Field Strength Meter

User Guide
and
Kit Assembly Instructions

PCB V1.1

Important: Always use or print this document in colour as there are references to the colours of components. Errors may occur otherwise.

Contents

Document History

Issue	Date	Changes
1	24th June 2007	First Issue

Field Strength Meter User Guide

This section explains how to use your Field Strength Meter. If you have not yet built the meter, proceed to the Kit Assembly Instructions section.

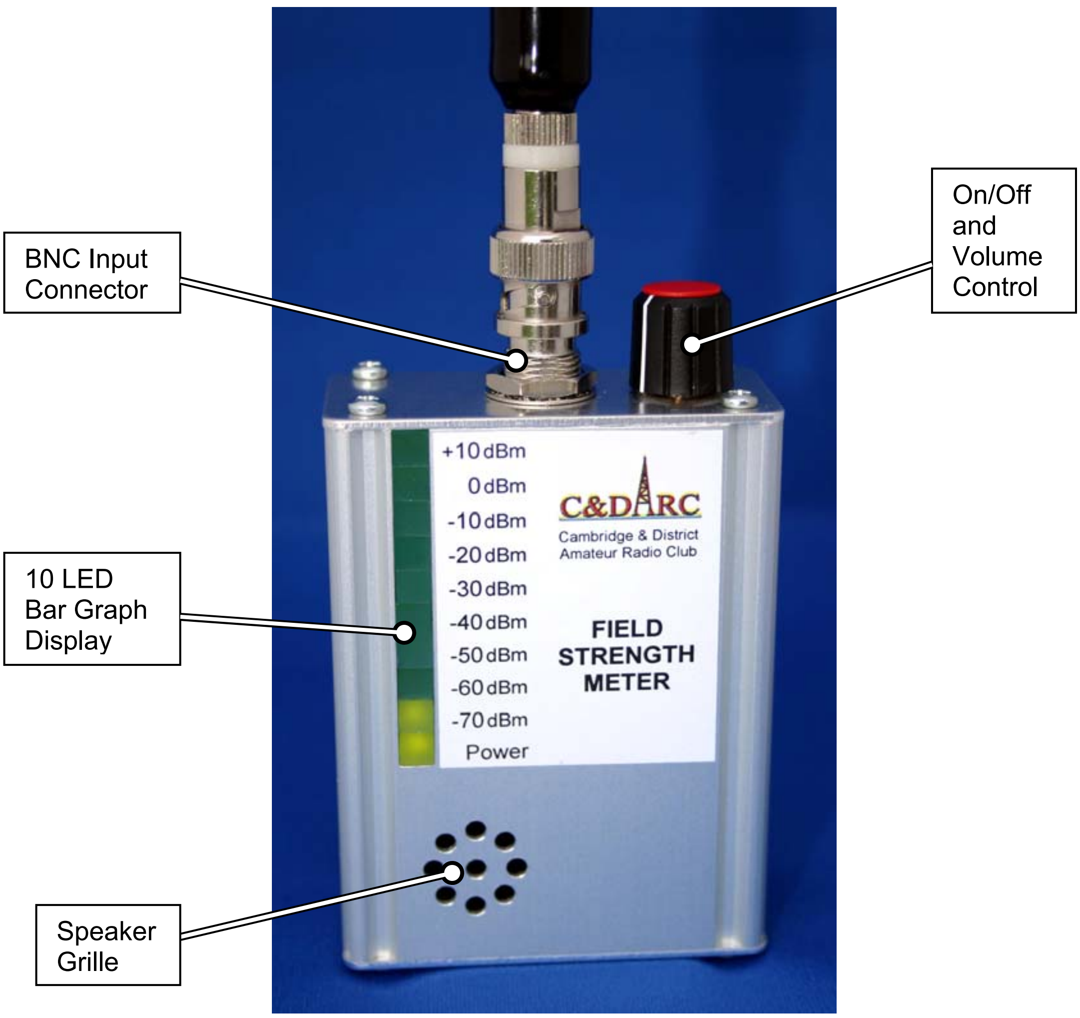
If you have any questions or are unsure about what is meant by anything, please email support@debuginnovations.com and we will be pleased to assist you.

Overview

A field strength meter is a general purpose instrument that has many uses including measuring RF signals, checking transmitters, tuning antennas and measuring antenna radiation patterns.

This design is based on the Shefford Amateur Radio club design, which in turn is based on the AD8307 data sheet. The major addition is an audio output. The new circuit and PCB were designed by Dave Adshead for the Cambridge & District Amateur Radio Club. The cases for the kits are supplied pre-cut, many thanks to Alan Hunter.

The major parts are shown below:



Basic Operation

Basic operation is simplicity itself. Simply attach a suitable antenna to the BNC input, switch on the unit and adjust for volume (fully anti-clockwise mutes the tone).

The LED display shows the relative signal strength on a logarithmic scale whilst the tone rises and falls in pitch on the same scale. The tone is useful for making remote measurements such as adjusting a transmitter. The tone is also useful for more sensitive applications since the pitch change can easily be heard in steps much less than the 10dB LED increments.

WARNING
The tone is loud enough to damage your hearing
Do not put the speaker near to your ear

Operational Tips

The unit is accurate from approximately 1MHz to 500MHz but will continue to work up to around 900MHz. This wideband response makes it very easy to use the meter for a wide range of measurements without adjustment.

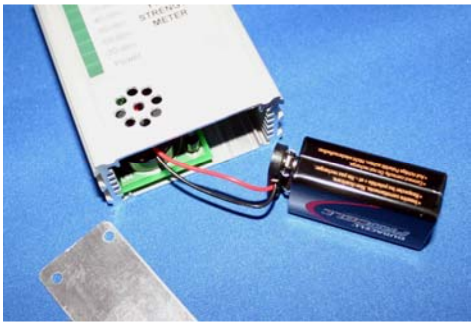
If a narrower bandwidth is required, a band-pass filter can be used at the input. However, be aware that filters are designed to operate into a 50Ω input whereas the field strength meter has a variable input impedance which will require a matching network for good filter performance – see Appendix F for more details.

The input is protected from excess voltage by a pair of diodes. It is important not to overload the input with signals exceeding 3V pk-pk. 50Ω attenuators can be used directly on the input connector if required.

WARNING
Never connect a transmitter output directly
to the field strength meter input

Replacing the Battery

The unit is powered from a 9V PP3 battery. To replace the battery:



1. Remove the bottom panel by unscrewing the 4 retaining screws.

2. Slide out the old battery, unclip the clip and replace the battery. Slide the new battery into the case. The end with the battery clip should go in first.

3. Replace the bottom panel using the 4 screws, being careful not to over tighten the screws. **Note that the panel is not symmetrical – it only fits in one orientation.**

FSM V1.1 Kit Assembly Instructions

This section gives step by step instructions to assemble and test the kit. It should be possible to complete the assembly in 2-3 hours. It is not a difficult kit to build but there are some surface mount components which need careful soldering. Therefore this kit is not recommended for novice constructors.

If you have any questions or are unsure about what is meant by anything, please email support@debuginnovations.com and we will be pleased to assist you.

Step 1: Unpacking Your Kit

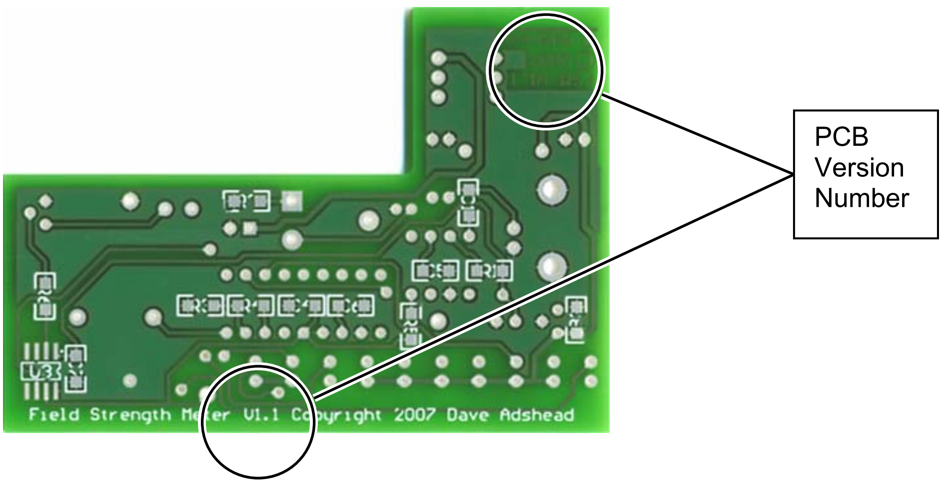
Your kit should come in a sealed package as shown below. These instructions are for PCB V1.1. Please check that your kit label says PCB V1.1.

Once opened you should have the following items. Ensure you have all the items before proceeding.

1. These instructions
2. The PCB
3. A bag containing the small components (mainly SMD)
4. A bag containing most of the through-hole components
5. A bag containing an LM3914 chip
6. A bag containing the mechanical parts (the box + end panels + label)
7. A knob & cap
8. A BNC connector
9. A potentiometer

Step 2: Component Identification

First check you have the correct PCB version (V1.1). The version number is shown on the bottom side of the PCB, both on the legend and etched in the copper.



Open the bags and check you have all the components on both parts lists (see Appendix B1 & B2).

