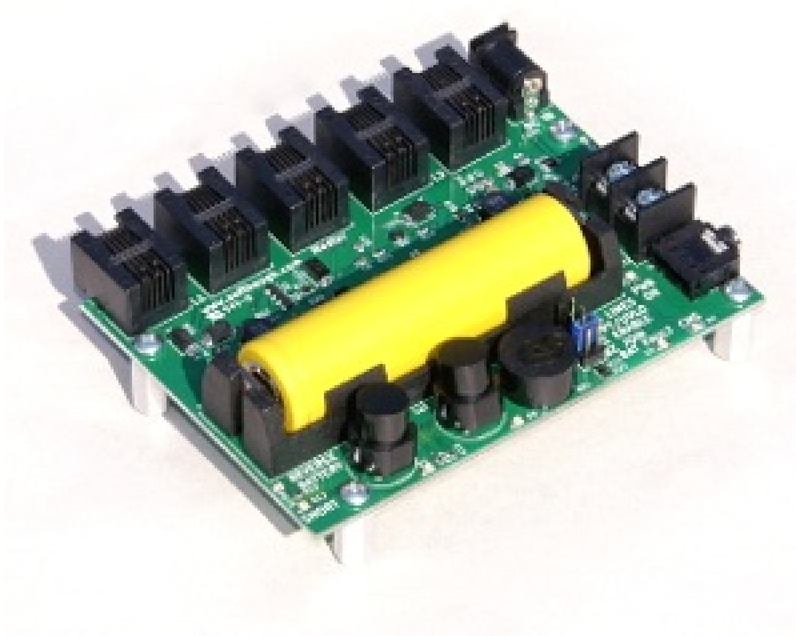
Field Phone System User's Manual

Version 1.0
19 September, 2016



by
SoftBaugh, Inc.

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softbaugh.com/fieldphone

Also participate in our field phone forum, linked from that site.

This manual is written to assist the novice user in effectively using the field phone system, as well as provide advanced users with additional details to help them make the most of the system's features. All users should read this manual in detail to achieve the most from this highly flexible system.

Whether used by a small family group, such as a family business or farm, or by the busy zombie defense team on the go, we recommend assigning someone to specialize in the care and configuration of the field phone system. There is a good chance that some feature of interest can be either used directly, or created from a modified version with reasonable effort. Your appointed specialist should read this manual often, and participate in our user's forum, to discover something new about the available features, charging options or battery care, as well as providing feedback so that we can improve future versions or products to better suit your needs.

Some configurations have been tested for FCC compliance and are noted herein, but due to the flexibility of this system, some technically proficient users may wish to create homebuilt modifications. See the relevant sections of this manual for guidance on maintaining FCC compliance.

Disclaimer: The field phone system is for hobbyist use and is intended for educational purposes. Some system components use or create high voltages or supply fixed currents and could present a hazard if wet, as does any telephone line. Use at your own risk and ensure that children operate the system only with adult supervision. Do not lick or ingest any system component. Water or zombie drool can damage system components. Zombies may become entangled in wiring and present a hazard to the operator.

Field Phone System Overview

The field phone host module allows the provision of a small, wired, voice communication network using off-the-shelf corded telephones and telephone wiring, but completely separate from the public telco network. This manual illustrates how to configure the field phone host module in a variety of typical installations.

A generic installation is shown below:

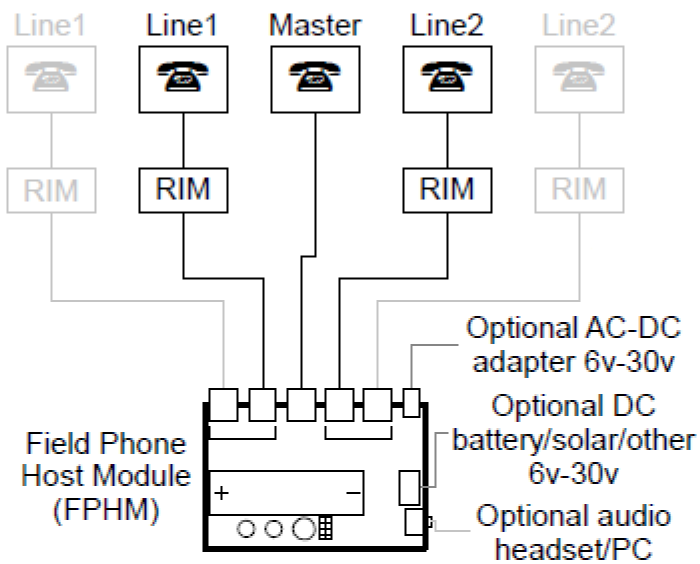


Figure 1: Field Phone System Components

The essential elements of a field phone system installation are as follows:

- Two or more normal, wired telephones. These can be configured to operate on up to two separate lines, or bridged to be one larger network. The master telephone should be, but is not required to be, a two-line phone with local conference feature. If a two-line conferencing master is not available, a jumper setting on the field phone board can serve this role.
- The *Field Phone Host Module* (FPHM), which powers the system via an 1100 mAh Lithium Iron Phosphate (LiFePO4) battery in the 18650 format. This battery will operate a full set of phones for many hours, and can be charged from a variety of power sources. The field phone host module also contains an audio connector to allow conversations to be monitored or recorded for increasing proficiency of zombie-defense teams.
- Optional *Ring Interface Modules* (RIMs), which are inserted into the line to provide ring indication at the remote, non-master phones. Much more on ring indication later, but the central idea is to provide silent or quiet ring indication to facilitate tactical use of this system against zombies.
- Wiring to connect all these components. Normal 4-wire (2-line) telephone cables are used, although if ring indication is not desired, 2-wire (1-line) telephone cables can be used to connect the remote phones to the field phone system. The master phone should always be a 4-wire cable. Either straight-through or reversed wiring can be used, system options allow these to be properly configured in hardware.

We will refer to this diagram in later sections to illustrate proper configuration and use of system components, but first, a note from the regulatory compliance people...

FCC Verification Statements

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Later sections of this manual will discuss exact configurations verified for compliance, along with notes to assist a technically proficient user to maintain FCC compliance when experimenting with home-built configurations.

Field Phone Host Module Overview

The fundamental component of a field phone system, the Field Phone Host Module (FPHM), is shown below in diagram form:

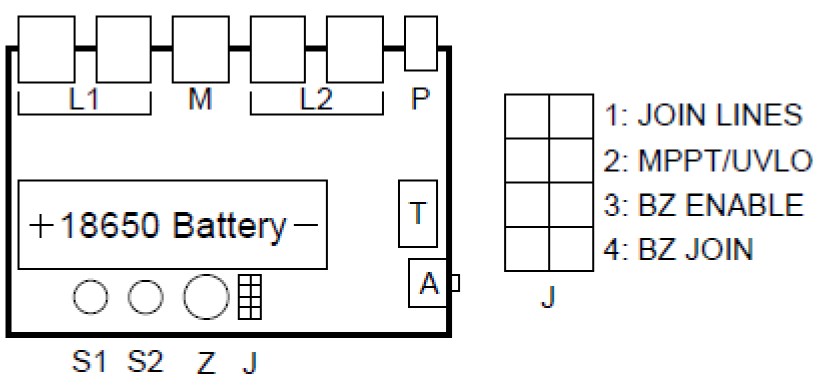


Figure 2: Field Phone Host Module

Five RJ11 (4-wire) phone connectors are along the top, split into two lines (L1 and L2), with a master connector (M) sitting astride both lines (this arrangement gives a large amount of flexibility in which kinds of phones can be used as well as how to configure single-line or dual-line operation). The recommended options for two-line and single-line operation are detailed in a later section of this manual.

The FPHM derives its operating power from an 1100 mAh LiFePO4 battery in the 18650 format. FPHM units ship with this battery, and with proper care and diligent charging, should last for years of continuous use. A single charge will operate the field phone system for hours of continuous communication, days if the phones are only used intermittently. The exact length of time a charge will last depends on the exact phones used, the lengths of wire used, and the patterns of use.

Charging power in the 6 volt to 30 volt range can be supplied via the power jack (P) or the terminal block (T). This arrangement gives a large amount of flexibility as to powering the field phone system. We will discuss the charger, external power options, FCC compliance tips, and proper battery care in more detail in later sections.

The 3.5mm stereo audio connector (A) allows both lines (L1 on the right channel and L2 on the left) to be monitored or recorded by an external PC. Under some circumstances, audio from an external PC can also be injected onto the lines. External software running on a PC is necessary to condition the audio and capture the signals. Operation of the audio interface is a bonus feature that is beyond the scope of this manual.

