

EMF Meter Build

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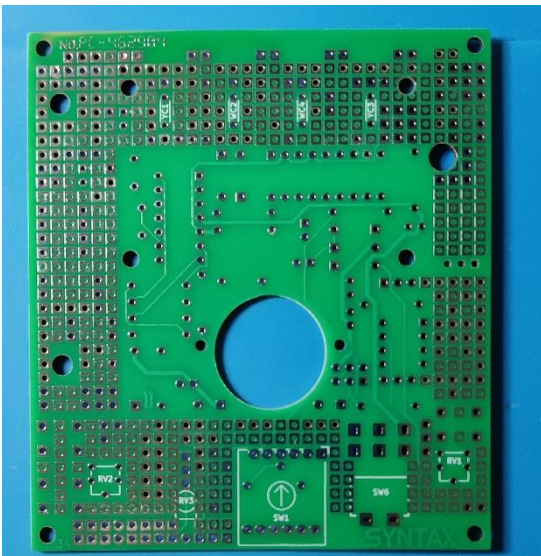
Description



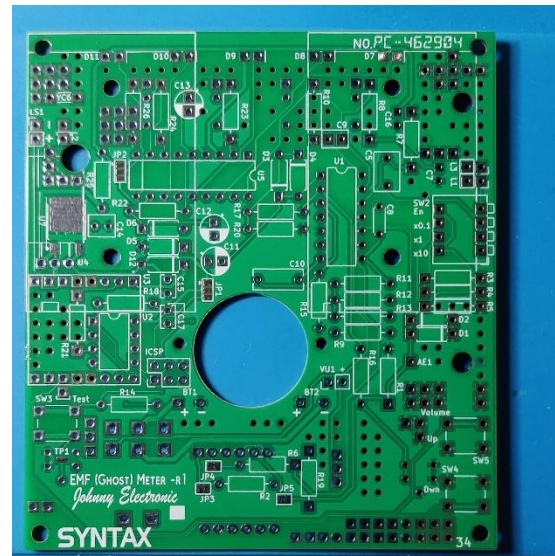
Assembled EMF Meter

Printed Circuit Board

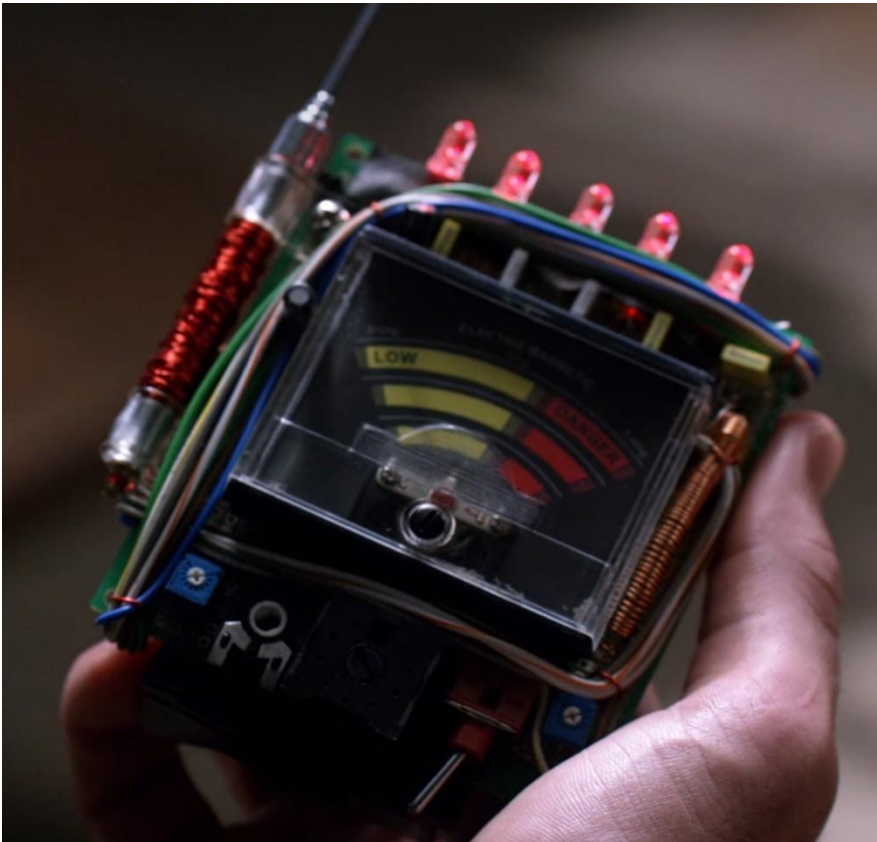
Front



Back



This document describes the assembly of the EMF Meter which was made to be a replica of the one used in the Supernatural TV series. I based my initial version on Sam's EMF Meter from S4 E13 (and seen in a few other seasons).