Resistors

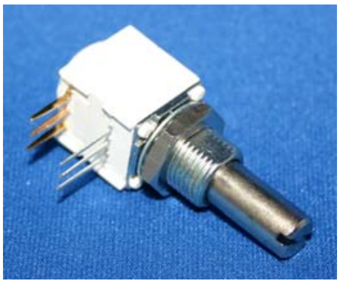
The SMD resistors are all clearly marked with a 3 letter code as follows:

Designator	Value	Marking
R1	22R	220
R2	22K	223
R3	1K0	102
R4	1K2	122
R5	2K2	222
R6	3K3	332

Variable Resistors

You should have a preset and a potentiometer as follows:

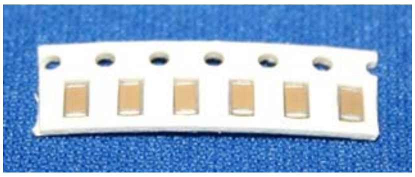
Designator	Value / Type
VR1	100K preset

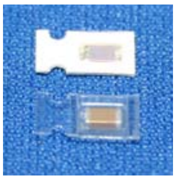


VR2	10K linear potentiometer with switch

Capacitors

The SMD capacitors have no markings. They can be distinguished by their packaging as follows:

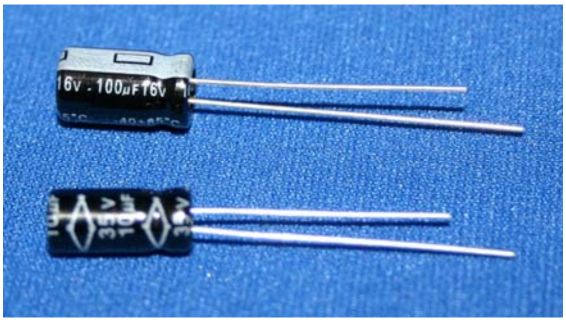




Designator	Value	Packaging
C1	100pF	Cardboard
C8	470nF	Clear plastic
C2-C7	100nF	Strip of 6

IMPORTANT: To avoid mis-identification, do not remove more than one capacitor from its packaging at a time. Unpack them one by one as they are soldered down.

The electrolytic capacitors are clearly marked. They may not be identical to the photo and may have different voltage ratings, as components from different manufacturers can look slightly different.



Designator	Value
C9 & C10	100uF
C11	10uF

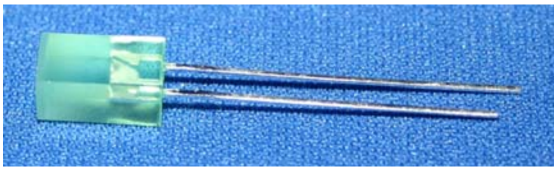
Inductors

There is only one inductor:

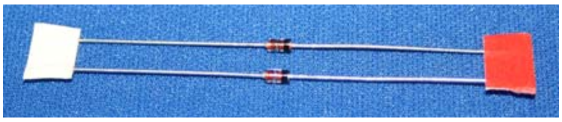
Designator	Value
L1	47mH

Diodes & LEDs

You should have 10 green LEDs and 3 diodes. The diodes are marked with the part number around their body.



Designator	Type
D1 - D10	5mm Square Green LEDs



D11 & D12	1N4148

D13	1N4001

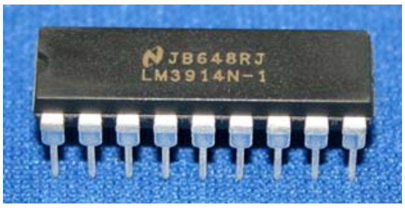
Transistors

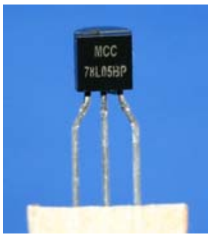
There is only one transistor. It is clearly marked with the part number. Be careful not to confuse it with U4, which looks the same.

Designator	Type
Q1	MPSA42

Integrated Circuits

You should have 4 ICs. They are all marked with the part number.





Designator	Type
U1	AD8307
U2	LM3914
U3	PIC12F675 (Programmed)
U4	78L05

There are no IC sockets. U1 must be soldered directly to the board for good high frequency performance. U2 must be soldered directly to the board for thermal reasons. U3 is mounted on the bottom side of the board and must be soldered directly to the board to maintain clearance from the box.

Other Components

These are the remaining components for the PCB.

Designator	Type
J1	BNC LP R/A PCB Mount

J2	Battery clip

TP1-2, TPG	Test Points

LS1	ABT-430-RC Piezo Sounder

In addition, you should have the parts shown in Appendix B2 (Additional Parts) all of which should be easily identifiable.

Step 3: Preparing For PCB Assembly

Before starting PCB assembly, ensure you have the following:

1. A large, clear, well lit working area. It is easy to lose SMD components by leaning on them, blowing them or ‘pinging’ them with tweezers etc. Also having plenty of light makes SMD soldering a lot easier. Use daylight if possible.

2. A fine tipped soldering iron and some thin solder. By SMD standards, 1206 packages are huge, but they are still a lot harder to solder than through hole components.

3. A good pair of tweezers for handling the SMD parts.

4. A multi-meter. If you spot a suspect solder joint or break a track, test it and repair it if necessary, before moving on.

5. Use a PCB assembly jig, if you have one.

Follow these basic tips for a good result:

1. Make sure your PCB is clean. If you have had your kit for a while, the plated areas of the PCB may have started to tarnish. This will make it harder to solder. A simple way to remove the tarnish is to rub the board with a standard pencil eraser.

2. Use only as much solder as necessary, particularly with the SMD parts.

3. Assemble the smallest components first, working up to the larger parts.

4. When soldering connections to the power plane, some of the heat of the iron will be drawn away. When soldering SMD parts it is easier to solder the other end first then do the power plane when you have both hands free.

5. When soldering large metal parts, turn up the iron temperature (if possible) and use a large bit, then use molten solder to spread the heat more evenly. Oh, and remember not to touch the hot component for quite a while!!

6. Observe anti-static precautions.

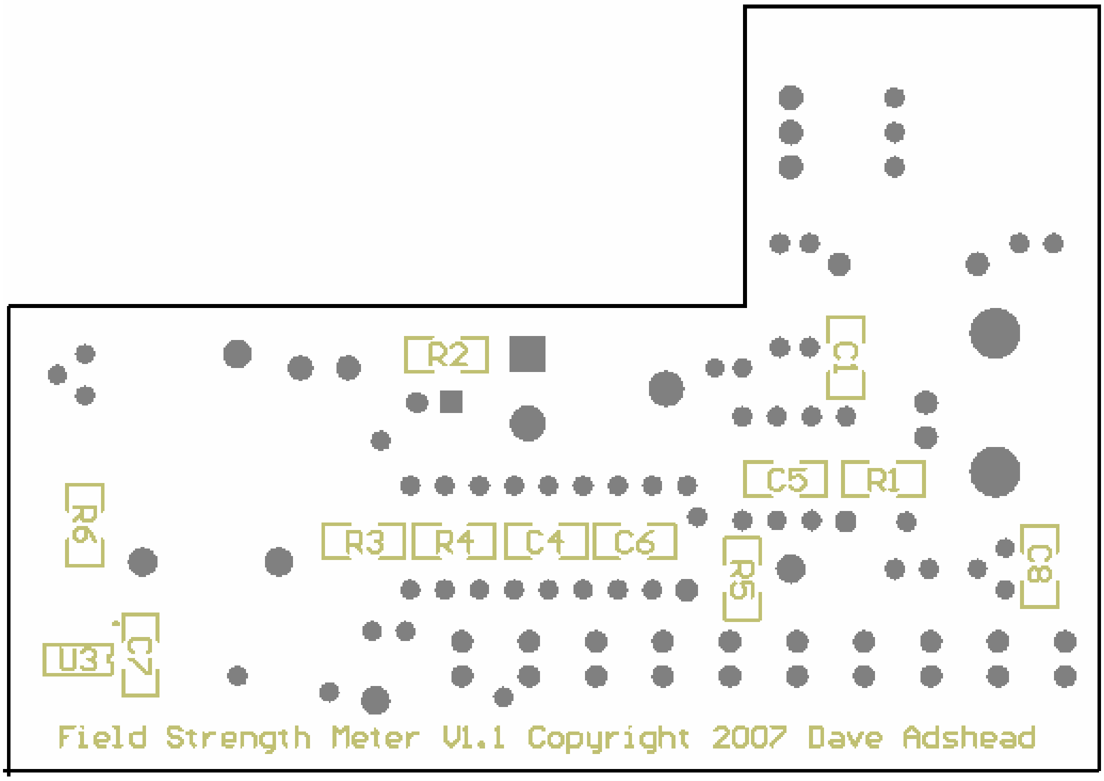
7. Most importantly, take your time.

A Tale Of Two Sides

Conventional through hole PCBs have a so-called “Component Side” and a “Solder Side”. Most surface mount PCBs, including this one, have components on both sides. Therefore the sides are referred to as the “Top Side” and the “Bottom Side”. Generally speaking the top side corresponds to the component side, and the bottom to the solder side. The bottom side only has low profile components (SMD resistors, capacitors etc) and the top side contains larger height components. That way, the PCB has a flat side making it is easier to handle.

We will first assemble the bottom side, then the top side.

Step 4: Bottom Side Assembly



Turn the board so it looks like the diagram above and fit the parts in the following order:
A fully assembled PCB is shown in Appendix C2.