The field phone system does not support the normal telco 48v ring signaling. This feature is by design, as zombie ears, evidenced by various popular documentaries on the subject, tend to be particularly tuned to the sound of telephones ringing while participating in rampages. Rather than a normal telephone ring, the field phone system supports silent (LED) or quiet (piezo) ring indication by using ring interface modules for the remote phones, as discussed later. The FPHM provides individual ring indication LEDs (not shown in the figure) and a shared piezo (Z) for the master phone, as well as switches (S1 and S2) to ring the remote phones.

The field phone system contains eight LED indicator lights, grouped into three categories. Normal status lights are green, ring indicators are yellow, and fault indicators are red. These are summarized in the following table.

Table 1: Indicator Lights

Name	Color	#	Location	Purpose
PWR ON	Green	D24	Mid-Lower Right	Indicates that the board is powered, either from an external supply, the LiFePO4 battery, or both.
DC IN	Green	D2	Upper Right	Indicates that an external charging supply has been provided at the power jack (P) or the terminal block (T).
CHG	Green	D4	Bottom Right	The battery is charging when lit. See the section on charging.
(Line1, not marked)	Yellow	D7	Bottom Left, Near SW1	Ring indication for Line1.
(Line2, not marked)	Yellow	D6	Bottom Left, Near SW2	Ring indication for Line2.
REVERSE BATTERY	Red	D19	Lower Left	Indicates that the battery is in backwards. Remove and insert correctly.
SHORT	Red	D12	Lower Left	Indicates that the buzzer circuit is shorted. Check wiring.
FAULT	Red	D3	Bottom Right	Indicates a failure while charging the battery. May appear after a few minutes of attempting to charge an undercharged battery. See the section on battery faults.

Finally, as indicated in Figure 2, the jumper block (J) allows the user to configure various system options. These options, summarized in the table below, will be discussed in later relevant sections of this manual.

Table 2: Jumper Block Options

Name	Pos	When Off	When On
JOIN LINES	1	Lines are separate, can be conferenced with a 2-line master phone. Line1 phones and Line2 phones are on separate circuits unless conferenced.	Lines are joined at the FPHM, and all phones talk to all other phones. A single line phone can be used in the master location. See also BZ JOIN below.
MPPT/UVLO	2	No analysis of charging input.	Applies a maximum-power-point tracking algorithm to the incoming charging source. Also performs an under-voltage lockout, halting charging if the input voltage falls below a programmed level.
BZ ENABLE	3	FPHM buzzer does not sound when either line rung.	FPHM buzzer will sound if either line is rung.
BZ JOIN	4	Ring indication is separated between the lines.	Use with JOIN LINES or master phone conference feature to enable ring indication across all phones.

Ring Interface Module Overview

Since the field phone system does not support normal telco ring, a ring interface module is used if call indication is desired at a remote phone. A diagram for this optional ring interface module (RIM) accessory is shown to the right. Each RIM supports three line connectors (Line, Rev in the diagram for Reverse and Phn in the diagram for Phone), a single jumper (J) to enable the call indication buzzer, a single pushbutton (S) to call other units, and a piezo buzzer (Z). As mentioned previously, the master phone does not use a ring interface module as the master's switches and piezo are on the FPHM itself. Not shown on the diagram is the silent ring indication LED.

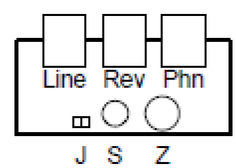
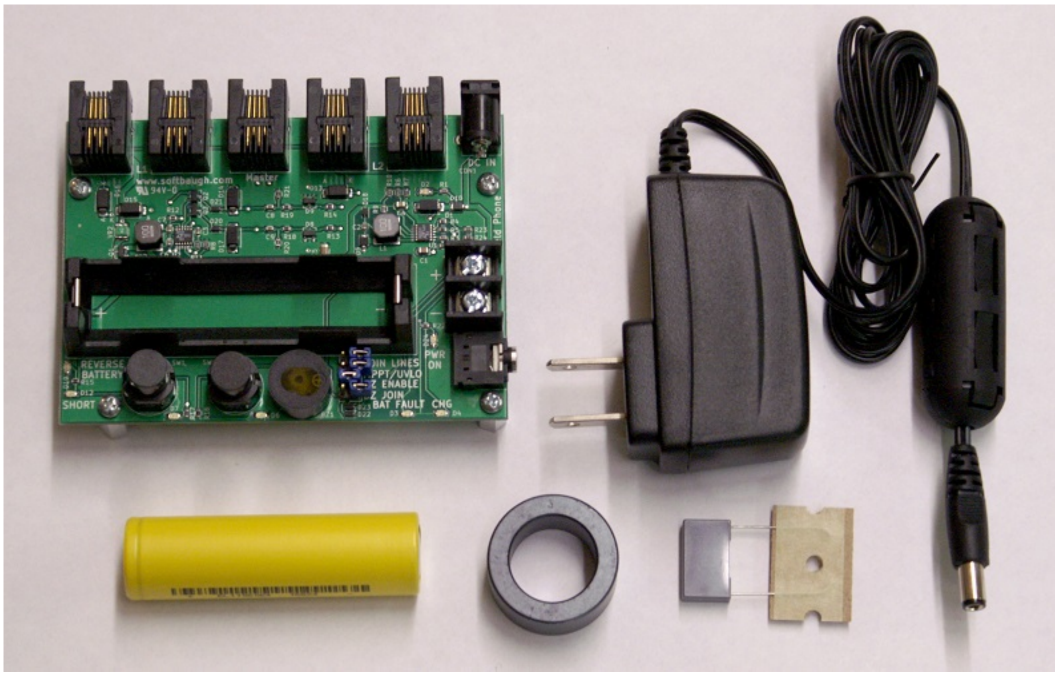


Figure 3: Ring Interface Module

The Phone connector is used to attach a phone to the RIM, while the upstream FPHM is connected to either the Line or the Reverse connector, depending on whether straight or reverse wiring is used. A later section will detail the use of these connectors when using either normal telco wiring or custom field wiring, and some usage ideas for remote stations without telephones.

Field Phone System Installation

The basic field phone system ships with the core items shown in the photo below:



One Field Phone Host Module (top left)
One SB6VF AC adapter, with EMI ferrite (top right)
One 1100 mAh LiFePO4 battery in the 18650 format (bottom left)
One common mode choke ferrite (bottom center)
One 0.01 uF EMI capacitor (bottom right)

The first three items create the minimally functional core system which is FCC-compliant and capable of both battery operation and charging from external power from AC sources.

The last two items are included to facilitate optional external DC charging in an FCC-compliant manner. A later section describes the installation of these optional components in detail.

The field phone system is capable of more advanced operation than that provided by the basic core system. Optional bundles include the above, plus one or more 4-conductor cables, ring interface modules, and wall adapters for custom wiring. This section will describe the basic setup for the field phone using the core items only. Later sections will describe adding these optional materials to the basic setup.

In addition to the SoftBaugh-supplied components in either the core system or optional bundles, two or more user-supplied normal wired telephones are required. These may be one-line or two-line phones, but it is recommended that the master phone, at a minimum, be a two-line phone. Additional cabling may be required; 4-conductor cable is preferred if ring indication is to be used.

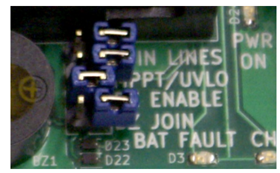
Now, we describe how to get the core field phone system up and running.

Mount the FPHM Board (optional)

The FPHM can be used in a mobile application and carried from site to site, but it is mainly designed to work in fixed installations such as between nearby buildings or other fixed locations. For fixed installations, it may be preferable to mount the FPHM to a wall so that it remains out of the way yet still accessible for the ring push-buttons.

If desired, the FPHM board can be mounted to a flat surface using screws at the four corner mounting holes. A non-conductive surface, such as wood, is preferred. Wood is more desirable than plastic because the slight conductivity of wood prevents a buildup of surface charge while plastic can get the zappies (technical term for Electro-Static Discharge, or ESD). If it is necessary to mount the FPHM board to a metal surface, be sure to use some spacers beneath the FPHM to keep the electronics from contacting the metal and shorting out. We have supplied the FPHM with 4/40-threaded standoffs to allow it to just sit on a bench by default.

