. Check for +9V at the top of resistor #27. Measure DC voltages at left side of #27 for about 6 volts; the top of #34 for 0.4 volts; the bottom of #33 for 1.17 volts if these are correct, the bias for the transistor is correct. Check the voltage at pin 2 of the PIC #84. With RF signal present, and the antenna extended, you should see about 0.5 to 1.5 volts. If the voltage is in that range, but there is only 000 displayed, ask Discovery Bay for help..

5.6.10 Self test runs, get Field Strength on the meter in the switch DOWN position, but no reading on the display when in IMD (UP) position. Your transmitter should be running BPSK31 Idle to see display in this position. First, check that the voltage on PIC #84 pin 28 is at about 4.75 volts, and that pin 6 is near 0.0 volts. If not, then the switch is not soldered correctly, or the PIC is not soldered correctly, or else there are solder splashes in this area. Do a good visual of the switch, resistors #85 & 74. If this is correct, then the problem is most likely in the detector, either in capacitor #37 or resistor #28. Visually check this area. Check that your software and interface are in fact transmitting and in the BPSK31 mode; that you have a Field Strength above 7 on the display (switch DOWN). Ask Discovery Bay for help if you can't resolve this.

5.7 Further Help - This ends the structured trouble shooting section. You should email Discovery Bay for further help with the IMD meter. Discovery Bay will trouble shoot and fix defective IMD Meter PC Boards for a flat fee of $30, including shipping back to you. If defective components are found, there is no fee for repair. In any case, you pay for shipping to us. Contact us at discobay@waypt.com for return instructions. Workmanship on the boards must be reasonably good, and there must be no evidence of acid core solder being used during construction, nor modifications made on the board to qualify for this service.

6 Assembly of the Enclosure.

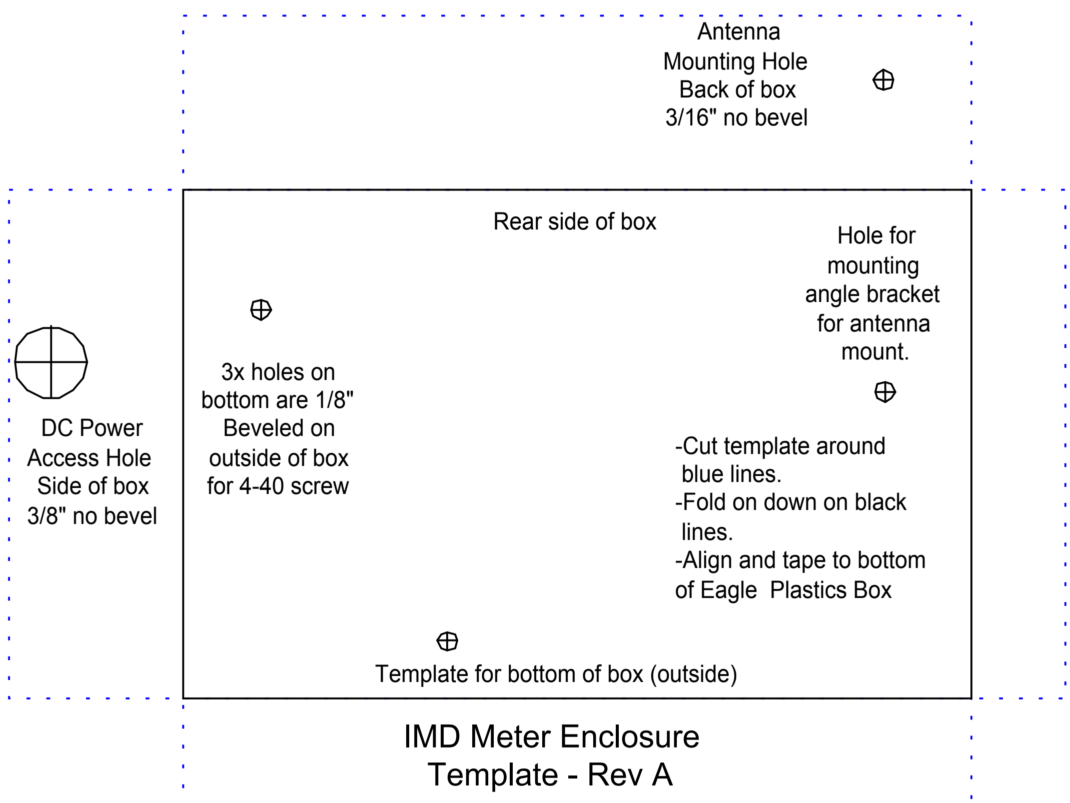
If you purchased the Eagle Plastics Enclosure Option for your kit, this section describes the drilling and assembly of this enclosure.

You must drill holes in the plastic enclosure, drill holes in the aluminum cover plate, drill and file the rectangular hole for the digit display, and assemble the hardware in box. Templates for drilling and fitting the holes are supplied with your IMD Meter kit, but used during this assembly procedure.

The next step is to install an angle bracket for the antenna, put in three aluminum standoffs inside the box for mounting the assembled board, add the cover plate over the top, install the legend overlay, tighten two nuts on the switches, and screw the panel down. The procedure for these mechanical steps are included in this section.

