

# Power Options for Field WiFi Stations

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## Overview

This paper describes a variety of ways to power a field station consisting of a WiFi radio, IP phone, IP camera, and other devices. Specific examples are given for both Linksys and Ubiquiti radios since both can be used to provide Part 15 unlicensed WiFi services as well as Part 97 amateur radio mesh networking services. Measurements of actual station configurations are included. This information will be most useful for those who are new to Power over Ethernet, WiFi radios, IP phones, IP cameras or similar devices. But even experienced WiFi users may find some of the field-oriented configurations and measured results useful.

The solutions shown here are just a few examples of how to construct a power supply for a field WiFi station. Many more combinations exist. These examples include only commercially-available off the shelf products. The specific products shown below are known to work and are shown here, along with vendor information, to provide the reader with a more specific idea of how to construct a solution for field power. Alternatives for both the specific products and specific vendors mentioned below may exist. Select whatever works best for the anticipated deployment scenarios.

## Power over Ethernet

All of the radios, phones, cameras and other client devices discussed in this document are connected by an Ethernet cable for their data connection. Rather than have to deal with both a power cable and a data cable for each device, it makes sense to use a single cable to provide both power and Ethernet data connectivity to the device. Power over Ethernet or “PoE” makes this possible by transmitting the DC power needed by the device on the same Ethernet cable that provides data connectivity to the device. This makes it much easier to deploy devices in the field because each device only needs a single cable and devices can easily be moved by using a longer or shorter Ethernet cable.

There are two general categories of Power over Ethernet. The “standard” method follows the IEEE 802.3af or 802.3at standard, which defines when power is applied and what voltages and current levels are supported. The “passive” or “non-compliant” or “non-standard” method places power on the Ethernet cable all the time. Both are discussed below.

### IEEE 802.3af and 802.3at PoE

The IEEE 802.3af Power over Ethernet standard was completed in 2003. 802.3af compliant Power Sourcing Equipment or “PSE” (switches, injectors, etc.) provide up to 15.4 watts of DC power. Due to dissipation in the Ethernet cable, 12.95 watts is available at the Powered Device or “PD”. This was sufficient power for most devices such as phones, but was not enough for some power-hungry devices such as large pan/tilt/zoom cameras with infrared illumination. IEEE 802.3at, also known as “PoE+” or “PoE plus” was standardized in 2009 and provides up to 30.0 watts of power from the “PSE”, of which 25.5 watts is available at the “PD”. After 802.3at was standardized, 802.3af also became known as 802.3at Type 1.

802.3af/at Power Sourcing Equipment only applies power to the Ethernet cable if an 802.3af/at Powered Device is detected on the other end. This makes it safe to plug non-802.3af/at devices into an 802.3af/at switch. 802.3af/at PD detection is performed by sensing a specific signature resistance on certain pins of the Ethernet connection. Once an 802.3af/at PD is detected, the PSE and PD negotiate how much current is needed by the PD vs. how current much is available from the PSE. This allows 802.3af/at PDs to alter their behavior in cases where only limited power is available. For example, a camera might disable its infrared illumination and/or its pan/tilt/zoom motor if insufficient power is available from the PSE.

### IEEE 802.3af/at Power Sourcing Equipment

Standard 802.3af/at power can be injected into the PoE cable through two principle methods. The first method, called “endspan”, uses the Ethernet switch to deliver the power. Ethernet PoE switches are available from a variety of vendors in a variety of port configurations and at a variety of price points. In fact, most major Ethernet switch vendors offer several models of 802.3af/at PoE switches. The use of Ethernet PoE switches can simplify new configurations by eliminating the need for separate injectors and lots of Ethernet jumpers.

The other method of injecting power into the PoE cable is called “midspan”. This type of injector is located between the PSE and PD and is usually co-located with the Ethernet switch. A short Ethernet jumper runs from the switch to the injector. The injector then outputs PoE over the cable that goes to the device. Midspan injectors are often used when a non-PoE Ethernet switch already exists or when most client devices do not need PoE. Midspan injectors are available in multi-port or single port units.

Many amateur radio field applications will only need one or two single port injectors. As an example, the following single-port injectors from Tycon Power Systems provide standard IEEE 802.3af/at outputs for a broad range of input voltage:

- TP-DCDC-1248D – 10/100 Ethernet, 9-36VDC input, 48V 17W 802.3af PoE Output
- TP-DCDC-1248GD – Gigabit Ethernet, 9-36VDC input, 48V 17W 802.3af PoE Output

The wide input voltage range makes these injectors appropriate for either 12V or 24V battery systems.

### Passive PoE

Many PoE devices, including Ubiquiti AirMax radios, use Passive PoE. Passive PoE has no active circuitry to either detect PoE devices or negotiate power levels. It places power on the Ethernet cable all the time. Passive PoE typically uses the pair of wires on pins 4 and 5 of the Ethernet cable for positive voltage and the pair on pins 7 and 8 for ground. Different devices use different voltage levels, but the most common voltages are 24V, 48V and 57V. For a given power requirement at the Powered Device, a higher voltage mean less current is required (Power = Voltage \* Current). Lower current means less voltage drop due to the resistance of the Ethernet cable. PoE voltages less than 24V are not common because the resulting voltage drop on the Ethernet cable is usually too high.