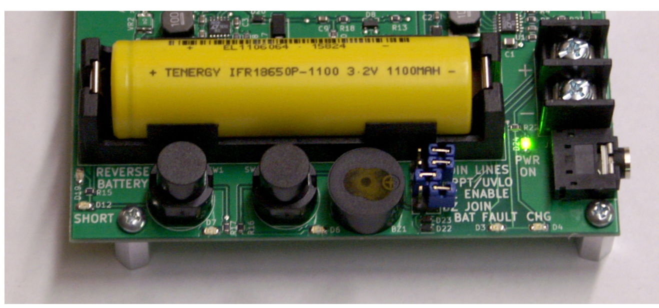
Configure the FPHM Jumpers

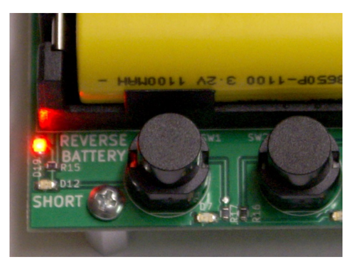


For this installation, start with all jumpers removed with the exception of the BZ ENABLE jumper. You can hang them to the side of the jumper block, as shown to the right. This is the default jumper configuration for the field phone host module.

Install the Battery

The next step in installing the field phone is to install the LiFePO4 battery. Insert this battery into the socket as shown. Note that the positive terminal is to the left and matches the silkscreen on the board. If inserted correctly, the green PWR ON light will illuminate:

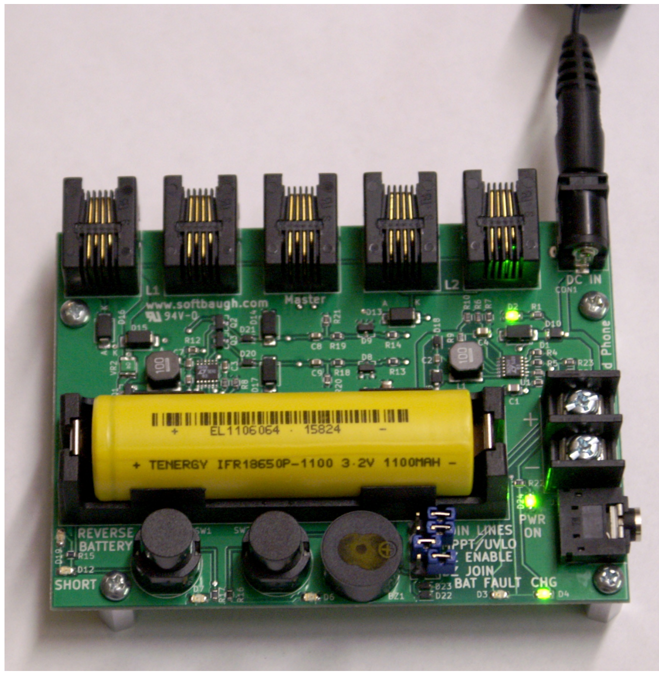




If the battery is inserted backwards, the red REVERSE BATTERY light on the bottom left corner of the board will illuminate, as shown to the right. Since zombie defense can occur in less than optimal conditions, the board is protected against damage in the event the battery is inserted backwards. Simply remove the battery and insert it correctly.

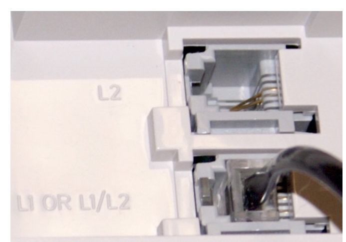
Apply External Charging Power

To charge the battery, apply external power using the supplied SB6VF wall adapter, with the installed EMI ferrite. Plug this adapter into the DC IN power jack (P) as shown below.



In this photo, the edge of the EMI ferrite is just barely visible at the top. Note that the green DC IN light, and the green CHG light, will both illuminate. Because the LEDs themselves draw current from the battery, the charger will typically remain on as long as external power is supplied, but the battery will be protected against overcharging by the charger circuitry. If after a few minutes the CHG light goes out and the red BAT FAULT light illuminates, then see the later section on battery faults for how to address this situation. Note also that the DC IN light's brightness will track the input voltage. See the section on modification tips if you wish to adjust this behavior. For maximum battery life, we recommend that the unit be left plugged in or otherwise constantly charged, if possible, leaving the battery fresh for use during power outages or other emergencies.

Attach the Master Phone



Select a two-line telephone, and connect it to the master connector (M) using a 4-conductor cable, as shown in the photo to the right. Be sure to connect the cable to the L1+L2 connector on the master phone. This connector is also sometimes labeled the “L1 OR L1/L2”, as it is in this case.

Attach the Remote Phone(s)

Determine whether you want to operate two separate lines or one single line. In this example below, we have connected a phone to one of the Line 1 (L1) connectors using a 4-conductor cable.

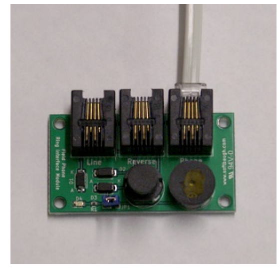
Test the Phones

Set the master phone to Line 1. Then, pick up the handsets on each phone, and notice that you can now communicate. If you can't hear anything, make sure the Master (M) and Line 1 (L1) connections are correct, as well as having Line 1 selected on the master phone.

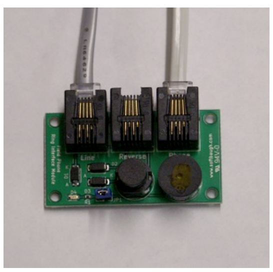
Inserting Ring Interface Modules

If you have purchased ring interface modules, you can add ring indication to your remote phones by inserting them into the line between the FPHM and the remote phone.

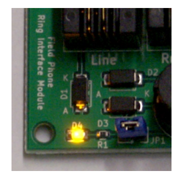
If you are using stock 4-conductor telco wiring with RJ11 connectors on the end, then installing the ring interface module will be fairly simple.



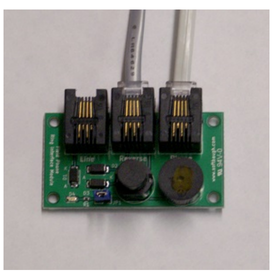
Disconnect the remote phone from the host cable, and using another cable, connect the remote phone to the ring interface module at the phone (Phone) socket, as shown to the right. For this connection, a two-wire cable can be used between the phone and the ring interface module. And, this cable should be relatively short, since the ring interface module should be within easy reach of the telephone during use. We offer an optional 7' cable for this purpose, but many phones come with short 2-wire cables in the box with them that will do just fine.



Next, insert the cable leading to the FPHM into the line (Line) socket on the ring interface module, as shown to the left. If all the wiring is “straight-through”, then the ring interface module should be working correctly.



If a “reverse” cable has been used, or if custom wiring has resulted in a reverse condition, then this will be immediately apparent as the call indication light will illuminate, as shown to the right.



If this condition is detected, then simply move the host cable from the line (Line) socket to the reverse (Reverse) socket, leaving the phone connected to the phone (Phn) socket. The call indication LED should now be dark, as shown to the left.

One of these configurations of the host cable should extinguish the call indication light, as well as allow the attached remote phone to work. If neither configuration works, check, repair or replace the host cable, particularly when using custom wiring.

To test the ring interface module, simply push the button (S) on the ring interface module, or the corresponding line switch on the FPHM (S1 or S2) and you will see the call indication light illuminate on both the remote phone's RIM and on the FPHM, and hear the buzzer (Z) sound on both the RIM and on the FPHM.

For silent, LED-only indication, remove the jumper (J) on the ring interface module and hang it to the side. Now the buzzer will remain silent when the ring button is pressed on either end. For a silent indication at the FPHM, remove the third jumper (BZ ENABLE). Note that a single buzzer (Z) is shared across both lines on the FPHM, but the call indication lights will show which line is calling.

While we recommend using a two-line phone as the master, a one-line phone can still be used. As mentioned before, the JOIN LINES jumper takes the place of a conference feature on a two-line phone, bridging both lines at the FPHM. Similarly, the BZ JOIN jumper allows any ring interface module on either line to ring any other ring interface module or the buzzer on the FPHM itself.

Installing the EMI Capacitor and Common Mode Choke

Since a deployed field phone system looks electrically like a giant antenna array, we have to prevent large (relative to the currents in all other wiring) charging currents from causing unintentional radio emissions. After all, you wouldn't want to accidentally cause submarines at sea to launch their missiles while telling your friends about approaching zombies, would you?

If you decide to use an external battery charger and replace batteries in the FPHM rather than charging them with it, then you do not need to install the EMI capacitor and choke, as no large charging currents are present at any time (when not charging, the FPHM is exceptionally quiet radio-wise). You also do not need the EMI capacitor and choke if you charge the FPHM's LiFePO4 battery using the provided SoftBaugh SB6VF AC adapter with the attached ferrite blob near the barrel jack.