6.1 Drilling the plastic box - the template provided with the kit is printed at 1:1 scale, so it may be cut out and temporarily taped onto the bottom of the box, and up the sides of the box. The template looks like figure 6.1 below.

Figure 6.1 Enclosure Drill Template



Cut the template around the blue lines. Fold along the solid rectangle in the center, and place over the bottom of the plastic enclosure. Carefully align the edges of the template along the bottom of the box. Then tape the template down on the sides with cellophane tape or masking tape. Use a sharp pointed tool, like an awl to mark the center of each of the holes on the template. Drill the holes as defined on the template, and bevel where indicated with a ½ inch countersink bit. Clean the edges of the drilled holes with an Exacto knife where required.

The hardware used for the enclosure is shown below. The first group is supplied with the Enclosure Option. The second group is supplied with the basic IMD Meter Kit, but used for this assembly.

Qty	Description	Mouser part number
1	Enclosure, plastic, 4.19” x 2.74” x 1.57”	400-5053
1	Cover plate, aluminum & 4 screws	400-7053
Supplied with basic IMD Meter kit, but used on this assembly		
1	Antenna , 4 section telescoping	43AR104
1	Nut #2 metric (for antenna)	
2	LED mounting clip	606-4304MC
3	Standoff , aluminum, 0.75” x #4 thread	534-1895
3	Screw, pan head 4-40 x 1/4”	
3	Screw, beveled, black anodized 4-40 x 1/2”	
10	Washer, flat 4-40	
4	Washer, lock, split 4-40	
2	Washer, flat 5mm	
1	Set drill templates	
1	Legend overlay	
1	Red filter	
1	Angle Bracket, 0.50” x 0.50” hole 0.169”	534-619

Install the hardware inside the enclosure: The antenna slides through the hole in the top left of the box. Connect the angle bracket to the antenna using a split washer and the metric nut. Adjust the position of the antenna stud in the hole so that the antenna is straight up, then tighten the nut. Position the other hole of the angle bracket over the hole on the left side of the back of the box. Put a beveled screw through the hole, add (2) flat washers and (1) split washer, then screw a standoff onto the bracket. Tighten until the split washer is flat.

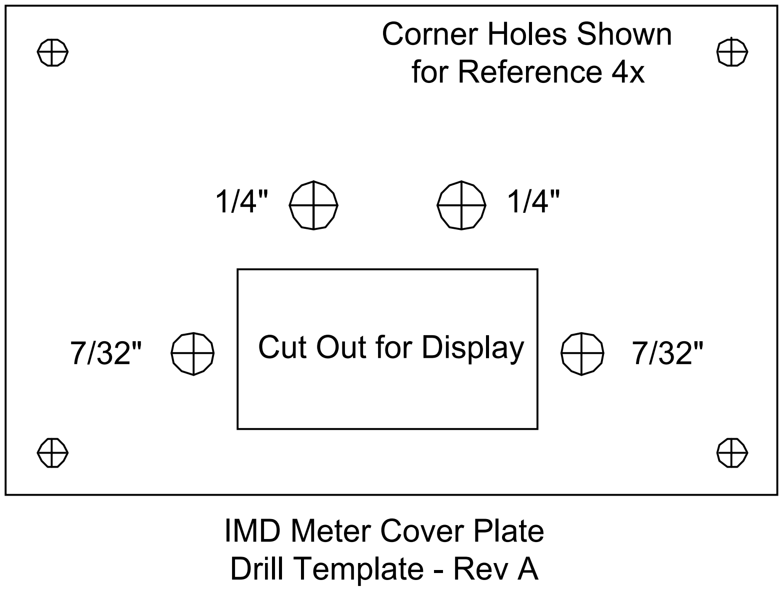
Next, install two more standoffs in the other two holes inside, on the back. Use a beveled screw, (4) flat washers, a (1) split washer and a standoff at each position. The PCB will rest on the top of the three standoffs, and is secured to them with the three 4-40 pan head screws. See the picture in Figure 6.2 below.

Figure 6.2 Enclosure Hardware Assembly

6.2 Cover Plate

The cover for the IMD Meter is an aluminum blank, with four pre-drilled holes for mounting the plate to the box. You will drill 4 additional holes in the plate, and cut a rectangle out of the middle for the LED digit display. A legend overlay is added to the cover plate as the last step in the process. The drill template is shown in figure 6.3 below.

Figure 6.3 IMD Meter Cover Plate Drill Template



The template is provided with the IMD Meter kit, and is scaled at 1:1 so that you can lay it over the plate, align it with the four holes already drilled, and mark where the additional holes and the rectangle will go. Remove the blue protective cover from the panel blank after you mark the holes. You should tape the template to the plate to hold it in position while marking the holes. Use a sharp pointed tool like an awl to mark the center of the four holes. Use a sharp Exacto knife to cut out the rectangle, scoring the aluminum cover underneath to show the limit of where you will cut.