SAM's EMF Meter with 5 Capacitors (S4 E13 25:10)

This is a functional EMF meter that can detect both Electric and Magnetic fields. It can also be built as a simple prop by not populating the analog components. The meter was designed to replicate a variety of the meter configurations used in the TV series.

The meter can be powered by one of three methods:

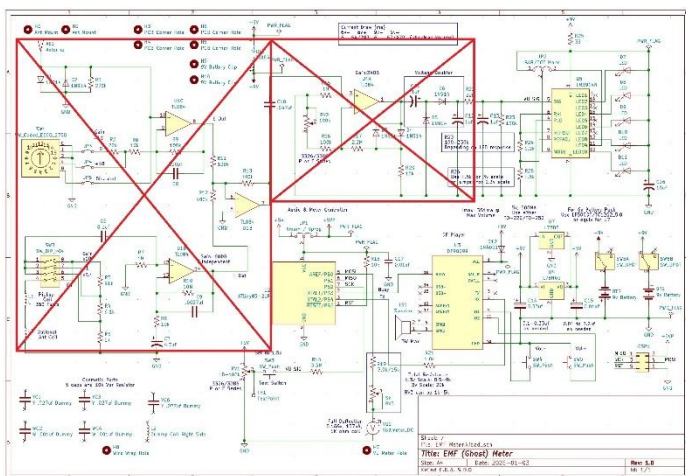
- Using two 9-volt batteries to provide +/- 9 volts
- Using either one or two 9v batteries with a 9v negative voltage buck converter
- Using 4 AA batteries to provide 6v with a 6v negative voltage buck converter

The board was designed to support a number of different part selections for the components:

- Optional 5th yellow capacitor
- Supports 3326 or 3386 F and P series blue potentiometers
- Supports PT10 or PT15 black potentiometer
- Uses a functional EECO switch to select gain for the E-Field detector and can support a number of different EECO switches. Specifically, EECO 2700 series -02, -19, -31, -33, -41, -44 will work as is and others can be adapted to work. The PCB footprint supports 6 and 12 pin switches.
- Flexible wiring options.

An ATTiny85 is used to control the DF Player sound board and the analog meter deflection. Programming for the ATTiny85 can be done before mounting and can also be accomplished using an In-Circuit Serial Programming (ICSP) port to program the mounted part on the board. There is a jumper option (JP1) to select either the main board power or to use the ICSP port for programming power. I also have available a soft touch programming cable for programming this part. There are many YouTube videos on Arduino programming options.

If you only want to make the prop version then do not populate IC1 and associated components and switches.



Board Details

- Dimensions: 86 x 95 mm
- Parts Supported:
 - RV1/2: 3326 or 3386 Bourns blue F or P series potentiometer
 - RV3: PT15 or PT10 series black potentiometer
 - EECO Switch: 27xx02/19/31/33/41/44
 - 5-volt regulator. Using a 9v supply a 7805, 500 ma regulator, TO-220 package can be used or similar DPAK type. If using a 6v supply a Low Drop Out (LDO) regulator must be used. The LF50 and TC1262 will both work.
- Programming using an ICSP port.

Parts List

See the EMF Board BOM for a detailed list of parts and part suppliers.

Pre-Assembled Boards

Due to the availability of certain parts the pre-assembled meters may vary. The listing for any pre-assembled meter will show the specific items used for that build.

In general, an assembled EMF Meter will have the following the standard build options:

- A 4 capacitor build (2 yellow and 2 White). A fifth yellow capacitor will be included with the meter in case that is a configuration you prefer to add. You can also make a comment with the order if you want it installed. An effort will be made to have the correct capacitor value of 22n for yellow and 10n for white.
- LED display mode set to BAR
- 6v AA power pack with a buck converter providing -6 volts.
- 5v LDO regulator
- 3326 Series blue potentiometers
- PT15 black potentiometer
- EECO switch will vary based on availability
- Antenna will vary based on availability. If the ATT 5100 6mm is available it will be used otherwise it will be a 5mm standard telescopic.

- See the Board Options/Configuration section for additional details.

Assembly Guide

Caution: Electrostatic discharge (ESD) is a sudden and momentary flow of electric current between two differently-charged objects when brought close together or when the dielectric between them breaks down, often creating a visible spark associated with the static electricity between the objects.¹

This type of shock can cause damage to ESD sensitive parts such as those used in this build especially U1,2,3,5. Proper ESD protection and soldering equipment should be used to prevent damage to parts during assembly and implementation into your project.

Assembly Planning

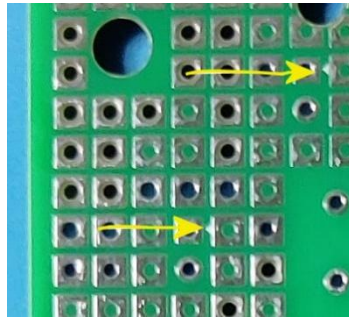
This assembly uses all through hole parts except for possibly the 5-volt regulator. A medium to fine tip soldering iron is useful along with 0.034" or smaller flux core solder and extra flux if needed. See the references section for a YouTube video link on assembling this board.