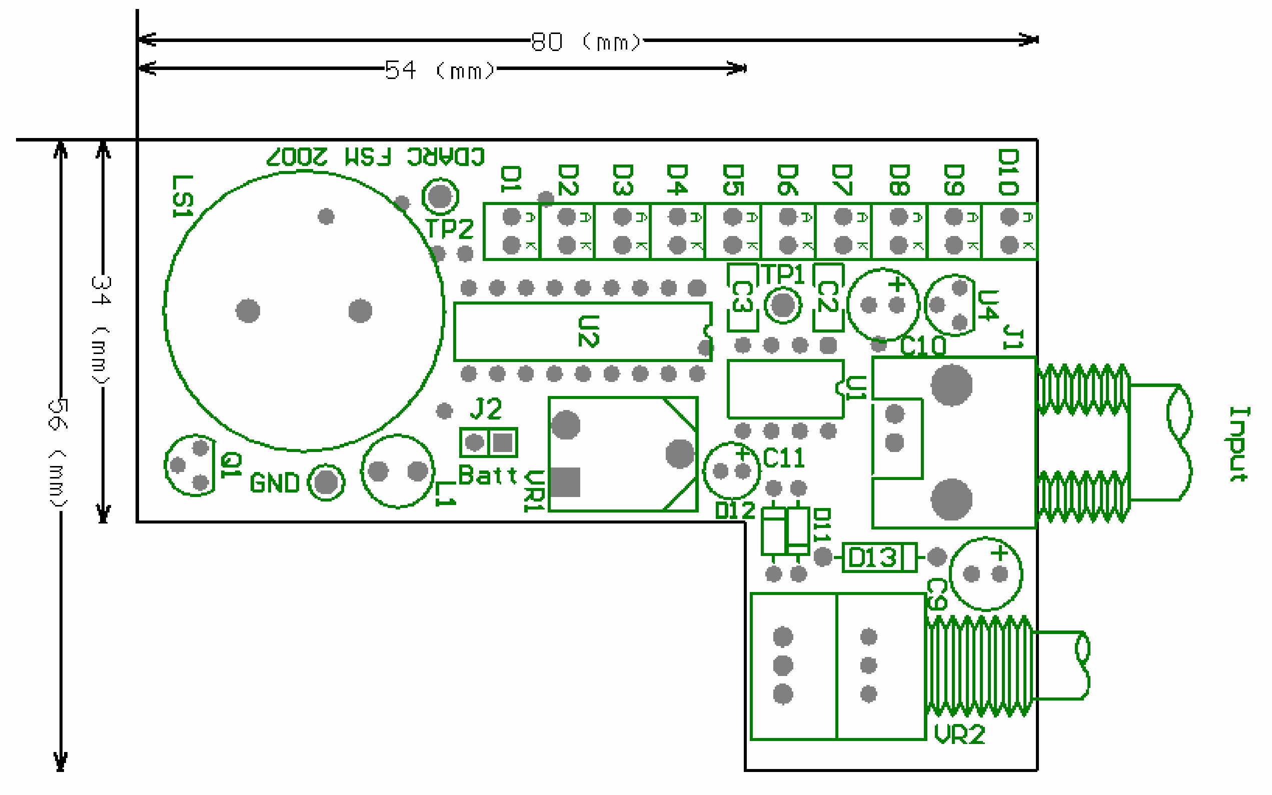
1. Fit resistors R1 (22R), R2 (22K), R3 (1K0), R4 (1K2), R5 (2K2) and R6 (3K3). Refer to the component identification section for the value markings.

2. Fit capacitors C1 (100pF, 1206) and C8 (470nF, 1206). IMPORTANT: Fit the capacitors one by one. DO NOT remove C8 from the packaging until C1 has been fitted as there are no markings on the capacitors.

3. Fit capacitors C4 to C7 (100nF, 1206). There are 4 x 100nF capacitors on the bottom side of the board and 2 on the top side so you will have 2 x 100nF left at this stage.

4. Fit U3 (Programmed PIC12F675). This is the most difficult device to solder on the board. Take your time and check your work carefully after soldering. Check for shorts with a multi-meter and use solder wick to remove excess solder if necessary.

Step 5: Top Side Assembly (Except LEDs)



Turn the board so it looks like the diagram above and fit the parts in the following order:
A fully assembled PCB is shown in Appendix C1.

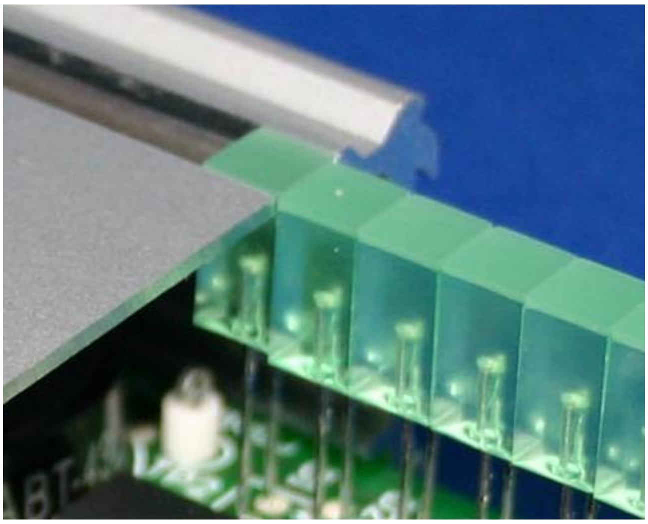
1. Fit capacitors C2 and C3 (100nF, 1206).
2. Fit diodes D11 and D12 (1N4148). Ensure they are fitted the correct way round.
3. Fit diode D13 (1N4001). Ensure it is fitted the correct way round.
4. Fit test points TP1 (Red), TP2 (White) & TPG (Black). TPG is marked GND on the PCB legend.
5. Fit Q1 (MPSA42) and U4 (78L05). Be careful as these devices are very similar.
6. Fit VR1 (100K Preset).
7. Fit U1 (AD8307) and U2 (LM3914). Ensure they are fitted the correct way round. The pins may need teasing inward as they are supplied splayed outwards. DO NOT use IC sockets - U1 must be soldered directly to the board for good high frequency performance and U2 must be soldered directly to the board for thermal reasons.
8. Fit C9, C10 (100uF) and C11 (10uF). These are polarised components that need to be fitted the correct way round. The long lead should be inserted through the hole marked '+' on the PCB legend.
9. Fit LS1 (Piezo Sounder) and L1 (47mH Inductor). L1 will not push down all the way to the board due to the solder at the top of the component legs near the body.
10. Fit J1 (BNC Connector). Ensure that it is exactly level with the board.

11. Fit VR2 (10K Potentiometer). Remove the nut and washer and discard them. Then prepare the shaft by sawing off approx. 4mm in length – this allows the knob to fit flush to the top panel. Solder the component, ensuring it is exactly level with the board.

12. Fit J2 (Battery Clip). First shorten the lead to remove some of the excess length (the lead only has to reach just beyond the base of the unit). The correct length is approx. 80mm. Solder the ends to the board using the 2 pads marked J2 (Batt). The positive (red) lead should go to the square pad and the negative (black) lead to the round pad.

Step 6: LED Assembly

The LEDs go through the slot in the front panel and finish up flush with the top surface (see photo, right). So, in order to get a neat finish, they must be stood off the board a precise distance and aligned accurately with the front panel slot.



In order to make this easier, some jigs have been made which are available on loan from the club. They are normal cases which have had the back removed. In this way the LEDs can be fitted and aligned in the slot, then soldered from the back of the case. The procedure is as follows:

1. Loosely fit LEDs D1 to D10 in their positions on the board. Do not solder them at this stage. Take care to insert the LEDs the correct way round (the anode is the longest lead and should be inserted in the hole marked 'A' nearest the edge of the board). You will find that the LEDs are a tight fit, especially if you try to push them down to board level *

2. Carefully slide the PCB into the special jig case. The PCB goes in the last slot (the one farthest away from the front panel). Push all the LEDs into the slot and turn the case over so the LEDs are resting on the workbench. If possible you can use a glass table to check the LEDs are all aligned before going any further. Make sure all the LEDs are aligned when pressed together, then solder them all. You may wish to solder one leg of each LED then check the result before soldering the second leg.

3. Once you are happy with the appearance of the LEDs, cut the excess lead length off and your board should fit in the real case.

* This is because the green plastic of the LED is not exactly square. It slopes from the base where it is nearly 5mm wide, to the top surface where it is only 4.9mm wide. The spacing between LEDs on the PCB is 4.92mm and the slot in the case is 49.2mm long. This forces all the top faces together to give a seamless appearance when finished.

Step 7: Testing & Calibration

After assembly the unit needs to be tested and calibrated before use as follows:

1. With the PCB out of the box and on an insulating surface, attach a battery and switch the unit on with VR2.

2. Measure the voltage between TP1 and GND. It should be approximately 5V. If it is not, there is a fault with the power supply on the board – first check the battery is good, then check D13 is fitted the correct way round. If you see a very low voltage on TP1, check for a short between the 5V power and GND.

3. Next do some basic checks to get confidence that the unit is basically ok *

   - Push a small wire into the centre pin of J1. Touching the wire should show a signal on the LEDs and make the tone change pitch. If it does not, check the voltage at TP2 – if it changes when the wire is touched, then the circuitry around U1 is working correctly and you have a problem with the LED driver (U2) and/or the tone generator (U3). If the voltage on TP2 doesn't change when the wire is touched, then you have a problem with the log amp (U1).

   - Adjust VR2 to check the volume control works correctly. The tone should be very loud. If you get no tone, check U3, R6 and Q1 are fitted correctly. If you get a quiet tone, check L1 with a multi-meter – it should have a resistance of about 120R.

   - Adjusting VR1 should change the LED display and alter the pitch of the tone. If it does not, check VR1 and R2.