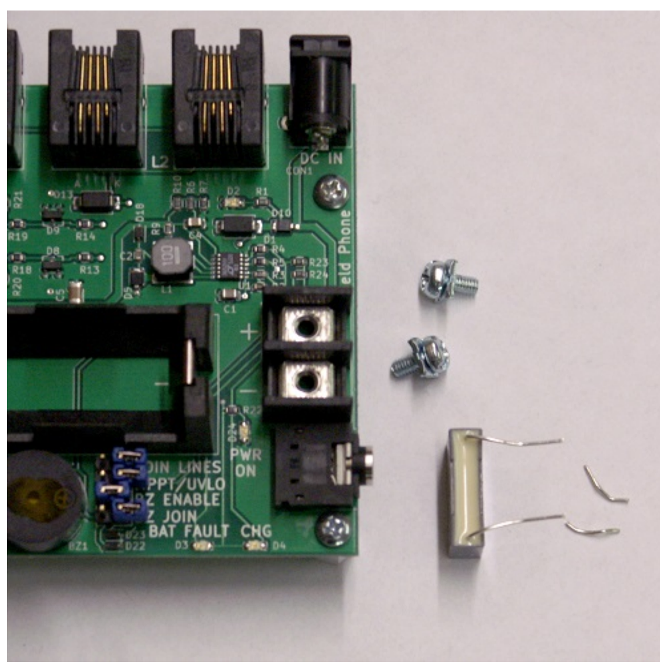
However, if you elect to charge the FPHM battery using an external supply (such as 12v battery or automotive power), then FCC compliance requires installation of the provided EMI capacitor and choke.

The EMI capacitor must be installed at the terminal block (T), and the choke installed on the power leads, near the terminal block, with five windings of the power leads passing through it. There are several ways to accomplish this (including soldering the capacitor to the back of the terminal block pins in fixed installations), but this section describes one neat and simple way to install these components to prevent unintentional radio emissions while charging.

Installing the EMI Capacitor

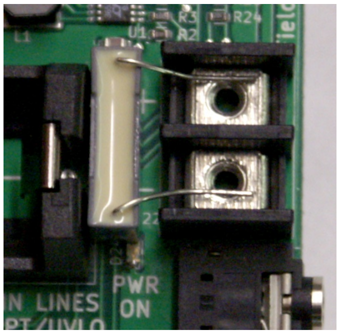
The first step is to install the EMI capacitor. It is important to note that the capacitor is non-polarized, which means that it is impossible to install it backwards. In other words, it doesn't matter which capacitor lead wire goes to which terminal block screw.

In the picture to the right, we have accomplished many things. First, we have removed the battery and disconnected all power supplies. This is very important! Then, using a screwdriver, we have removed the terminal block screws in their entirety, including their captive wire clamps.



Next, we have removed the capacitor (shown upside down) from its handling tape and trimmed off about a quarter of an inch of the leads. The exact amount is not important as long as they are not too short. You may want to test-fit the capacitor as shown in the next photo, we want the leads to fit under the wire clamps, but not extend beyond the edge of the clamps too much.

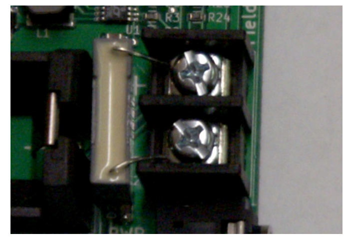
Also, we have bent those leads to the side, and inward, in a hockey-stick shape, to make them fit the wire clamps better.



Next, as shown in the picture to the left, place the capacitor in the gap between the battery holder and the terminal block. Lay the capacitor leads as shown, on the outside of the screw holes, and to the left against the edge of the battery holder. This position will allow the plus and minus signs to be seen in the gap.

Also, note the position of the PWR ON LED. Nudge the capacitor upwards toward the phone connectors slightly to make sure this LED is not obscured. It is not necessary that the capacitor be firmly against the board. Again, it is not important whether you trimmed the leads exactly correct. As long as they make reliable contact with the wire clamps, then that is good enough.

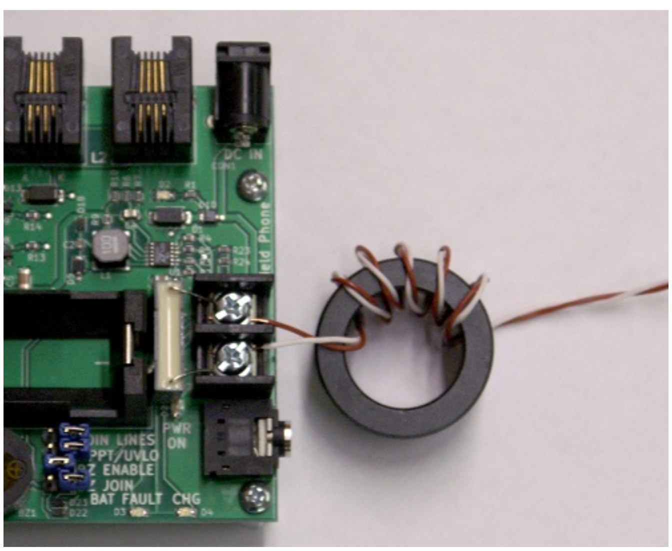
Now, reinstall the screws and their wire clamps, as shown to the right. These clamps fit in any orientation, so just drop them in the holes and run the screws in about half way.



This technique keeps the capacitor out of the way, which keeps the leads from being damaged by handling, and eventually being broken off. It also keeps it out of the way of the external power leads, which we will install next.

Installing the Common Mode Choke

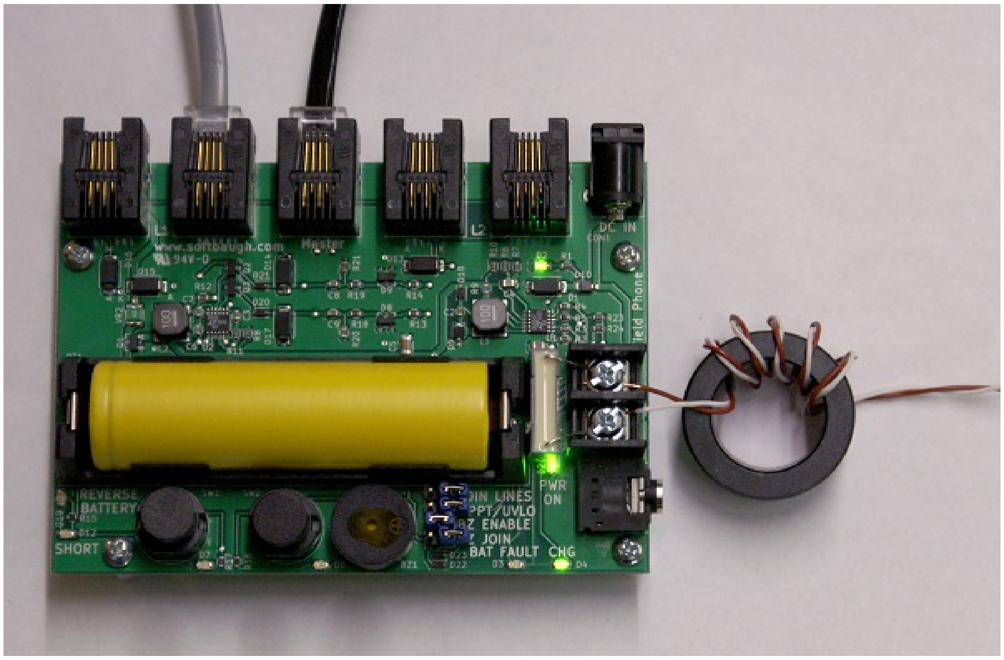
After the capacitor is in place, we have to prepare the choke by running both the positive and negative lead wires through the hole five times. We have provided two examples of this process.

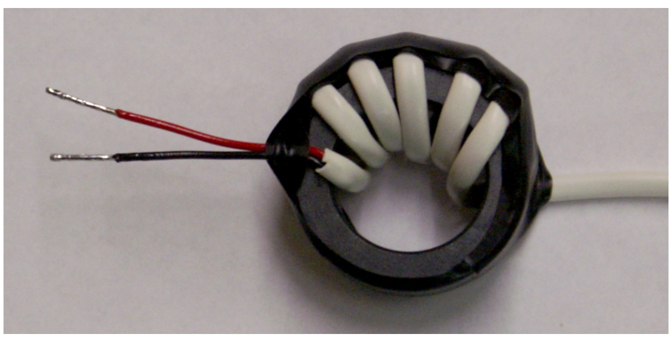


The first example, shown to the left, uses solid core wire. This is a length of twisted pair taken from a section of Ethernet cable. We happened to choose the brown and white pair, but any pair will do. For our purposes here, the twist in the wire is helpful for handling, but not required. You could also just as effectively use two individual wires.