PCB Assembly

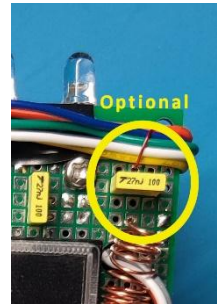
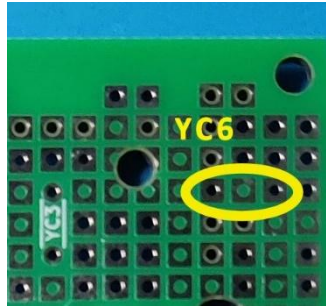
- PCB assembly can be completed in any order except with U2 and U3. See assembly notes below.
- You will want a good set of wire cutters that can cut flush to the PCB surface. The area under the meter should be as flat and level as possible. **Also, any components soldered under L2 should not have leads through to the top surface as they may be shorted by the coil. Cut the leads as short as possible before soldering. There is no connection between the top and bottom pads for connections in this area.**
- The majority of components will be installed on the back of the PCB. The board was designed to hide most of the components under the VU Meter.
- My recommendation is to complete the back of the board first by mounting all the IC's starting with U1 and U5.
 - o **NOTE: U2, R18 and R21 must be installed before U3. Install U2, R18 and R21 then U3 on top of those parts.**
- Mount the 5-volt regulator (U4 or U7 depending on the type used) next.
- You can apply solder jumpers for JP1 and JP2 now or later but do not forget them.
- Install the resistors, capacitors, and diodes next.
 - o **NOTE: Capacitors C5,8-13 should be mounted as flat as possible against the PCB so there will be clearance for the battery pack latter in the assembly. See assembly images at the end of this document.**
 - o **NOTE: C7, C16, YCx, WCx will all be installed on the top of the PCB. C7 and C16 mounting locations are shown on the bottom of the board. Both of these are polarized parts so look for the small "+" on top of the board for proper placement. You also have the option of installing a 5th yellow capacitor and it's mounting location is shown on the bottom also.**

Cap Polarity Marks

¹ Definition provided by From Wikipedia, the free encyclopedia. For more information on ESD see https://en.wikipedia.org/wiki/Electrostatic_discharge



YC6 – 5th Yellow Capacitor

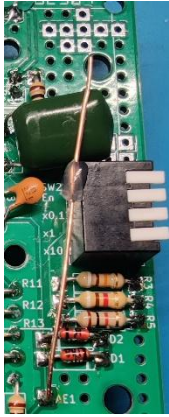


- Next install SW2 to SW5
- The LEDs can be installed either on the bottom or the top. Looking at images from the TV series they have done it both ways so it's your choice. Mounting on the bottom lets you use some hot glue to better secure the LEDs to the PCB.
- This completes the bottom assembly

- Continue to the top of the PCB and mount the power switch SW6 and EECO switch SW1
- If you did not mount the capacitors C7, C16, YCx, WCx then mount them now.
- Mount the potentiometers RV1-3
- This completes the PCB assembly. Continue to the mounting of the antenna and coils for the next step for this assembly.

Antenna, Coil Assembly and Mounting

- Main Antenna. An antenna is used to detect electric (E) fields. The telescopic antenna can be used for this except that if you touch it with your hand, it will detect your E-field and react. Thus, a different antenna should be installed for E-fields. Use a short piece of wire about 1 ½ - 2" (You can use the same 22 AWG solid copper wire used for coil L2). Make a right-angle bend at one end and solder that short section to pad AE1. Use some hot glue to secure the remining part to the back of SW2.



- There are three coils that can be mounted with two of them functional and one cosmetic only.
- Coil L2 is mounted to the right side of the meter and is cosmetic only. The mounting holes are marked on the bottom of the meter. The coil was made using 22 ga. plain copper wire around a wire wrap tool (I used a #2 Craftsman Philips screwdriver shaft to get a 6.4mm diameter coil). The coil should be the length of the meter or about 1 3/4".



There are two upper pads and one lower pad for mounting L2 so you can stretch the coil or make it longer if desired.

Note: If you have any wires that poke through and touch the coil you can add a small bit of hot glue to coil bottom to both secure it and isolate it from shorting out parts.

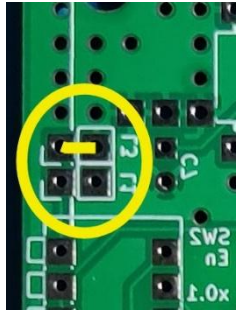
- Coil L1 and L3
 - o Coil L1 is a 350 turn of 36 AWG enameled wire that is hot glued to the bottom of the PCB at either the lower left or right side. See the available video of making the coil and 3D files are available for printing the core.