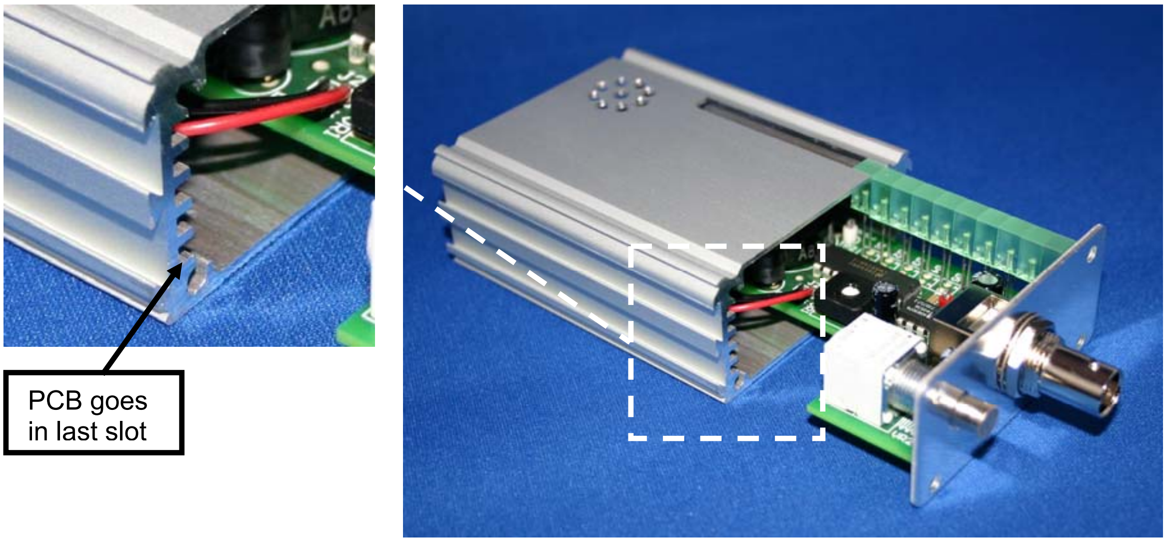
4. If you wish to calibrate the unit, inject a suitable signal into J1 from an RF signal generator (e.g. a 10MHz sine wave). DO NOT exceed 3V pk-pk. Adjust VR1 to get the LEDs to match the scale (0dBm = 1mW). It is possible to choose a different intercept point and make a new scale but the gain is fixed at 10dB per LED.

5. Alternatively, simply adjust VR1 until D1 just lights. In this configuration, D1 behaves as a power LED.

6. If you have a suitable signal source, apply a signal to J1 and check the LED meter works correctly and all the LEDs can be lit. DO NOT exceed 3V pk-pk signal amplitude. You may also want to check the frequency response (the unit should work from 1MHz to 500MHz).

* If your meter doesn't work you may find it useful to read the circuit operation section to help with fault finding.

Step 8: Final Assembly



Finally the unit can be put into its box as follows:

1. Drop the top panel over the thread of J1 and the shaft of VR2. Make sure it is the correct way round (so the screw holes line up with the case). Fit the nut and washer on J1 (the washer goes on the visible side of the panel, directly beneath the nut). Do not tighten the nut at this stage.

2. Slide the PCB into the case, being careful not to damage the LEDs as they feed into the front panel slot. The PCB goes in the last slot (the one farthest away from the front panel). See photos.

3. Screw the top panel in place using 4 of the screws supplied. You may find it better not to fully tighten the screws until step 4 is complete as the LEDs will be very difficult to move.

4. There is a small amount of play where J1 goes through the top panel. Use this play to adjust the height of the LEDs to remove any alignment error with the front panel surface and tighten J1's nut. Check that VR2 turns freely in the top panel hole. If it does not, the simplest thing to do is enlarge the hole slightly as it will be covered by the knob.

5. Fit the knob to VR2. Take care to fix it with a suitable clearance from the panel and positioned so that the white line points correctly when operated. Push the cap in place.

6. Connect a battery (not supplied) and slide it into the case. The battery clip should go in first and end up touching VR2 when in place.

7. Peel the protective plastic from the bottom panel and screw it in place using the remaining 4 screws supplied, with the unprotected side on the inside of the box. Note that the panel is not symmetrical – it only fits in one orientation.

8. Peel the back off the panel label and carefully stick it on the front panel so that it is aligned with the LED display as shown in the finished product photo.

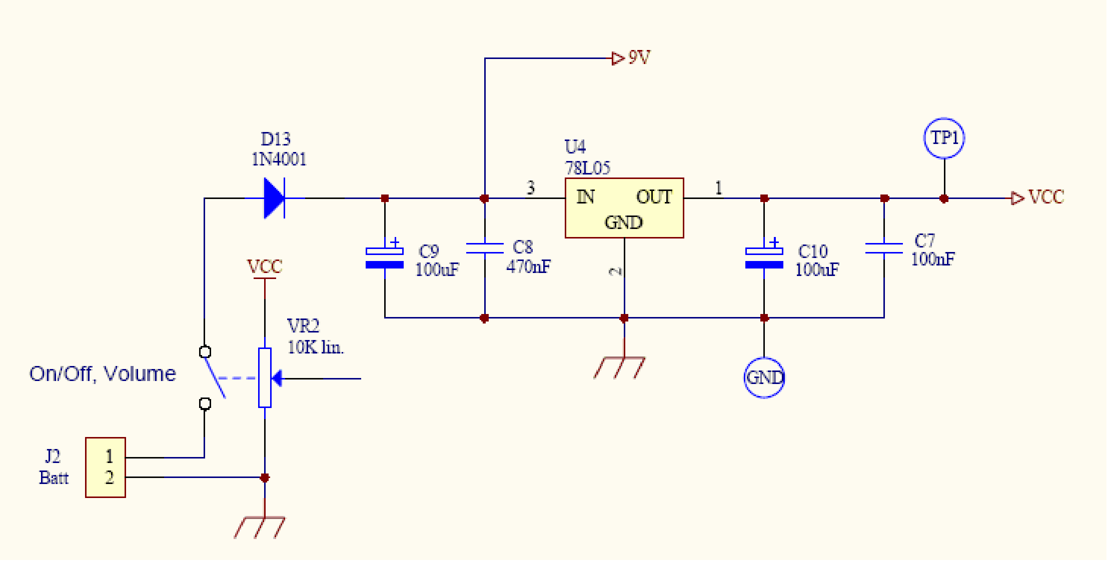
9. Check the unit still operates as expected.

Your Field Strength Meter is complete. We hope you enjoyed building this project.

FSM V1.1 Circuit Operation (How It Works)

This section describes the circuit operation to help with troubleshooting and for general interest. Appendix A shows the full schematic (circuit diagram) of the field strength meter.

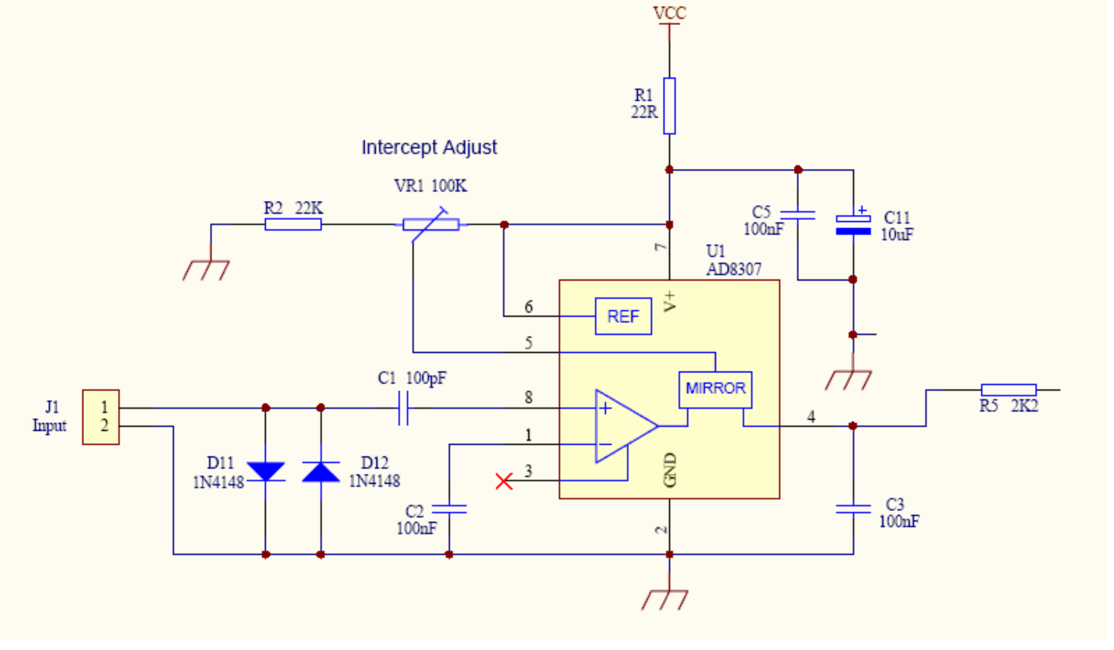
Power Supply Section



The unit is powered from a 9V battery which is connected to J2. Power is switched on and off by the switch incorporated into the volume control VR2.

D13 protects the circuit from an accidentally reversed battery. Power flows through D13 into C9. U4 is a step down regulator with a 5V output. C8 decouples the input of U4. C10 provides bulk storage decoupling for the rest of the circuit. TP1 is the 5V test point.