After stripping some insulation from the ends, wrap the wire through the choke five times (known as "turns"), as shown. Keep the amount of wire on the FPHM side short, but not so short as to be inconvenient to handle. The exact appearance is not as important as the five turns. To make it all lay neatly on the bench, we have chosen to have the wires enter on the bottom and emerge on the top.

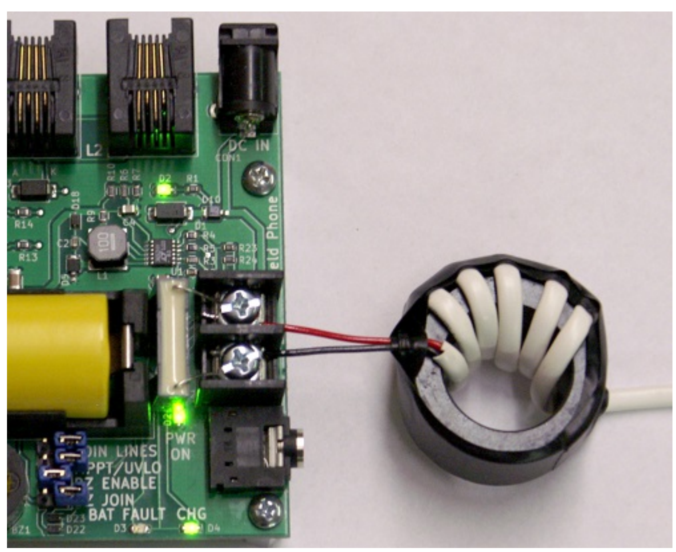
Then, insert the stripped ends under the wire clamps in the terminal block, this time to the insides of the screws. Tighten the screws enough to keep the wires in the clamps, but not so much as to pinch and weaken them. Now, re-install the battery and apply power. Note that both the power jack (P) and battery input terminals (T) are reverse-polarity protected. If you hook up your external power source and the DC IN light remains dark, then check to see if you connected the wires backward. The battery is now charging in an FCC-compliant way, as shown below.





The second example, shown to the left, uses stranded wire, which came wrapped in a jacket. This is security system wire we removed from an old building. The jacket is not strictly necessary, but it does help protect the power leads from abrasion against the choke. Because the wire and the jacket are springy, we wrapped the entire thing in electrical tape to keep the wires from unspooling. We also tinned the leads with solder to help keep them from wearing out, but in a pinch you don't need to.

To the right, we show the cable installed on the FPHM and supplying power.



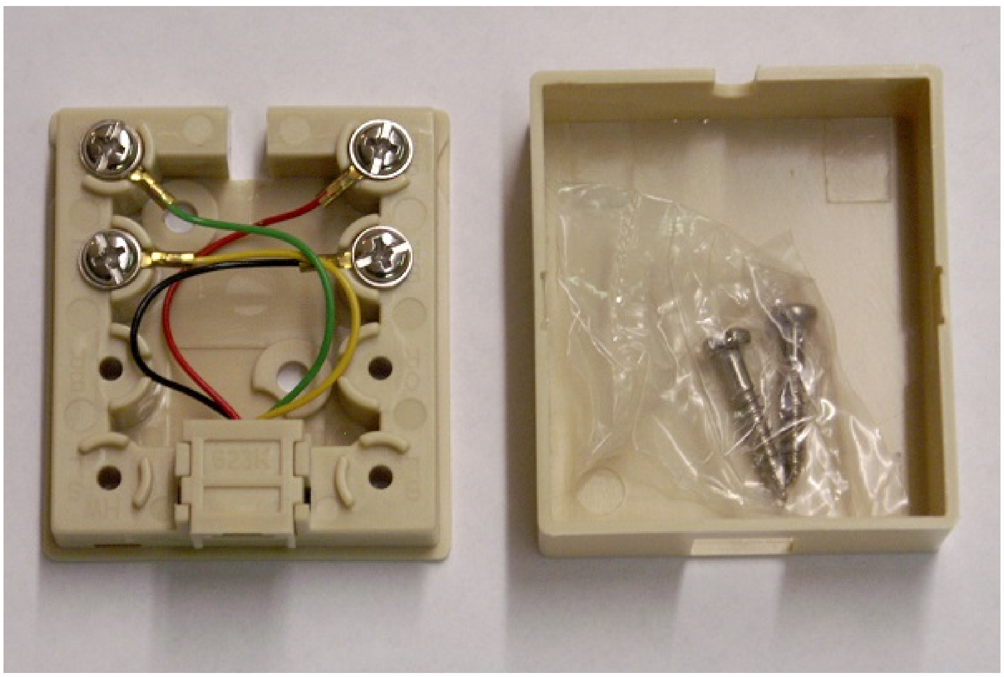
Because the FPHM only uses an average of 1.6 W to charge, which is less than 150 mA at 12 volts, it is acceptable to use small gauge wire over distances of a few feet. You could also use larger gauge wire; the size of the choke admits fairly beefy options. Just make sure that you pass both wires together through the coil the requisite five times.

You can also increase the robustness by adding terminal connectors, heat-shrink tubing and so on, but such things are beyond the scope of this manual.

Configuring Custom Phone Wiring

While the FPHM has been verified for FCC compliance using 7' cables for the master phone and between each remote phone and its corresponding ring interface module, and 25' cables between each ring interface module and the FPHM, other wiring configurations may be attempted as homebuilt options. If other wiring is desired, the most convenient way to integrate custom wiring is the use of telco wall boxes, which convert custom wiring into the RJ11 format.

These wall boxes come in a variety of styles and wiring configuration, but all of them feature one or more pairs of wires. You will use the two center-most pairs of wires in your installation, the others can be ignored. The photo below is an example of the wall box we provide, which has two pairs:



The pairs are determined by where they are attached to the connector on the bottom, and are reflected in the ordering of the wires at the terminal screws above. This box reflects the standard telco wiring, which uses one center pair, and then wraps that in another pair, one wire to either side of center.

Assigning Colors

In the standard telco format, the center pair is red-green. This is the pair shown at the top pair of terminal screws. The next pair is black-yellow, the black being outboard of the red, and the yellow outboard of the green. It is difficult to see this ordering in this and subsequent photos. But, the good news is you don't have to care much about the ordering on the telco cables, all you need to care about is making sure the colors match up on each end of the cable. These little adapter boxes are excellent for that.

In the field phone system, the red-green pair carries the voice signals, and the outer black-yellow pair carries the ring indication signals. You can use practically any kind of wire between these adapter boxes and any number of hops of any kind of wire in between adapter boxes. As long as the same string of wire is connected to the red terminal on both adapter boxes, and a different string of wire is connected to the green terminal on both boxes, and so on, then what you do in the middle between adapter boxes is entirely up to you.

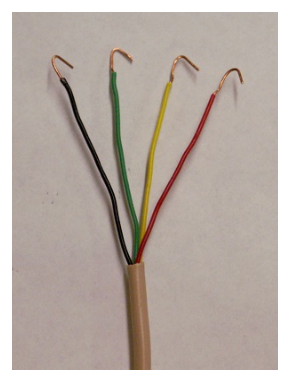
For example, we have a test case installed which uses a variety of intervening cables, all of them recovered from an old building. One leg of this sytem runs from one of these adapter boxes through an old 4-conductor security system wire to an ancient telco punchdown panel, then through two twisted pairs on a scrap Cat5 Ethernet cable to an unused telco post outside, then hops through an old underground and unused 25-pair telco conduit between two buildings to another telco post outside the second building, then more Cat5 to another punchdown panel inside, then back through more security system wire to another wall box on the other end inside the second building. Standard 4-wire 7' telco cables then connect those wall adapter boxes to the FPHM and RIM, respectively.

In between these hops in this example installation there are several varieties of color coding and wire types. At each hop we label each wire according to its color in the field phone system (field phone red, field phone green, etc.) and then maintain the standard on each end of each leg. So, when traversing one leg of Cat5, we might say that orange is field phone red, orange-white is field phone green, brown is field phone black and brown-white is field phone yellow. Yet, on another leg of Cat5, we might mix that up if other wire pairs are available or some of them are damaged. Throughout all of these hops, the only thing that ultimately matters is that each signal winds up connected to its corresponding color on the wall boxes at each end.

The most important thing is that each color must be assigned individually, and then that color consistently applied from end to end. Otherwise, you can use practically any kind of wire, and connect them as you wish.

Custom Wire Examples

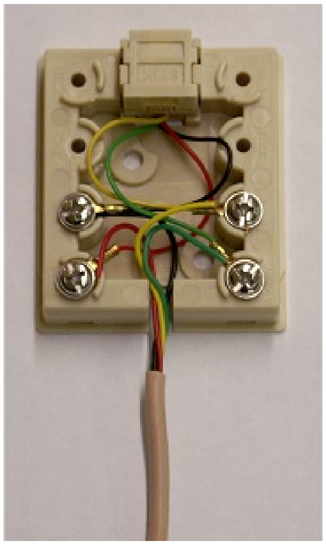
Now let's look at some examples of custom wiring using some salvaged cables, which is what you will experience during a zombie rampage. Note that you can use any kind of wire or cable you can get your hands on, these are only two examples.