- o Coil L3 is the coil around the antenna and it can be included in the circuit to pick up magnetic fields. I used 26 AWG red enameled wire to wrap around the antenna. Before wrapping the antenna with wire, you will want to attach the p-clips with 6-32 3/8" screws with nuts. Align the screws/p-clips with the PCB mounting holes but do not mount it to the board. Once you have the p-clips aligned tighten the nuts so the clips do not move. You can now start wrapping the enameled wire between the two p-clips. If you will be

using the coil in the circuit you will need to start and end the coil toward the top of the antenna so it can be attached to the circuit board.

- Make the first layer wrap tight and uniform around the antenna. On the second pass feel free to add multiple layers and give it a non-uniform look much like a free-handed wire wrap.
 - **NOTE: If you do not use the coil in the circuit then a small jumper wire will be needed to jump the L3 connection.**



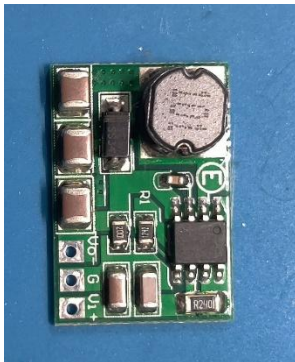
- Mount the antenna/coil using P-Clips. 3D files are also available for printing these.
- Coil sensitivity is based on form size and number of windings. Increasing windings will make the magnetic field detection more sensitive.

Attach Speaker

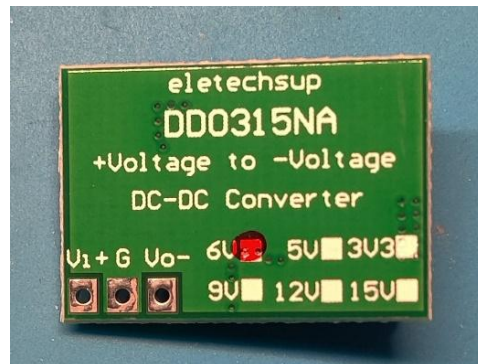
- Connect the speaker to the LS1 pads following the polarity printed. You will mount the speaker to the battery holder in the next step.

Mounting Battery Packs

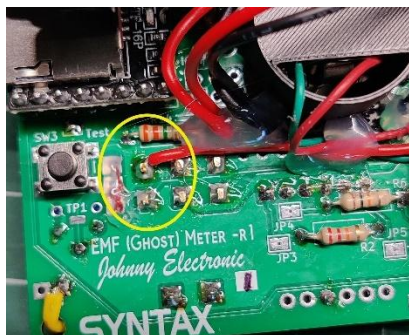
- Using hot glue attach the speaker to the bottom of the battery pack. Make sure you have enough wire to allow the battery pack to attach to the PCB.
- Use either 4-40 or M3 to mount the battery packs with a minimum of 10mm standoffs. I've provided some 3D files for 9-volt battery and a 4-AA battery pack so they can be mounted to this board.
- For 9v connect two battery clips to BT1 and BT2 following the correct polarity, Red +, Black -.
- For 6v connect the 4-AA battery pack to BT1. Connect a buck converter such as a DD0315NA configured for **-6v with Vo- to BT2 - and G to BT2 +**. This was originally the negative supply which is why the connections may seem backward. The Vi+ will connect to the power switch terminal shown below. You can use hot glue to mount the buck converter on the underside of the battery holder.



Buck Converter Front



Buck Converter Back



Buck Converter Vi+ Connection

- 9v systems can also use a -9v DD0315NA instead of the second battery or the two batteries can be connected in parallel for longer use.

Mounting Meter

- Once the battery packs are mounted the VU meter can be installed. Review the available video for options for making the meter. I've provided a 3D print file for the meter base I used and it will also align with the battery pack mounting screws.
- Use a small dot of hot glue in each corner of the meter and mount the meter to the front of the PCB placing it through the hole provided. Use more hot glue on the back of the PCB around the area where the meter goes through the PCB. This will add additional hold for the meter.
- Connect the meter wires to VU1 and follow the proper polarity.

Adding Cosmetic Wires

- This board was designed to support various wiring options. The wires can be either hot glued to the back of the PCB or in some cases soldered to available pads.
- From various references wire gauge is either 28 AWG or 24 AWG. My preference was 24 AWG based on the various images from the TV series. I've noted some of the wire combinations seen in the series in the table below.
- Available wire clamp locations are also shown in the image below (Marked in RED). 22 AWG wire seems to be what was used in the show versions.
- Feel free to pick your own wire colors and routes.