Log Amplifier Section



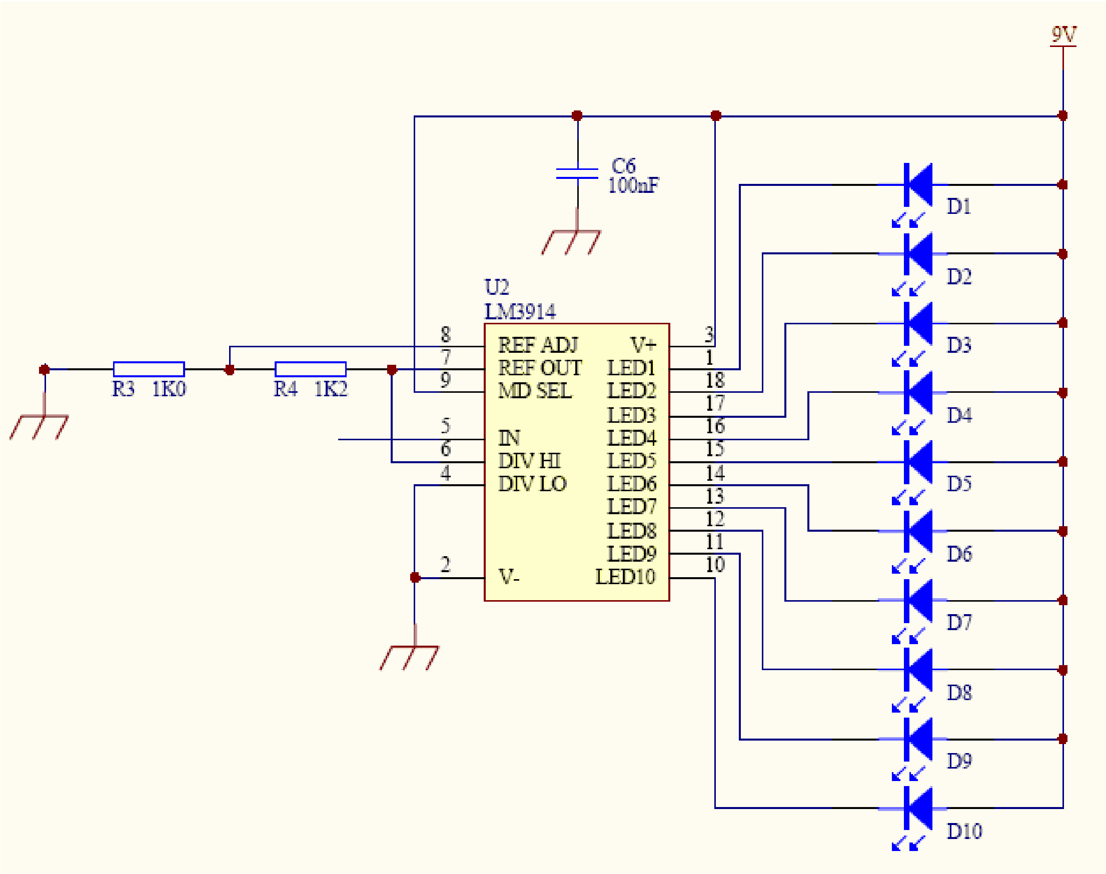
The input signal comes in on J1. D11 and D12 protect U1 from excessive input voltages due to static build up or being in close proximity to a transmitter. C1 AC couples the signal to U1. The input impedance at different frequencies is shown in Appendix F.

U1 is a logarithmic amplifier. It produces a DC output that is proportional to the log of the amplitude of the input signal – in other words its output voltage represents the signal strength of the input signal. Its internal operation is beyond the scope of this document.

The output is on pin 4. R5 and C3 prevent RF from entering the output of U1 in a high field strength environment. C4 decouples the output. The voltage on TP2 is proportional to the signal strength at J1. It is possible to use this signal directly for measurements, however this is not an option provided by the standard kit.

R1 and C11/C5 produce a low noise 5V supply for U1. VR1/R2 feed a variable voltage into pin 5 which adjusts the intercept point. VR1 is used to calibrate the scale of the unit.

LED Bar Graph Section



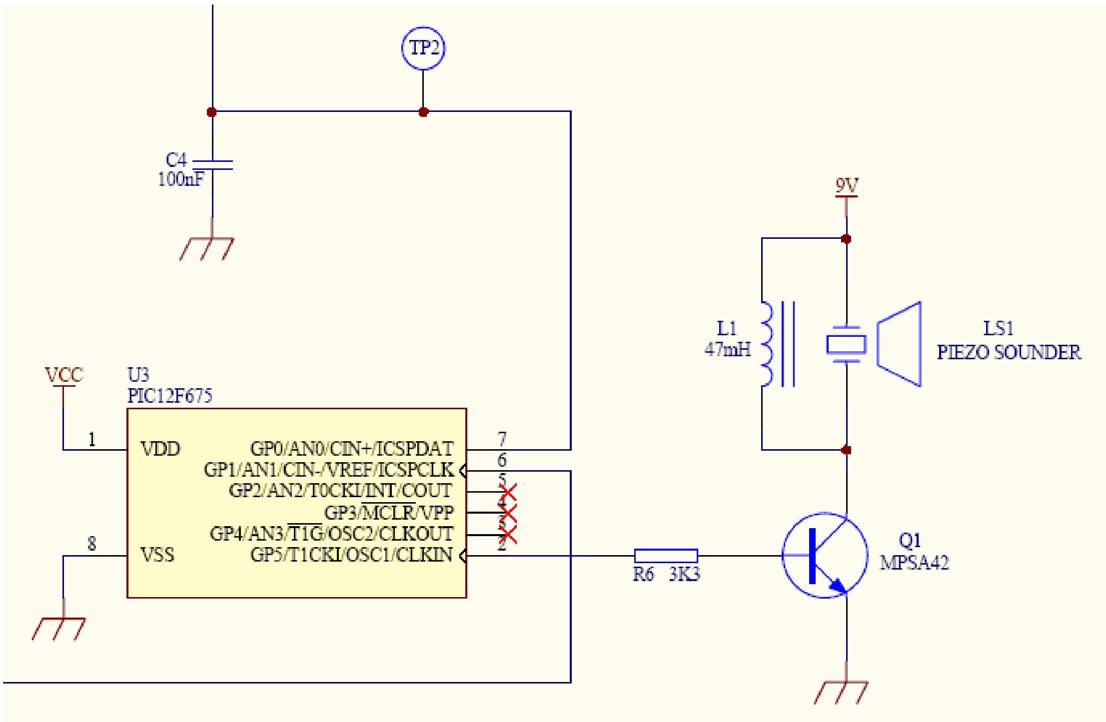
U2 is a self contained bar graph IC. It implements all the logic needed to drive 10 LEDs without the need for resistors. The LED outputs are driven by current sources, programmed to a specific current by the sum of R3 and R4. The ratio of R3 and R4 determines the scale of the bar graph. The bar graph output is linear with respect to the input voltage (the log part of the job has already been done by U1).

U2 is powered directly from the 9V supply, decoupled by C6. There are 2 reasons for this:

- U4 can only supply 100mA. A larger regulator could be used but it would need a heatsink.
- To keep high current swings on the LED supply from disturbing U1 which has a very large dynamic range.

Internally U2 contains 10 comparators and a voltage divider. The outputs of the comparators are connected to the LEDs. As the input passes each threshold, the next comparator is turned on giving the familiar rising bar pattern.

Tone Generator Section



U3 is a general purpose microcontroller programmed to operate as a tone generator (a sort of audio frequency VCO).

The program takes 2 analogue inputs:

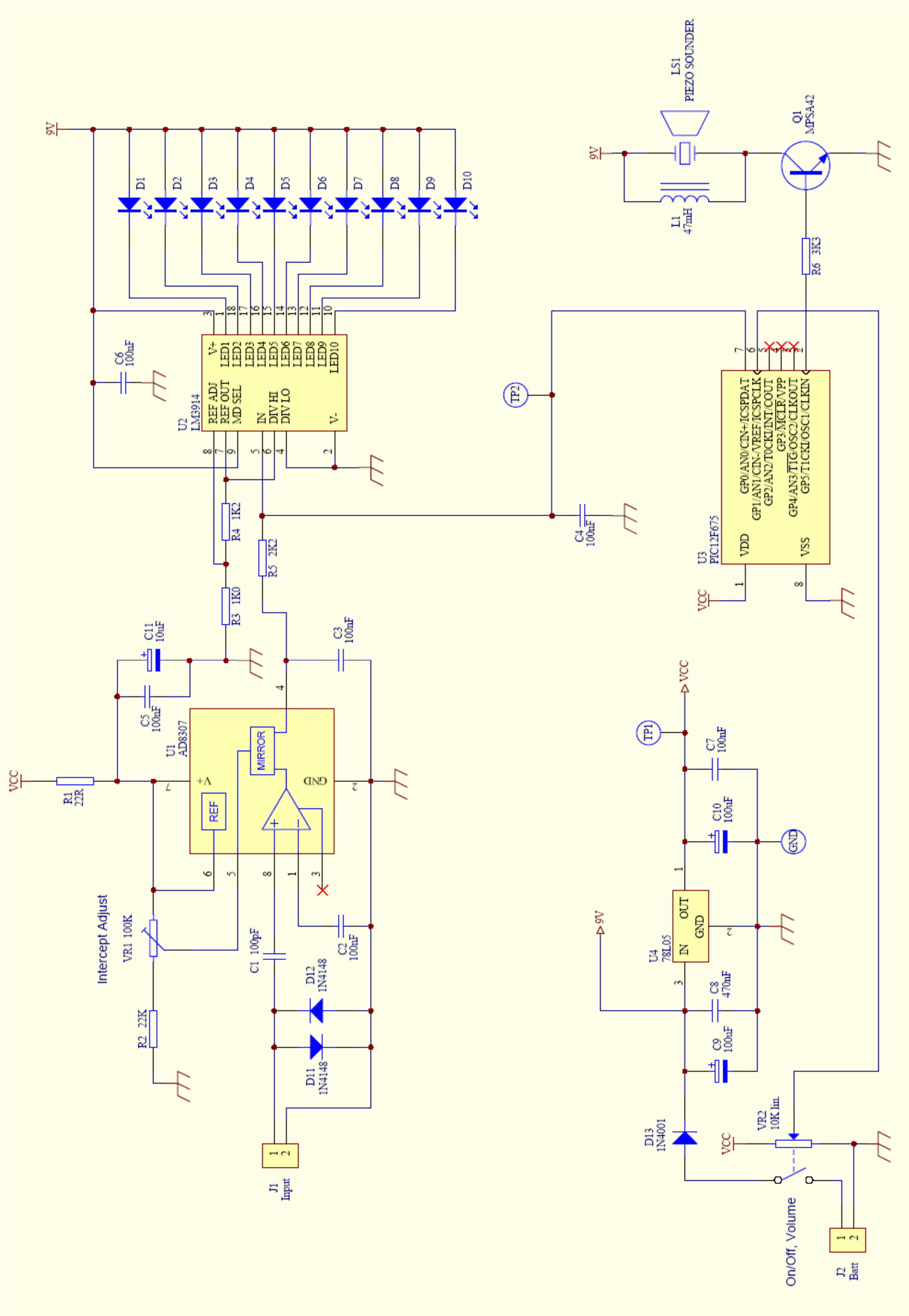
- The signal strength output from U1
- A 0 to 5V control signal from the volume control potentiometer

These signals are processed by the program so as to control a free running software oscillator whose output appears on pin 2. The signal strength determines the oscillator frequency whilst the volume control signal controls the mark:space ratio of the output.