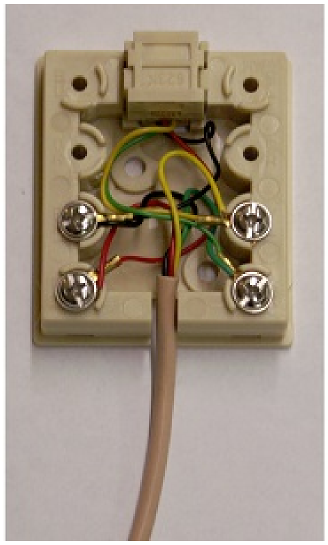


Also, in an actual installation, before attaching the wires, you may want to fasten the wall boxes to a convenient surface using the included screws. This is much harder to do later without damaging something, so plan ahead.

The first example uses salvaged telco 4-conductor cable, which features solid wires. These are the easiest kind of wire to use, as the colors match already, and the solid wires are easier to bend and attach to the wall adapter boxes. In the photo to the right, we have exposed the wire strands from the cable jacket (give yourself plenty of room to work with), stripped about a quarter-inch from each end, and bent the ends into a C shape. This C shape will make it much easier to get a good connection on the adapter box screw terminals and keep the wire from squirting out from under the screw.

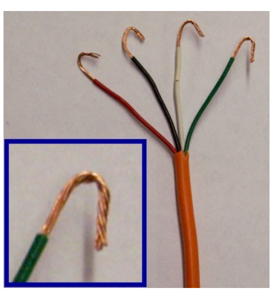
Next, place those bent ends under the screw terminals of the corresponding colors, and tighten enough to hold them firmly in place, press all that up into the box, and snap the cover onto the box, as shown in the following sequence of photos:



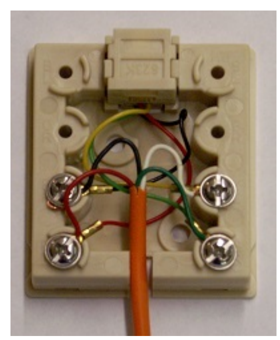


Never over-tighten the screws, as this makes the wire more likely to squirt out. These adapters have little walls to help prevent that, but it still happens. Also, over-tightening can damage the wires, making them more likely to break during use or handling, or strip the screw out completely. Only hand-tighten, never use a power screwdriver.

Also, when placing the curved wires under the screws, always place the wires under the terminals so that the curves are clockwise, the same as the direction the screw tightens. This will make sure that, if there is any slip, that the wire tightens around the post rather than backing out. If you look closely at the red wire, you can see that it slipped a bit, but tightened around the screw post anyway. If the curve had been in the other direction, the wire would have been pushed off the post and mangled a bit.



The photos to the left and to the right show the use of stranded wire, this time within fire-rated smoke alarm cable, also taken from an old building. Note, in the inset, that the stranded wire has first been twisted, and then bent into the C shape. Also, the colors almost match, with a white instead of yellow. These two colors have been connected, with all the others connected to their respective mates. With stranded wire, it is especially important to not over-tighten, as the twisted strands can separate, become a mess and likely short.



Shorted Lines

Custom cabling always introduces more chance of accidentally shorting lines together. If the inner pair of wires, the voice wires, becomes shorted, the phones will not work at all. If the outer pair becomes shorted, either ring indication will sound continuously, or the ring indication will be completely disabled, depending on the type of short. In the latter case, the SHORT indicator light will illuminate, as shown to the left. If any of these conditions happen, check the wiring for shorts.

FCC Compliance For Other Configurations

As a review, the field phone system has been verified for FCC compliance in these three configurations:

1. When running only from the onboard LiFePO4 battery, no charger operating.
2. When charging from the external SB6VF 6v AC/DC adapter, with attached Laird ferrite.
3. When charging from an external 12 volt battery, with attached EMI capacitor and common mode choke.

Other configurations fall outside the scope of our verification tests, but may qualify for FCC exemptions. The FCC allows generous exemptions for homebuilt designs and modifications (**not** kits), mobile applications, battery-only applications and special rules for emergencies. It is worth taking time to read the FCC Part 15 and Part 68 regulations (available at fcc.gov). For purposes of finding the applicable regulations, the highest frequency produced or used by the FPHM is 2 MHz. Also, ask an amateur radio hobbyist for help. Amateur radio people tend to be very technically proficient, and will often have the right equipment to help you test your setup for compliance issues, and can help find and fix a non-compliant modification.

In all cases, it appears that you can immediately buy a 1.5 dB margin simply by not using the 3.5 mm audio cable. As mentioned before, the audio interface is irrelevant for most applications.

The basic principle is that if your equipment is causing interference, you have to stop using it. This also applies to devices such as the FPHM which have passed FCC testing, as seen earlier in the FCC verification statements. From a practical and tactical point of view, it is best to try to reduce your emissions even if FCC exceptions would apply or no one is complaining, as needless emissions might interfere with your other electronic equipment.

From our testing experience, most of the undesirable emissions will be around 140 MHz and 190 MHz when charging (when not charging, the field phone system is exceptionally quiet from an emissions perspective). An amateur radio expert can tune a receiver at those frequencies and listen while you plug the external power in and out while using a partially charged battery. We recommend taking a baseline measurement (which may be somewhat subjective) with an unmodified FPHM first, and then comparing results.

External Power Configurations

For all external power options applied at the power jack (P), we recommend the use of a ferrite. Our SB6VF uses a Laird 28A0592-0A2, 511 ohm snap-on ferrite, which we offer for sale at our webstore and currently include with each basic FPHM to enable a baseline FCC-compliant installation. However, we have had many high end supplies fail compliance testing even with this or other ferrites attached.

For all external power options applied at the screw terminals (T), we recommend the use of the provided filtering capacitor and common mode choke with five windings, as shown earlier.

Solar Configurations

Solar power presents a special set of circumstances, most of them regulatory. Testing a solar powered field phone system for FCC compliance would be prohibitively expensive and introduce a set of uncertainties regarding solar flux, time of day, weather, and so on. Even so, the results might only apply to that specific type of solar panel, as solar panel designs can have wildly different parameters. A 10 W solar panel from one vendor might behave dramatically different from a 10 W solar panel from another vendor.

As a result, we cannot currently bundle or market field phone systems with solar panels, although we can sell field phone systems and sell solar panels, and even ship them in the same carton. If you decide to create a homebuilt system using any particular solar panel, here are some tips to help you remain compliant.

First, everything discussed throughout this manual regarding using external power also applies for solar panels. A prudent application would still use the EMI capacitor, and the common mode choke coil with five turns, as well as taking baseline measurements. The MPPT/UVLO jumper on the field phone board is intended to help with marginal panels or those being used on a cloudy day, as well as shutting down the charger when the input power is insufficient, preventing additional noisy operation.
An important feature of solar panels is that they spend most of their operating life well below their rated power. Although the FPHM only uses 1.5 W for charging, a 10 W panel would be appropriately sized. Remember that a panel only performs as well as the least-performing cell, so if zombie pus is covering one cell, you may only get a trickle of current out of the entire panel, although it might be near full voltage at no load.

An advantage of the FPHM charger design is that it accepts a large input voltage range. This is helpful when selecting solar panels and reading the detailed specifications. Make sure that the full-sun solar panel voltage (known as the Open Circuit Voltage, or V_{OC}) does not exceed 30 volts, and that the maximum power point voltage (often known as V_{MPP}), is at least 9v, to allow some possibility for droop under less than optimal conditions. Finally, a minimum of 3W, or better, 10W, allows the charger to operate continuously even if full sun isn't available. After all, when defending against zombies, tossing a solar panel on the roof, in whatever random orientation, may be the best you can do.

Another option for solar power (which is fully FCC compliant as-is provided the EMI capacitor and choke have been installed) is to use a solar panel to charge a 12v battery via an inexpensive PWM controller (we prefer the Outback Power models), and then charge the FPHM from that battery. Even a small 4.5 Ah battery, such as the kind often found in a small PC UPS, can fully charge an FPHM in three or four hours, while only consuming about ten percent of the capacity of that battery. A 100 Ah deep-cycle marine battery won't even notice.