Series/Episode Shown	Upper Harness	Lower Harness	Option 1A	Option 1B
General Prop Analysis	2-3 Grn, Blu, Wht/Brn, Wht/Org	Wht/Brn, Grn		
Rainbow Prop Analysis	Wht, Org, Yell, Blu, Grn, Red			
Westaby Rainbow (28awg)	Grn, Blu, Purp, Gry, Wht	Brn, Red, Org, Yell, Blk		Brn, Yell, Blk
S2 E18 8:54 - Dean's, 4 caps	Brn, Wht, Blu,Grn, Gry?, Yell	Brn, Grn, Yell	Yell	
S11 E23 14:30 - Dean's 4 caps, no blue pots	Red, Org, Blu, Yell, Wht, Grn	Wht, Purp, ??? Different routing		
S3 E14 17:08	Wht, Blu, Yell,	Yell, Grn, Blu,	Yell, Brn?	

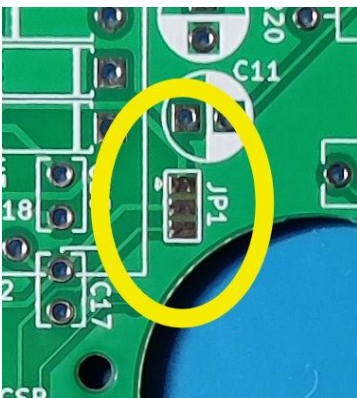
Board Options/Configuration

This section should be reviewed for those that are assembling the board themselves or purchased a pre-assembled version.

Using the table below determine which power method will be used for programming. Selecting JP1, 1 & 2 will connect U2 (ATTiny85) to the main 5-volt supply for programming. Using JP1, 2 & 3 you can draw programming power from the ICSP port instead. You will need to remove the solder jumper on 2&3 after programming and connect 1&2 for normal use.

Jumper Options

JP1	1-2 – Main 5v
	2-3 – ICSP 5v

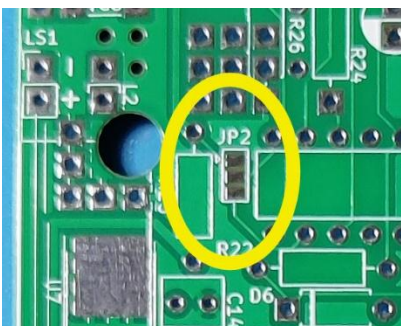


Solder jumper selecting programming power option. ^ marks pin 1

Using the table below determine which display method will be used for the LED's. Selecting JP2, 1 & 2 will provide a BAR display mode. Using JP2, 2 & 3 will provide a DOT display mode and also helps conserve battery power.

Jumper Options

JP2	1-2 – BAR Mode
	2-3 – DOT Mode



Solder jumper selecting display mode option. ^ marks pin 1

Making a solder bridge

You can make your connection by selecting which half of the bridge to connect but make sure you do not connect both parts. The center pad will connect to either the upper or lower pad, ie pad 1-2 or 2-3. Once you determine the pads to connect add some solder to each pad then continue to heat both pads adding more solder if needed until the two pads are connected. The images below show some examples:



Step 1
Example bridging pad 1 & 2



Step 2
Completed Bridge



Bad Solder Bridge
All pads connected

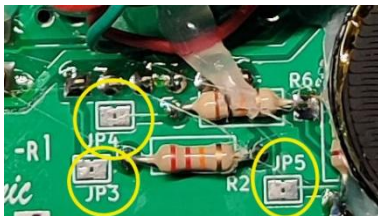
Switch Settings

SW1

EECO Series 2700 Switch

The rotary EECO switch is used to control the gain and operation of the E field circuit. The operation of the switch will depend on the type of switch used. The tables below show a number of switch types and their associated setting. This allows adjustment of the E-fields sensitivity or the ability to disable the E-Field and just check for H-fields.

Most of the pre-assembled boards will have a 271131M installed and use the last chart below. If you need to use another type of switch or want to rewire an existing one you can use JP3,4 and 5. These bridged jumpers can be cut in the center so that the connection is broken. Wires can then be added to attach to different terminals.



27xx -02, Table B02 (Terms 1,2,8)

BCH 1-pole, 10 position

27xx -33/34, Table B07 (Terms 1,4,8)

BCH 1-pole, 16 position (Orange and Blue Section)

Dial	1	2	4	8	Function	
Truth Table					B02	B07
0					Gain 0	Gain -10
1	●				Gain -10	Gain 0
2		●			Gain +10	Gain -10
3	●	●			Gain +10	Gain 0

4			●		Gain 0	Gain +10
5	●		●		Gain -10	Gain +10
6		●	●		Gain +10	Gain +10
7	●	●	●		Gain +10	Gain +10
8				●	Disabled	Disabled
9	●			●	Disabled	Disabled
10		●		●		Disabled
11	●	●		●		Disabled
12			●	●		Disabled
13	●		●	●		Disabled
14		●	●	●		Disabled
15	●	●	●	●		Disabled

-19, Table C13 (Terms 1,2,8)