To generate a loud signal on the piezo sounder, Q1 and L1 are 'pumped' by the oscillator output. L1 resonates with the capacitance of LS1 to produce a large voltage across LS1 (approx. 50-100V). Q1 is a high voltage transistor.

C7 (shown in the power supply section) decouples U3.

Appendix A – FSM V1.1 Schematic



Appendix B1 – PCB V1.1 Parts List

Designator	Part Type	Footprint	Qty	Part Number
R1	22R	1206	1	FN 923-6686, RS 223-2041
R2	22K	1206	1	FN 924-1027, RS 223-2439
R3	1K0	1206	1	FN 924-0942, RS 223-2265
R4	1K2	1206	1	FN 923-6821, RS 223-2271
R5	2K2	1206	1	FN 924-0969, RS 223-2300
R6	3K3	1206	1	FN 924-0977, RS 223-2338
VR1	100K	PRESET	1	RAP 67-0245, FN 122-7542
VR2	10K lin.	Vishay 148 Series + SW	1	RS 484-9180, FN 855-7250
C1	100pF	1206	1	FN 360-6077, RS 264-4056
C2-C7	100nF	1206	6	FN 644-316, RS 464-6852
C8	470nF	1206	1	FN 128-8280
C9-C10	100uF	CAP_RAD_2.5P_6.5D	2	RAP 11-0245, FN 945-1188
C11	10uF	CAP_RAD_2P_5D	1	FN 945-1242
L1	47mH	IND_RAD_3.5P_7.5D	1	FN 107-7047
D1-D10	Green	LED_SQ_5MM	10	RAP 56-1855, RS 229-2576, FN 114-2620
D11-D12	1N4148	DIODE-0.3	2	FN 956-5124
D13	1N4001	DIODE-0.4	1	RAP 47-3130, FN 956-4993
Q1	MPSA42	TO-92	1	FN 101-7719
U1	AD8307	DIP-8	1	DK AD8307ANZ-ND
U2	LM3914	DIP-18	1	RS 534-2977, RS 534-2977A, FN 948-6500
U3 *	PIC12F675 *	SO-8	1	DK PIC12F675-I/SN-ND, FN 975-9026 *
U4	78L05	TO-92	1	DK MC78L05BP-APMSCT-ND, FN 959-3853
J1	Antenna	BNC LP R/A PCB Mount	1	RAP 16-0075, RS 447-437, FN 107-6295
J2	Batt	PP3 battery clip	1	RAP 18-0094
TP1	+5V	1mm scope loop test point, red	1	FN 873-1209, RS 262-2220
TP2	RSSI	1mm scope loop test point, white	1	FN 873-1225, RS 262-2062
TPG	Ground	1mm scope loop test point, black	1	RS 101-2385, FN 873-1195, RS 262-2214
LS1	ABT-430-RC	Piezo sounder	1	FN 102-2403, RAP 35-0286
		TOTAL COMPONENTS	**44**	

* U3 needs to be programmed before assembly. The blank part number is given above. Parts supplied in the kit are already programmed.

Appendix B2 – Additional Parts List

Designator	Description	Qty	Part Number
PCB	Double sided PCB V1.1, 80mm x 56mm	1	-
CASE	Aluminium extruded 80mm x 63mm x 30mm	1	FN 114-8681
PANEL1	End panel for top of box, drilled	2	FN 114-8691
PANEL2	End panel for bottom of box, plain		See PANEL1
KNOB	15mm collet knob	1	MAP JZ47B
CAP	Red cap for knob	1	MAP JZ68Y
LABEL	Sticky label for box	1	-

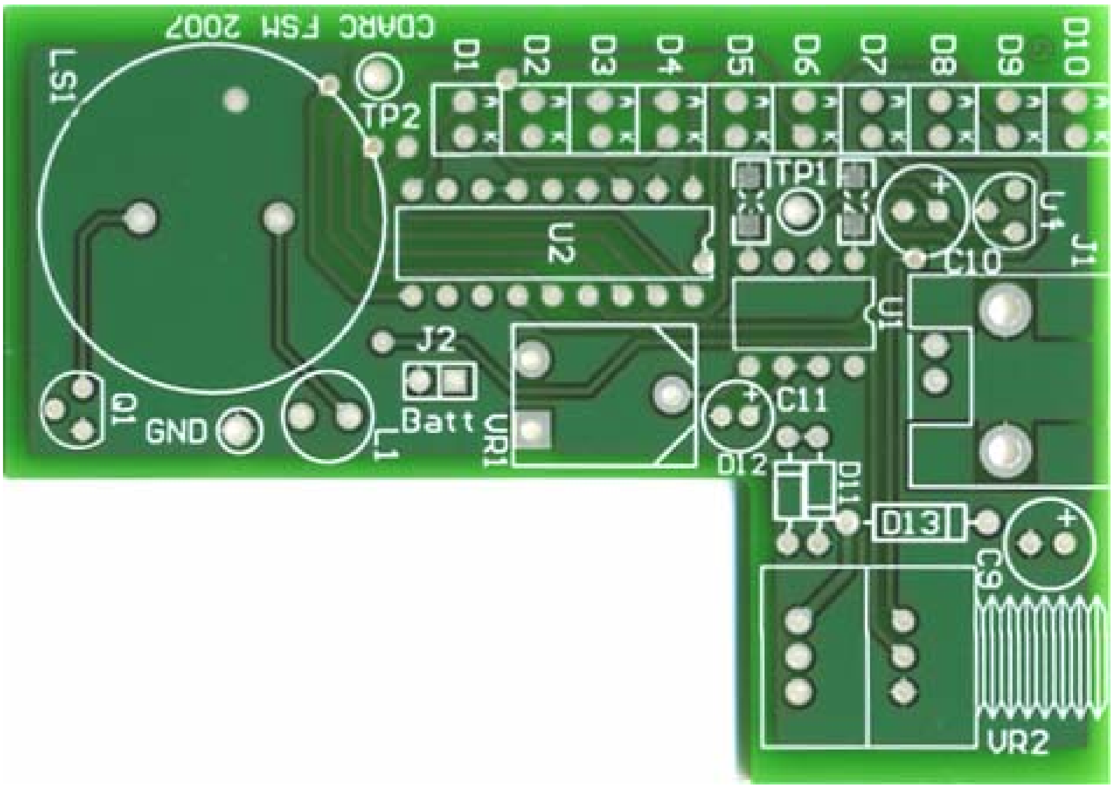
Parts List Key

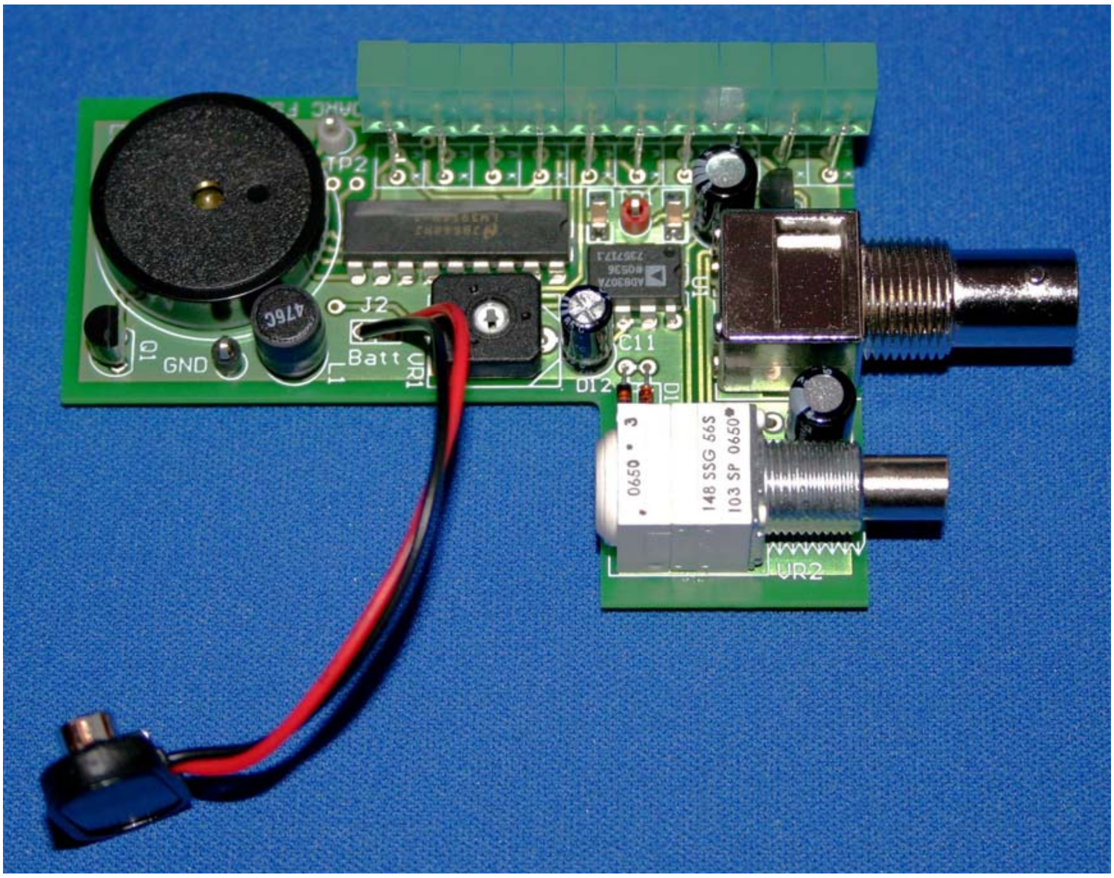
Designator	A unique identifier for this part on the board e.g. R1, C1, Q1 etc. This can be given as a range or list e.g. C1-C3 means C1, C2 and C3.
Part Type	The type or value of the component e.g. 10K, 100nF, 74LS04
Footprint	The shape of the area on the PCB for the component. Often this translates to the package style e.g. the same value of resistor comes in several different sizes, transistors come in standard cases e.g. TO-92 and you can often get the same IC in a DIP or a surface mount package.
Qty	Quantity required on the PCB. A blank indicates that the component is accounted for somewhere else. A quantity of zero indicates that there is a space on the PCB but the component is not fitted in the standard build.
Part Number	Part numbers are for guidance only and all part numbers shown are suitable, however part numbers are listed in order of preference (usually because of price).