Drill the four holes with the drill sizes shown on the template, and de-burr the holes with the Exacto knife, or with a ½" countersink bit on the drill. Cut out the rectangular hole using a small metal cutting coping saw, or a "nibbling" tool. You will have to drill access holes in the corners of the rectangle to accommodate your saw blade or "nibbling" tool. After the metal is cut, finish the edges of the cutout with a small flat file. The scribed hole is slightly larger than the cut out in the legend overlay that will cover it, so that the edges of the hole will not be seen when the unit is completely assembled. The hole locations on the plate are not symmetrical, the top side is the side that you scribed earlier.

Install the PCB assembly into the enclosure, and secure with three 4-40 x ¼" pan head screws. Remove the toothed washers and the flat washer with the tab from the switch, these will not be used in the assembly. Adjust the lower nut on the switches until they are level with the recess in the edge of the enclosure. Use the short side of the aluminum panel as a guide. The finished panel should just rest on these nuts when installed onto the enclosure.

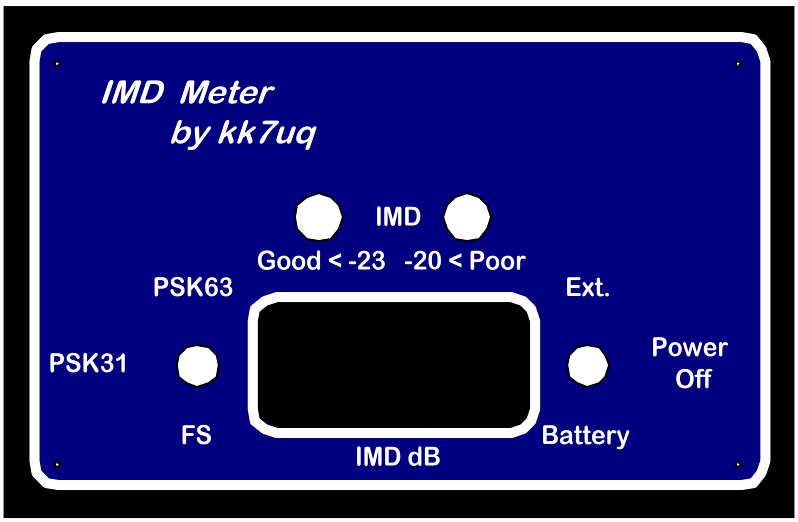
Fit the finished panel over the PCB assembly. The 3 digit display should fit inside the hole in the center of the panel. If not, increase the size of the hole with a small flat file.

6.3 Panel Overlay

The panel overlay is supplied with your IMD Meter kit. It will be trimmed on the outside, have the inner holes cut out with an Exacto knife, and laid over the finished panel. The overlay is held in place by the four screws which hold the panel to the box, and the nuts on the switches.

The overlay is shown in figure 6.4 below. Cut the overlay around the black perimeter, just inside the black edge. You don't want any white showing at the edge, since it will show against the black of the box. Then use the Exacto knife to cut out the four round holes. Use a piece of cardboard as a backing to cut against. Then cut out the rectangular black portion in the center, just inside the white edge. You don't want any black showing here. Then, take a sharp tool like an awl and punch small holes in the four dots in the corners. These should match the center of the four corner holes of the aluminum panel. Align the overlay over the panel, using the LED and switch holes as the guide. Then increase the size of the holes in the corners to match the size of the holes in the panel beneath them.

Figure 6.4 IMD Meter Legend Overlay Panel



IMD Meter Overlay - Rev A

A red plastic filter is provided to cover the 3 digit display. Cut it out in the shape defined on the filter, and place it smooth side up over the display and the panel, between the two switches.

The last step is to modify the two plastic LED mounting clips that are used to cover the edges of the holes for the Red and Green LEDs. Use a pair of side cutters to trim the plastic tube at the point where the split occurs. This removes the locking shoulder from the clip. If you don't remove this, and if you snap it over the LED, **you will not be able to remove it from the LED**!

Take the overlay and place it over the panel. Then insert the modified clip in the hole over the two LED holes. The clip should now cover the edge of the overlay around the hole. Take the overlay and slide it over the PCB assembly and the panel plate. Slide it over the LED and the switches. You may need move the LED slightly so that you can push the clip through the hole. The LED should be low enough so that the clip does not interfere with the shoulder of the LED. If it does, remove the clip, and trim some more off the bottom. Finally, attach the panel to the box with the four screws supplied, put the nuts and a 5mm washer on the toggle switches and hand tighten into place. The 5mm washers are provided to dress up the front panel. If you find that there is not enough thread left, use the nuts without the washers. Put the "rounded" side of the nut down if you can't use the washer.

Congratulations! Your IMD Meter assembly is now complete. Your meter should look like the photos in figure 6.5 below.

Figure 6.5 IMD Meter Photos

ACCESSORY
REMOTE
MIC
SERIAL INTERFACE
IMD Meter
by kk7uq
IMD
Good < -23
-20 < Poor
Ext.
Power
Off
IMD
Display
Off
FS
Batt.
IMD / FS db.
PTT/FSK
Model II
PTT
Off
On
LC02189 23:51 LA