BCH 1-pole, 10 position

Dial	1	2	4	8	Function	
Truth Table					C13	
0	●			●	Disabled	
1				●	Disabled	
2	●	●	●		Gain +10	
3		●	●		Gain +10	
4	●		●		Gain 0	
5			●		Gain -10	
6	●	●			Gain +10	
7		●			Gain +10	
8	●				Gain 0	
9					Gain -10	

27xx -31/41, Table C16 (Terms 1,4,8)

BCH 1-pole, 16 position

Dial	1	2	4	8	Function	
Truth Table					C16	
0	●	●	●	●	Disabled	
1		●	●	●	Disabled	
2	●		●	●	Disabled	
3			●	●	Disabled	
4	●	●		●	Disabled	
5		●		●	Disabled	
6	●			●	Disabled	
7				●	Disabled	
8	●	●	●		Gain +10	

9		●	●		Gain +10	
10	●		●		Gain +10	
11			●		Gain +10	
12	●	●			Gain 0	
13		●			Gain -10	
14	●				Gain 0	
15					Gain -10	

SW2

Piano DIP Switch

The lever DIP switch is used to control the gain and operation of the H field circuit. The table below shows the setting for each switch position. **For proper operation switch 1-3 must always have one selection enabled.**

1	Gain x10 – Provides a gain setting of 10
2	Gain x1 – Provides a gain setting of 1
3	Gain x0.1 – Provides a gain setting of 0.1
4	Enable – Connects or disconnects coil L1 and L3 if used. Enables checking for E-fields only

Sound Files (MP3)

The sound files are stored in a folder named /mp3 on the SD card. Six files are available but only five are used in the program for the EMF meter. This table lists the files, functionality, and associated code define.

File Name	Define Name	Function
0001_emf start.mp3	EMF_TONE_START	Initial start up when a signal is detected or test button pressed
0002_emf low short.mp3	EMF_TONE_LOW	Used for mid-point signals that are neither high or low
0003_emf steady short.mp3	EMF_TONE_STEADY	Not used
0004_emf steady long.mp3	EMF_TONE_STEADYL	High tone when signal reaches maximum
0005_emf steady end.mp3	EMF_TONE_END	Signal going back down to off
0006_emf power up.mp3	EMF_POWER_UP	Used for initial setup/power on.

EMF Meter Adjustments and Power Up

1. Before powering up the meter check for any shorts by doing an ohm measurement across the +/- battery connector.
2. Adjust all three potentiometers to their mid points.
3. Enable one of the gain switches of SW2 (1-3) and enable 4.
4. Set SW1 (EECO Switch) to one of the enabled gain settings.
5. Connect or install batteries and flip the power switch on.
6. Within a second you should see the meter briefly deflect.
7. Press SW3 (Test Button) and you should see the LED's and VU Meter deflect and some sound effects. While pressing SW3 adjust RV1 until all 5 LED's are on.
8. Again, press and hold SW3 and adjust RV3 for full meter deflection.
9. RV2 (Detector common gain) will not need further adjustment.
10. Insert SD card with audio files.
11. Toggle power switch. The audio player will initialize with a short sound effect and a meter deflection.
12. To test the E-field circuit touch the copper wire antenna with your fingers. The meter should react.

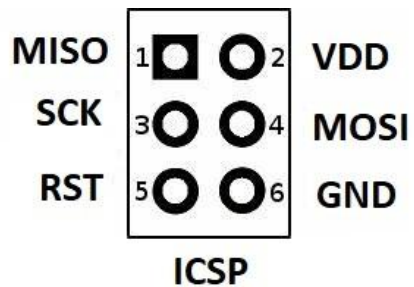
13. To test the H-field circuit move the meter toward a transformer or electrical appliances.



Meter Adjustments

RV1	Test button voltage – CCW increases level
RV2	Common Gain – CW increases gain. Reduce if H/E-Field too sensitive
RV3	Meter Deflection – CW increases deflection