Part numbers are prefixed by supplier as follows:

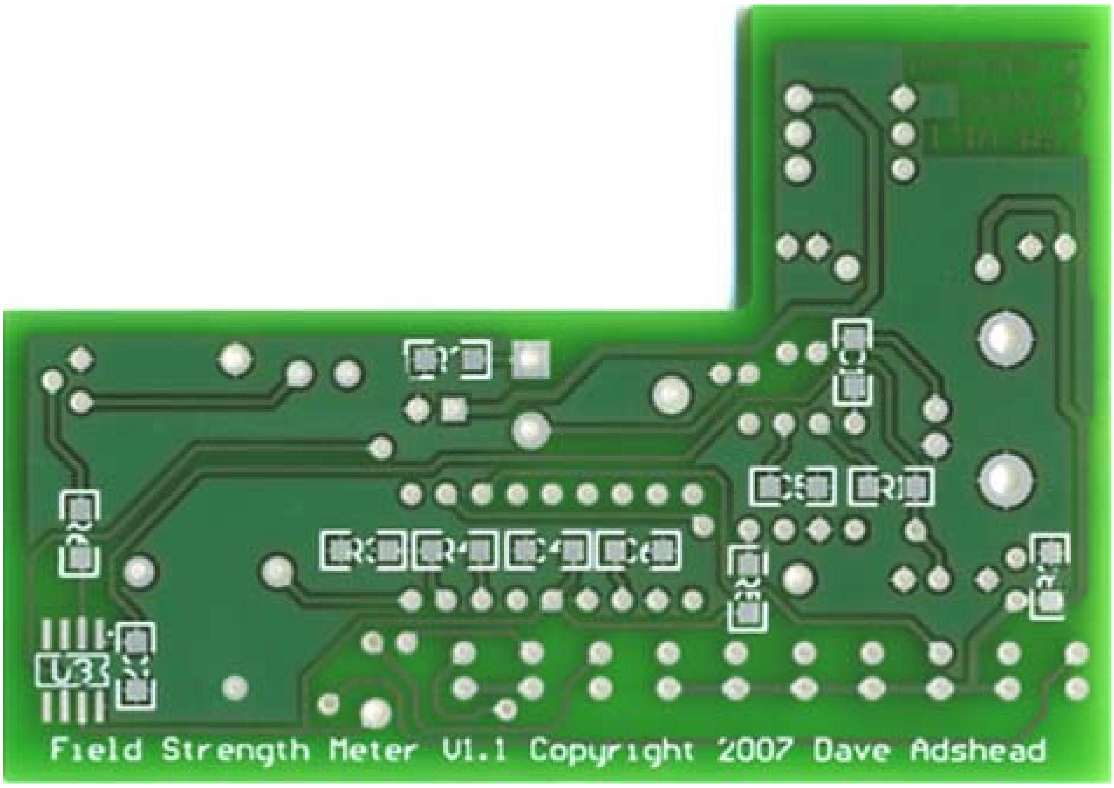
Prefix	Supplier	Website
FN	Farnell Electronics	http://uk.farnell.com/
RS	RS Components	http://rswww.com/
MAP	Maplin Electronics	http://www.maplin.co.uk/
RAP	Rapid Electronics	http://www.rapidonline.com/
DK	Digi-Key UK	http://dkc1.digikey.com/uk/digihome.html