Vehicular Configurations

One could mount the field phone system to a vehicle, and then charge from that vehicle's auxiliary power output, such as a cigarette lighter circuit. Wired this way, the field phone system would only draw current from the battery when the ignition is on (better, when the engine is running), but when the engine is off the field phone system would operate from its LiFePO4 battery. And, this application could fall under the FCC exemptions for mobile or vehicular applications, as well as a homebuilt modification, if not in direct compliance for running from a 12v battery. Be sure to use the included EMI capacitor and common mode choke as described in detail in a previous section. For 24v industrial equipment or truck battery arrays, check the aux voltage when the engine is at full throttle. Ideally, this voltage should not exceed 28.8 volts, but some alternators run a little hot. If the voltage is above 30v, such as might be found for a vehicle running AGM batteries, a technical expert can help you install some upstream diodes to drop the incoming voltage some (see the section on modification tips, below).

Battery Charging Options and Tips

Subject to the guidance in the previous section for FCC compliance, the field phone host module is designed to accept a variety of charging inputs. This section details the technical aspects of various charging options, while the next section provides information to help minimize the risk of a non-compliant homebuilt application.

When using any rechargeable battery, the lifetime of the battery is usually measured in charge-discharge cycles. Typically, the deeper the discharge, the fewer cycles that can be expected from the battery. The meaning of "deep" depends on the model and chemistry of the battery. A deep-cycle marine or golf cart lead acid battery may tolerate many more 50% discharges than a starting battery, which only experiences a few percentage discharge when cranking. This is why off-grid alternate energy applications typically use more expensive deep-cycle batteries. Still, lead-acid is severely limited in lifetime cycles. Getting more than a year of daily deep discharge service out of even the best deep cycle lead acid batteries is quite a feat, and two years is miraculous.

The LiFePO4 battery, on the other hand, can survive a large number of 100% discharges, well into the high hundreds of cycles, even as much as a thousand cycles, and even then still have much of its nameplate capacity available. Consult the appropriate datasheet for your specific battery for details, but the LiFePO4 is almost a miracle battery for most applications.

The best way to ensure a long lifetime for your LiFePO4 battery is to keep it topped off constantly. Leaving the FPHM attached to the wall supply, ready for service during power outages, is the best choice, but, of course, this may not be practical for most zombie defense applications. In a pinch, you may have to use a variety of charging sources to keep your batteries fresh.

To this end, we designed the FPHM so that it can be charged from any DC voltage source between 6 volts and 30 volts which is capable of supplying at least 1.6 watts. But, since nothing comes for free, one cost of this flexibility (and reduced system cost to keep it affordable) is that the charging circuit on the FPHM exceeds FCC limits for radiated emissions with some combinations of external power. We supply the SB6VF 6 volt, 300 mA wall adapter with an attached ferrite, a power source which has been verified for FCC compliance for both conducted and radiated emissions when used with the FPHM. Other sources, including high-end high-power supplies, failed verification even with external ferrites.

As noted previously, the FPHM can accept charging inputs at either the power jack (P), in the case of the SB6VF, or at the screw terminals (T), in the case of an external battery. As with the power jack, the screw terminals can accept inputs between 6 volts and 30 volts, so this can support 6v and 8v golf cart batteries, 12v batteries, or 24v industrial equipment arrays, including the over-voltages that typically result when charging from alternators. To achieve FCC compliance, which we have tested with a 12v lead acid battery, the supplied 0.01 uF EMI capacitor must be attached at the screw terminals, with an external common mode choke wound five times. This capacitor and common mode choke are supplied with each FPHM for installation by the end user, as shown in an earlier section in detail. We will discuss other charging input options, including solar panels, in the next section regarding FCC compliance for homebuilt applications.

Because the LiFePO4 battery can be replaced so easily, another option is to keep a supply of batteries charging, and then simply replace batteries periodically, perhaps at each watch change in the case of zombie defense. Or, if your charging source is dependent on periodic power, such as a generator budget each evening or solar panels during the day, the batteries may not need explicit changing at all.

As mentioned previously, it is impossible to predict how long the battery charge will last. Long wires, and more use of the phones, will both affect battery life, and lifetime available charge/discharge cycles. It would be best to run some test exercises with your specific installation and get a feel for what is reasonable for you.

To protect the battery, the field phone host module will, on its own, shut down the relatively power-hungry phone lines when the battery discharges to about 2.7 volts. At this point, the green power LED will still be lit, and the ring interface features will still function, but the phones will be dead. If you encounter this situation, it is time to change or charge the battery. A full discharge is usually rated at 2.0 volts, but the trip from 2.7 volts to 2.0 volts is a rapid descent; at 2.7 volts the battery will only have about five percent of its capacity remaining.

Once the phone lines go dead, the power LED will discharge the battery down to about 2.0 volts, the full rated capacity of the battery, after another twelve or so hours. At this point, the power LED will be noticeably dimmer. The battery will continue to discharge very slowly from this point. Actual damage will begin to occur around 1.5 volts, but it will take the FPHM a long time to reach this level as even the LEDs will draw very little current. Even so, a battery left in the FPHM uncharged can eventually be damaged, and result in a battery fault when charging is attempted. See the next section regarding handling battery faults.

Again, an undamaged LiFePO4 battery can tolerate hundreds of 100% cycles, more 95% cycles, and many more 80% cycles. Any of these cases represents years of daily cycles of full discharge. You may wish to run an experiment with an actual installation and actual usage patterns to determine a typical schedule for replacing batteries. With a freshly-charged battery, remove any external charging power, take all phones off hook, and determine how long the phones run before the phone lines go dead. This is approximately the 95% discharge point, and represents the worst case talk time. Given that batteries lose capacity as they age, $4/5^{th}$ of this time would be a good maximum talk time goal over the first several hundred battery cycles.

Budgeting less continuous talk time than this $4/5^{th}$ metric, and having spare charged batteries on hand, might allow 1000 cycles or more each out of two batteries, rather than wearing out a single battery in 600 cycles. We sell additional LiFePO4 batteries at reasonable prices on our webstore for this purpose. In general, if in doubt, change or charge the battery. Unlike older battery technologies, LiFePO4 batteries are not subject to state-of-charge memory effects or discharged storage issues, so you can't go wrong by charging or swapping it often.

For planning purposes, a fully-discharged battery will take about 3 to 4 hours to fully charge on the FPHM, regardless of whether 1.6 watts or 160 watts are available at the input. You can purchase separate chargers to keep a supply of charged batteries on hand, but **be sure to get a charger designed specifically for LiFePO4** (which may include a LiFePO4 switch). We do not trust chargers which claim to be for any generic rechargeable lithium battery or which claim to detect LiFePO4 among other options. A Li-Ion charger can destroy a LiFePO4 the first time it is used, and if the lowest-bidder firmware inside the charger decides your LiFePO4 is a Li-Ion or lithium polymer, your battery is toast. Zombies can also smell burning batteries, we are told.

Finally, in a pinch, the FPHM can be operated solely from external power with no LiFePO4 battery at all. We have not tested this mode for FCC compliance.

Battery Faults

If you forget to change, charge or remove the battery, it will eventually over-discharge. When this happens, and charging power is reapplied, a battery fault may occur after a few minutes of attempted charging. This fault will be indicated by illumination of the red BAT FAULT light, just to the left of the CHG light. If sufficient charging power is applied, the phones will still work in this condition. If the battery is not severely damaged, after a few hours of preconditioning, the fault light will go out and the battery will begin to charge normally. Mark this battery for a profile test, as described in the previous section. Fortunately, unless you allow such over-discharges on a routine basis, the battery should still be serviceable, with little or no degradation in its service life.

If the fault light does not go out after several hours of charging, then remove the charging source, remove the battery, re-install the battery, and re-apply the charging source. The fault light may reappear after a few minutes and then go out sometime later, as described above. If the fault light never goes out after many hours over many attempts of this process, then the battery is probably ruined beyond recovery. We would feel comfortable using a battery which required two or three such cycles of fault preconditioning. We would not feel comfortable using a battery which failed ten such cycles. We would not rely on a battery which came back to life in the middle of that range, but it would be fine for keeping around rather than operate the field phone system with no battery at all. Mark it accordingly and use another battery for normal usage.

If you do find a battery that will not come back to life after ten or so fault preconditioning cycles, then mark it but keep it around. There is a jumpstart process using a current limited (1-10mA) voltage source (3v) that can sometimes work, but which is beyond the scope of this manual. The battery may not have very much useful capacity at that point, but ten years into zombie-war we would rather try that than have nothing.