ICSP Header

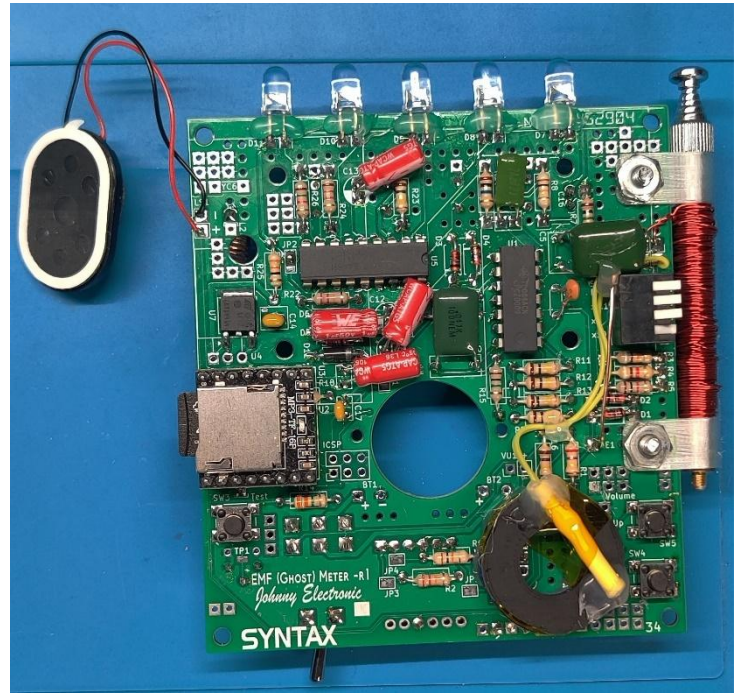
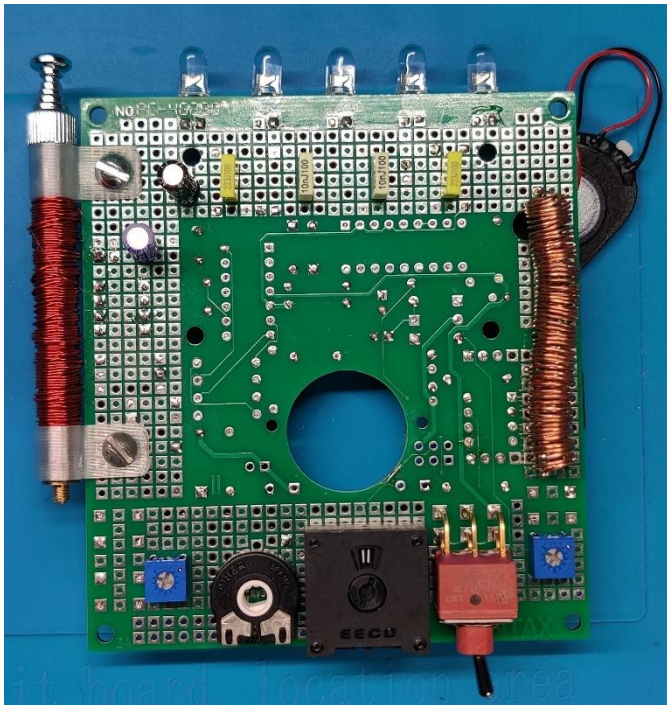


The ICSP connector follows this layout which is the same used for Arduino boards. There are a number of YouTube videos showing various methods for programming including using UNO or Nano boards as an AVR In System Programmer using the ArduinoISP sketch.

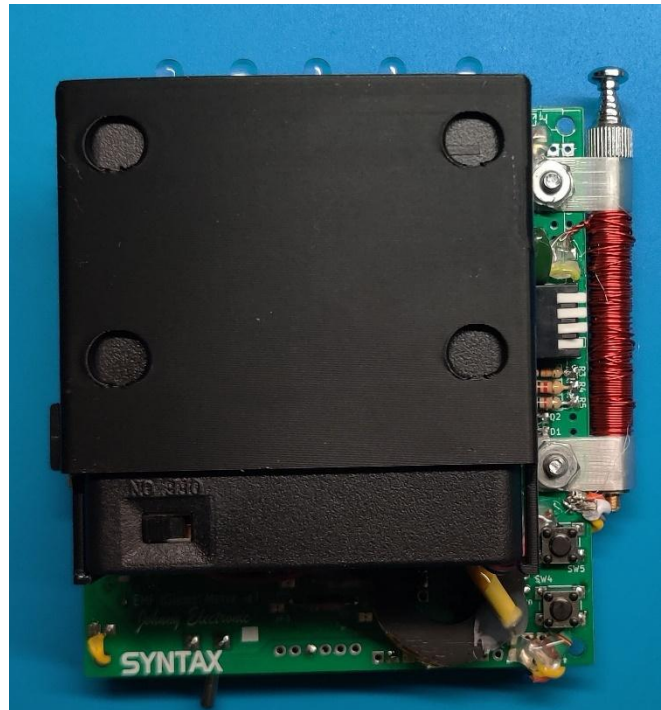
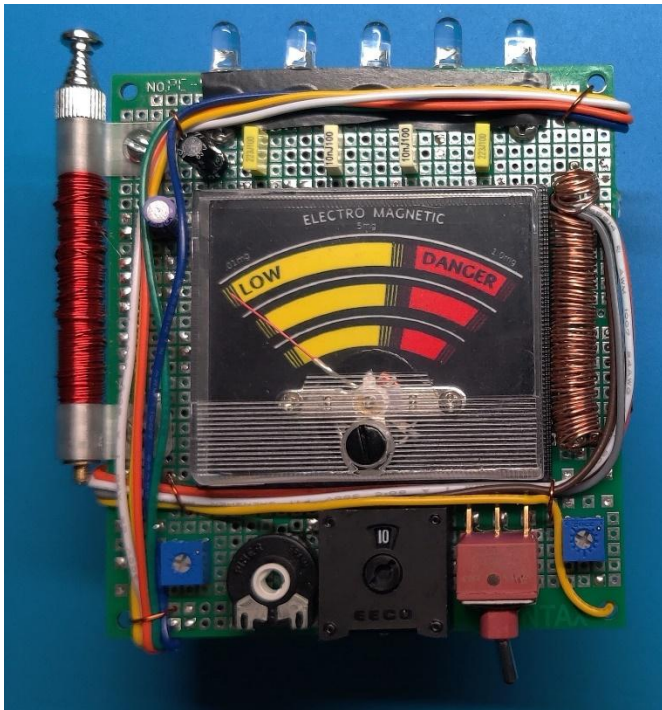
I also offer a soft touch programming cable to eliminate the ICSP header and connect directly to the board.