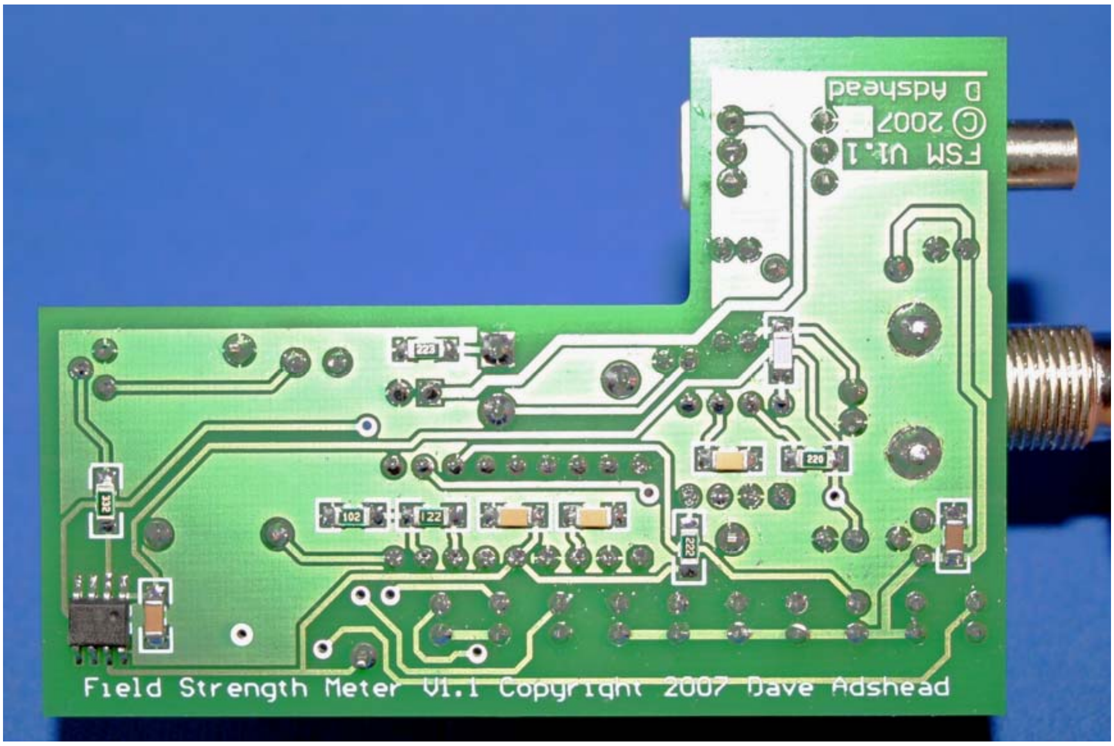
Appendix C1 – PCB V1.1, Top Side



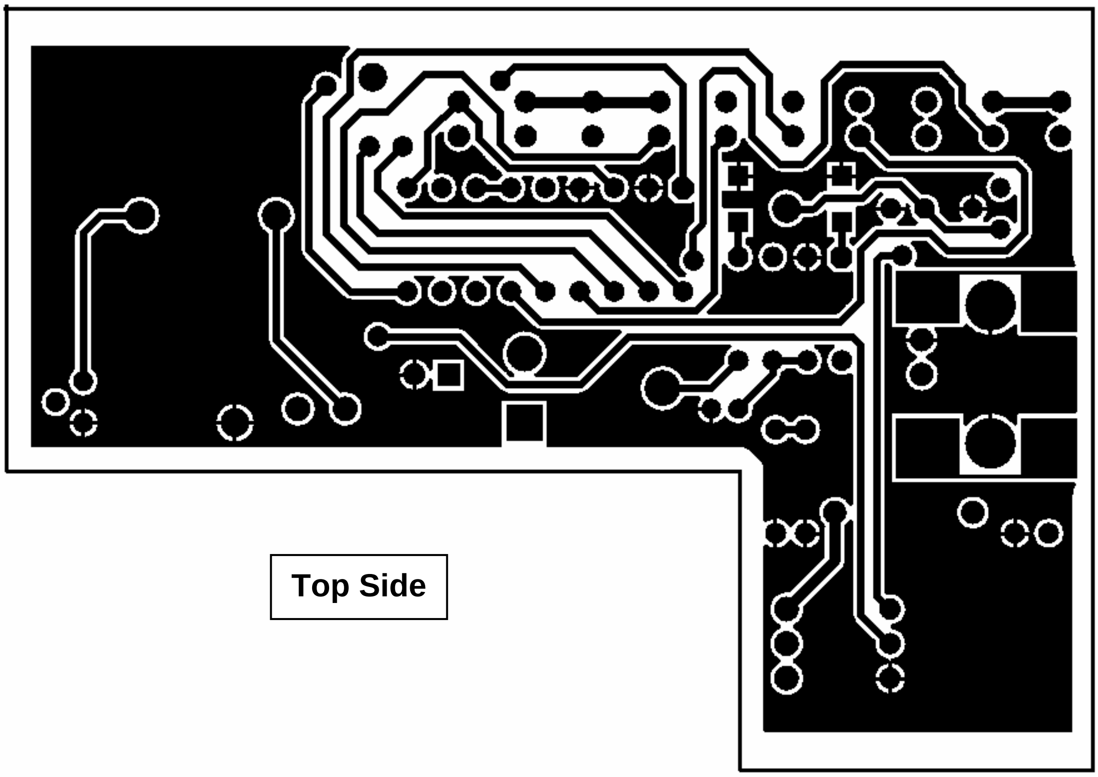


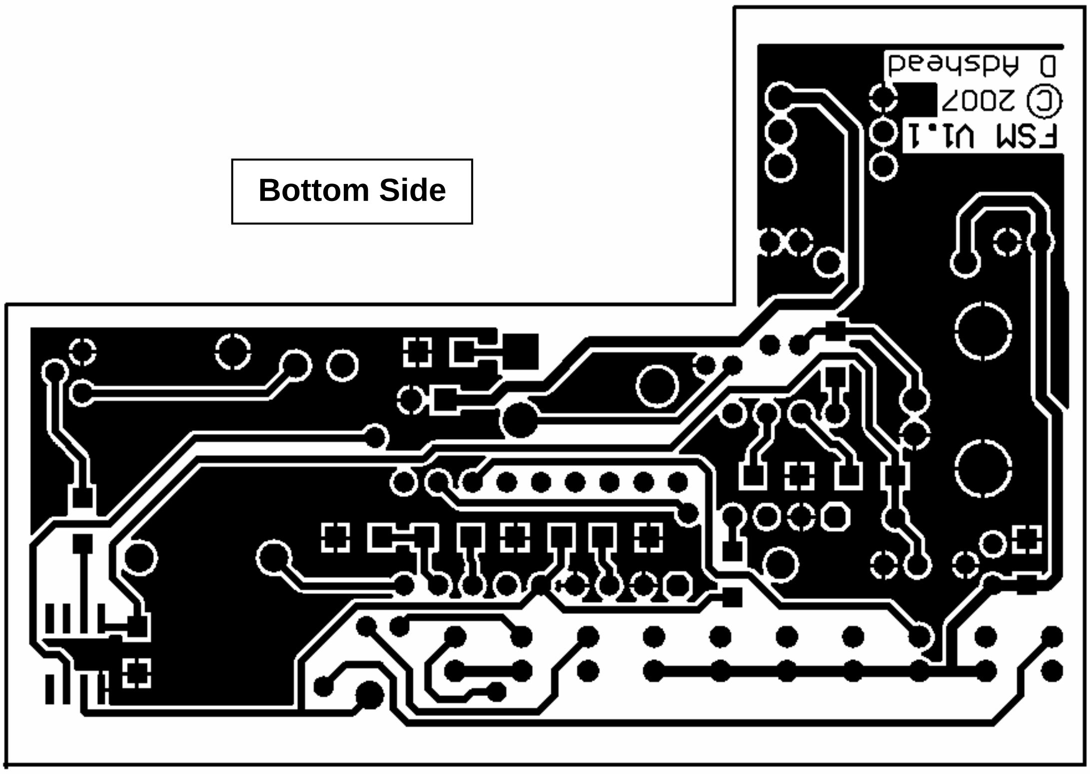
Appendix C2 – PCB V1.1, Bottom Side



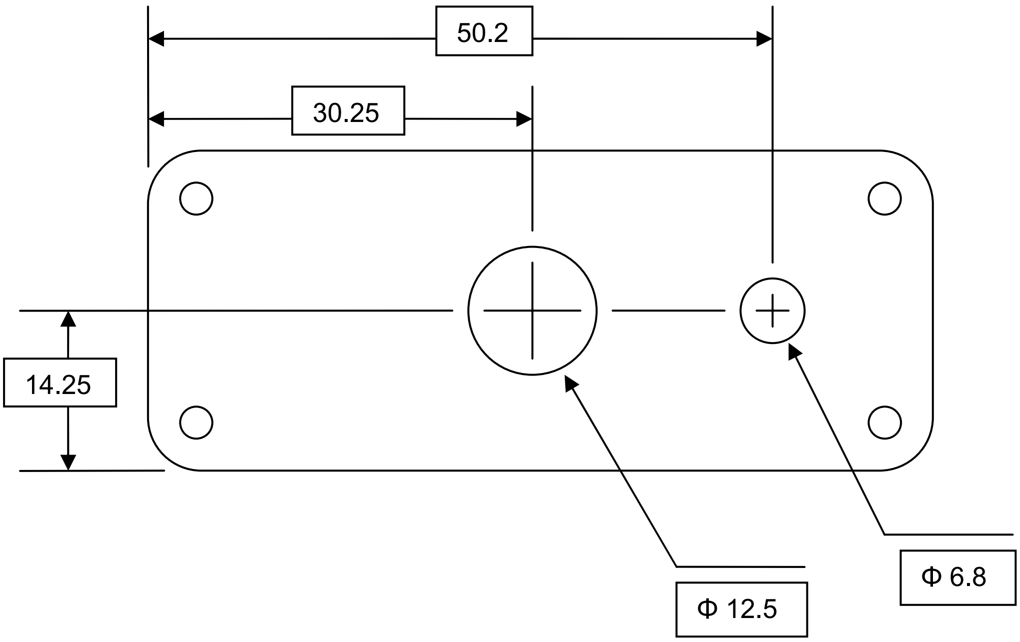


Appendix D – PCB V1.1 Copper Pattern (not to scale)



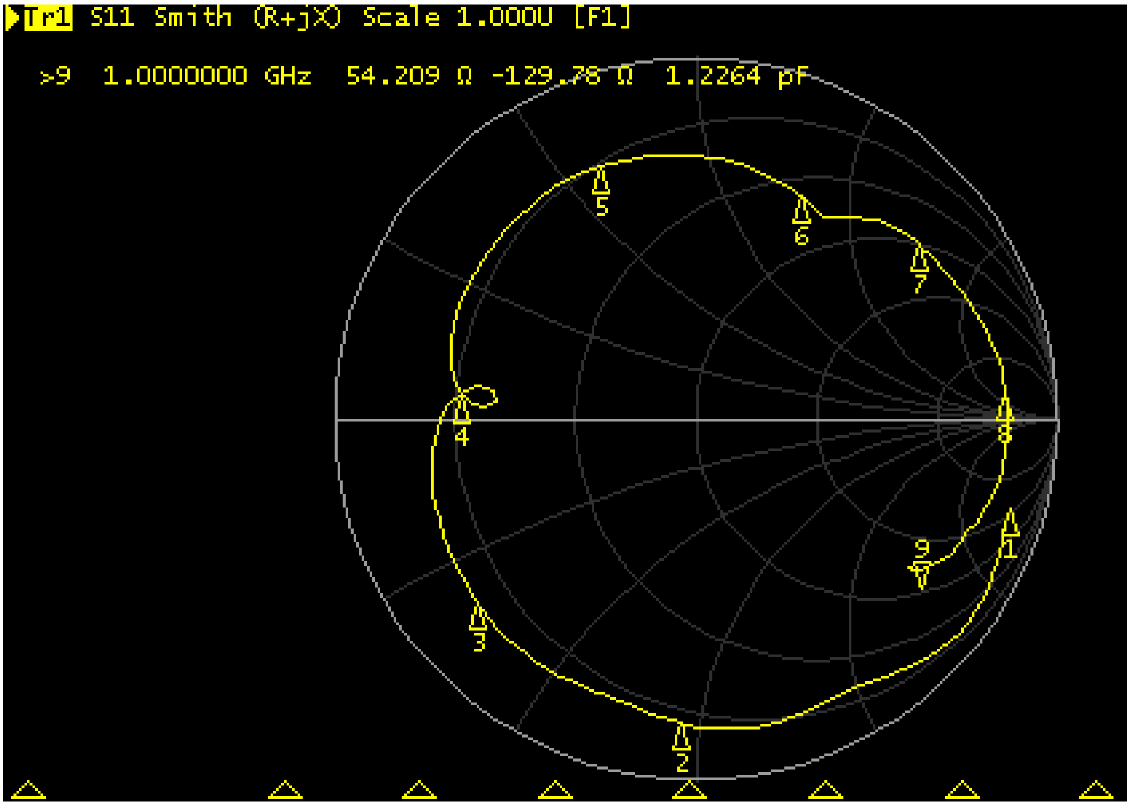


Appendix E – Top Panel Drill Drawing



All dimensions in mm.

Appendix F – Input Impedance



Point	Freq (MHz)
1	10
2	200
3	300
4	400
5	500
6	600
7	700
8	800
9	1000

As is apparent from the Smith chart, the input is not matched to 50Ω. The chart can be used as a guide for designing matched filters etc. Some useful frequencies are given below. More data is available on request from Dave Adshead.

Freq (MHz)	Real	Imaginary	Equiv. C / L	Matching L / C	R for 50R
10.00	115.03	-313.80	50.72pF	5uH	88R (p)
19.90	83.97	-272.72	29.33pF	2.2uH	124R (p)
143.65	12.01	-75.14	14.75pF	83.25nH	38R (s)
430.75	8.35	11.75	4.34nH	31.45pF	42R (s)