Practical Tips

We've done a lot to try to convince the reader to take good care of the battery, and battery care is important, but fortunately, actual practice isn't likely to be that bad. A fixed installation, such as a farm, will likely have more or less reliable or intermittent charging power, such as a solar-charged battery bank for incidental loads. A command-post scenario, the most likely to experience more or less continuous phone use, will likely have shifts, and it is sensible enough to assign battery management as part of the operational checklist. The scenario most likely to experience long-term loss of charging power is a deployed zombie response field team, but that situation is not likely to experience continuous phone use either. Even so, that team could easily solve the battery problem by bringing a few spares, and LiFePO4 batteries are significantly lighter than other power alternatives.

It is possible to use the ring indications as a telegraph by using Morse or other codes, and thus greatly limit the amount of talk time. Ring indication uses only a few tens of milliwatts, depending on the number of attached stations and enabled buzzers, and that only when the button is pressed, while a full complement of phones in constant use is more like a half a watt. Some simple ring indication codes can be worked out to indicate specific messages or status updates, saving the talk time for essential communication.

The Morse or other code option introduces another possibility, and that is the use of the field phone system without phones at all, and simply sending Morse code or pre-arranged signals between stations using ring-interface modules as telegraph terminals. Further, if a listening post were to remove the jumper on its ring interface module, and cover its LED with a black marker to greatly reduce its intensity (or remove that LED's drive resistor entirely as shown in the modifications section later in this manual), then signals could be sent to the base FPHM unit with relative stealth. The listening posts could then have their wire and RIM sealed in a clear bag, making their end relatively weatherproof.

Look forward to future options in this regard, including the application of quiet, piezo ear buds, if sufficient interest exists. Or, a technical specialist may be able to wire additional options for you. Fortunately, the FPHM backbone provides a lot of the technical foundation you can use as a building block for more advanced systems.

Modification Tips

Most users will never feel the urge to modify the field phone system at all. However, there are those who want to modify things to better suit them. The purpose of this section is not to encourage modifications, but to inform those who wish to create custom homebuilt designs. We expect that anyone attempting any modifications is technically proficient, and assumes all risk for damaging their field phone system or operating in an FCC non-compliant mode. Be sure to read this manual in full to understand some fundamental principles, as we will not repeat them here. A technically proficient user may also wish to have the manufacturer's datasheets for the LT3652HV and LT3909 handy.

That said, if you blow up your field phone board for any reason, send us a photo and we'll treat its scorched carcass as a 25% coupon toward a new one (single board only, no bundles, power supplies, EMI accessories or batteries).

Adjusting LED Intensity or Usage

Some users may wish to modify the LED intensity, whether to make them brighter, dimmer, re-route their display to a remote panel, or disable them entirely. Table 1 presented an overview of each indicator LED. The corresponding resistors, and resistor values and voltages used to drive them, are shown in the table below. A technical specialist can make suitable modifications to the board by using this table, if desired.

Table 3: LED Drive Resistors

LED	Color	D #	R #	Value	Source Voltage
PWR ON	Green	D24	R22	220	VBATT
DC IN	Green	D2	R1	1k	VIN
CHG	Green	D4	R5	220	VBATT
(Line1, not marked)	Yellow	D7	R17	220	VBATT
(Line2, not marked)	Yellow	D6	R16	220	VBATT
REVERSE BATTERY	Red	D19	R15	330	VBATT
SHORT	Red	D12	R15	330	VBATT
FAULT	Red	D3	R4	330	VBATT

VIN: Charging voltage, 6v to 30v typical.
VBATT: LiFePO4 voltage, 2.7v to 3.4v typical.

Green LEDs: Kingbright APHCM2012CGCK-F01
Yellow LEDs: Kingbright APT2012SYCK
Red LEDs: Kingbright APT2012SURCK

Slightly Higher Input Voltage

We have specified the input voltage rating at 30 volts, but this is a limitation of the 30v input zener diode (D1), rather than the charger chip (U1). The charger chip can actually handle up to 34 volts, but D1 helps protect this part against transients. D1 can also help pull down low-current high-voltage inputs (such as weak, high-voltage solar panels) as long as its 1 W rating is not exceeded. Also, D10 is a Schottky diode, which gives an extra 0.4v of input voltage (which is why we specify a 6v input rather than the 4.95v the charger chip handles). For small voltages above 30.4 v, some upstream series silicon diodes will work nicely. The switching charger is set to consume about 1.6 W, so at 30 v it is using very little current. As a result, even low-power fractional-wattage diodes will do. Remember, however, that this will also raise the minimum voltage at the low end, and increase the current through the additional diodes at low input voltages.

Also, pay attention to the DC IN indicator LED. At voltages near the high end of the 6v to 30v input range, this LED begins to consume a larger and larger fraction of the available power. If your intended mode is to consistently operate at the high end, increase R1 to decrease the current consumed by this indicator. This LED has a typical forward voltage of 2.1v, and can handle up to 30 mA on a continuous basis, but operating it near 5 mA produces excellent results.

Much Higher Input Voltage

Amazon is littered with convenient little buck regulator modules that cost less than what we can buy the parts for in bulk. Even the small versions of these can handle the input current requirements at the high end of the input voltage range. Hot-melt glue one to the back of the FPHM, wire it up, and you are done.

Adjusting the Charge Current

The charge current is set to 500 mA by R9, a 0.2 ohm 1% 0603 surface mount resistor. This value can be changed in accordance with the LT3652HV datasheet to allow as much as a 2A charge current or as low as desired to reduce charger noise. While we wouldn't recommend 2A to charge the provided 1100 mA 18650 battery, a higher charge current might be acceptable for larger format LiFePO4 batteries wired into the same contacts. If you do go for a higher current, blue-wire the trace between R9 and C4 to make it much thicker.

Adjusting the Float/et al Voltage

Don't, unless you want to use some other battery technology besides LiFePO4. Such as if you have cases of lithium ion or lithium polymer batteries lying around. This is a non-trivial modification; examine the circuit board and figure out what components are what by comparing to the datasheet (if you get stuck, ask us, but you really shouldn't).

It would probably be cheaper in time, effort and cash just to buy some LiFePO4 batteries in bulk.

Custom Ring Indication

The FPHM buzzer gets energized with battery voltage, less at a RIM on the far end of a long wire. Even with long wires, there should be enough residual voltage to run the base of an NPN to help boost the indication or trigger a dependent relay. Be careful with custom ring indicators, a nearby lightning strike could trigger a ring, and those buttons are easy to hit by accident. Make sure you really want that thing to ring if you take this route.

Using More Phones

To support additional phones beyond the five supported innately, the line current may have to be increased on the LT3909. This is currently set to 30 mA on each line by R8, a 30k 1% 0603 resistor.

Using Longer Wires

Although we have tested the unit with simulated 1/4 mile wires (for technical feasibility, not for FCC compliance), longer wires will require a higher line voltage. R11 (30k 1%) and R12 (330k 1%) currently set this to a maximum of about 14.6v (normal operation will be around 8v). The chip is capable of creating line voltages up to 36 volts, but the higher you set this, the more current the FPHM will draw.

With higher voltages, you may also lose your master phone. The reason for this is that this constant current driver pumps 30 mA into each line (60 mA if the lines are bridged), while most phones pull the line down to a few volts. Those few volts then have to go over long lines to the remote phones. If the master phone is located close to the FPHM (reasonable assumption because that is where ring indication lives), then when it goes off-hook, the voltage available to the far-away remote phones dwindles to nothing.

The solution to this is to run lengths of wire to all phones as equal as possible, or simulating length to a nearby phone by using series resistors. This will make the voltage at the FPHM nearly equal when any phone goes off-hook. You may have to experiment with this some for your particular installation, but we have found that 22 ohm resistors work pretty well.

Another victim of long wires is ring indication. Although the AI-1441-TWT-12V-R buzzer uses only 7mA, this causes a significant drop over long distances. A custom ring indication circuit with a local power supply and a transistor to trigger things can solve this problem. If the field phone system sells well enough, we may introduce such a thing. Or, if someone wants to provide an open-source option, we'll let our customers know about it.

Conformal Coating

A useful modification, once you are satisfied with the operation of the field phone board and don't want to make any further modifications, is to add a conformal coating, which will provide additional protection against electro-static discharge or shorting, including, to some extent, by water. This can be done a variety of ways, whether by a plastic dip coating or spray, multiple sprays of urethane or other sealant, or epoxy. Be sure to tape off the phone connectors, switches, jumpers, battery socket and power connectors first, and any LEDs you want to be able to see, assuming you aren't using a clear coating.

Obviously, many portions of the board can't be coated, but you can reduce the possibility of shorting the board, especially by accidentally laying it on metal obstructions. Accordingly, the first location to conformal coat is the back of the board, which will greatly eliminate the chance of such shorts, and you won't need to mask off anything back there.

Bulk Purchases or Special Combinations

Want to buy components in bulk for groups of enthusiasts, or want discounts on special combinations we haven't listed on our webstore? Let us know and we'll try to help.