Assembly Images

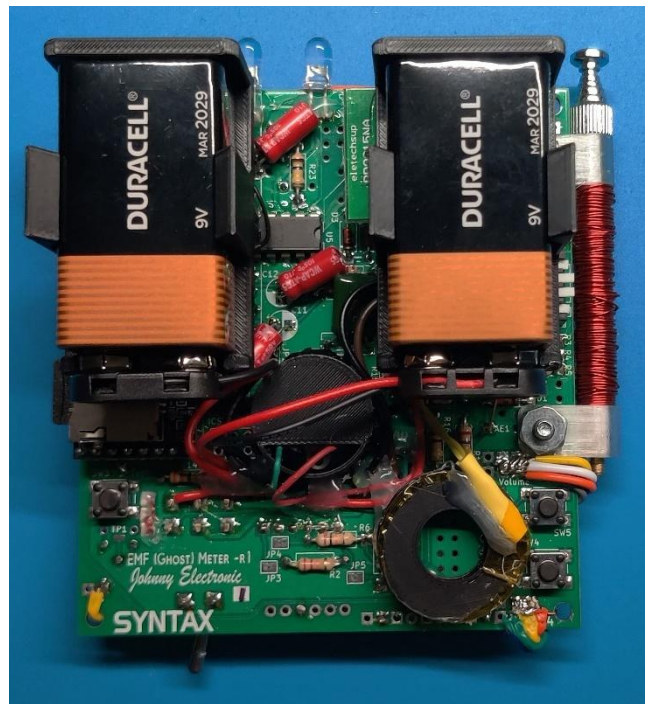
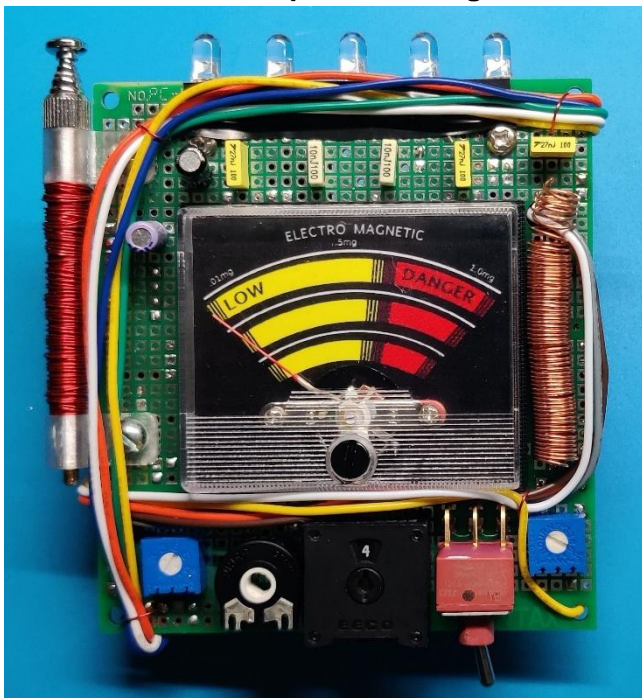
Partial Assembly



EMF Meter with 4 Capacitors, Smaller 3326 Blue Potentiometers, and AA battery pack



EMF Meter with 5 Capacitors, Larger 3386 Blue Potentiometers and 9v Batteries



References

- **Github: Development board documentation and schematics.**
 - https://github.com/JohnnyElectronic/Dev_Boards/
- **YouTube: Board assembly and project videos that are related to this board.**
 - https://www.youtube.com/@Johnny_Electronic
- **Arduino IDE board files**
 - megaTinyCore - <https://github.com/SpenceKonde/megaTinyCore>
 - It can be installed manually or through the Boards Manager

Revisions

R1.1	First board release, First document release
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Disclaimer

This information is provided "as-is" with no representation or warranty of any kind whether express or implied. However, I've tried to make this document (as well as the supporting videos) as useful and accurate as possible. If you find something that is incorrect or confusing, please let me know as I would like to make the correction so others will not have the same issue.

This meter is for entertainment purposes only and there is no representation as to the accuracy of the meter readings.

Feel free to email me any time for issues you may have with this build.

johnnyelectronic1@gmail.com

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