### Passive PoE Injectors

Like standard IEEE 802.3af/at PoE injectors, passive POE injectors exist in both endspan and midspan configurations. However, Ethernet switches which deliver passive PoE are fairly specialized devices available from a few vendors who are focused on the WiFi network equipment market. Some example vendors include: Netonix, Tycon, and Ubiquiti.

Fortunately, a variety of midspan injectors are available which accept wide input voltage ranges and output passive PoE at various voltages. Many amateur radio field applications will only need one or two single port injectors. As an example, the following single-port injectors from Tycon Power Systems provide passive PoE outputs for a broad range of input voltage Following are just a few examples.

- TP-DCDC-1218: 9-36 VDC Input; 18 VDC 18 W Passive PoE Output
- TP-DCDC-1224: 9-36 VDC Input; 24 VDC 19 W Passive PoE Output
- TP-DCDC-1248: 9-36 VDC Input; 48 VDC 24 W Passive PoE Output

The wide input voltage range makes these injectors appropriate for either 12V or 24V battery systems.

### Voltage Drop on the PoE Cable

Power to most PoE devices is provided using two pairs of the Ethernet cable. One pair (pins 4 and 5) provides the positive voltage while another pair (pins 7 and 8) provides the return/ground.

Ethernet cables come in a variety of wire gauges. Most Cat5E jumpers are 24 AWG, although 26 AWG is also commonly found. 22 AWG is not very common and usually only found in Cat6A installations. Note that some discount Ethernet jumper cables may not strictly adhere to the EIA/TIA wiring standard for each cable category. So, be sure to check the specifications when purchasing Ethernet jumpers.

Each wire gauge has a standard resistance per foot. In PoE, a pair of wires is used for both positive and negative, which halves the resistance. But both the positive and negative pairs contribute to the total

resistance of the loop out to the device and back. So the round trip resistance of a pair is the same as the single wire resistance. The equation for calculating the voltage drop is:

$$\begin{aligned} \text{Vdrop (volts)} &= \text{Current (Amps)} * \text{Resistance (Ohms)} \\ &= \text{Current (Amps)} * [\text{Round trip Resistance/foot (Ohms/foot)} * \text{length (feet)}] \end{aligned}$$

The following table summarizes the expected voltage drop at the end of various lengths of Ethernet cable using 1 pair for positive and 1 pair for negative, based on wire size and current. A value of 600 mA has been used for the calculations because this value has been observed as the peak input current during startup of several Ubiquiti AirMax radios running at the maximum RF output. Substitute a different value for the current to calculate voltage drops for other devices.

AWG	Resistance (mΩ/ft)			Current (mA)	Round Trip Voltage Drop (volts)				
	1 wire	1 pair	Round Trip		Per ft	10 ft	25 ft	50 ft	100 ft
26	40.81	20.40	40.81	600	0.02	0.24	0.61	1.22	2.45
24	25.67	12.84	25.67	600	0.02	0.15	0.38	0.77	1.54
22	16.14	8.07	16.14	600	0.01	0.10	0.24	0.48	0.97

For example, consider a typical outdoor field application utilizing a radio that needs at least 10.5 volts and up to 600 mA of current. The workstation and power supply is in a pop-up tent and the radio/antenna can be located on a 10 to 12 foot mast attached to the corner of the tent. A 25 foot Ethernet jumper would be the ideal length to reach between the radio on the mast and a power supply located under the tent. Assuming the jumper is 24 AWG, the voltage drop for 600 mA across one 25-foot long pair of wires is 0.38 volts. Therefore, to power the radio with at least 10.5 volts, the battery voltage must not drop below  $10.5 + 0.38 = 10.88$  volts, or else the voltage drop in the cable will cause the voltage at the radio to be too low.

Indoor applications will typically require at least a 50 foot and possibly a 100 foot jumper to reach between the indoor workstation and the outdoor radio/antenna. For a 100 foot long, 24 AWG jumper, the battery must not be allowed to drop below  $10.5 + 1.54 = 12.04$  volts. This means that only a small portion of the available capacity of a typical 12V battery can be used.

Another issue to consider with respect to voltage drop is the fact that no electrical connection is perfect. All connections have some resistance and that resistance will result in some voltage drop. When few connections are used and they are of good quality, the voltage drop is typically small, perhaps negligible. But a small safety margin above the minimum of 10.5 volts is recommended, especially for EmComm setups which absolutely, positively need to work.

It should be clear from the above calculations that, for the example radio, which requires at least 10.5V, the use of an unregulated 12 volt battery should only be considered as a power source when the PoE cable length is fairly short (about 10 feet or less). If longer cable lengths are needed, the output voltage will need to be regulated to keep the voltage at the device end above the minimums. Any of the previously mentioned regulated power injectors would work well.

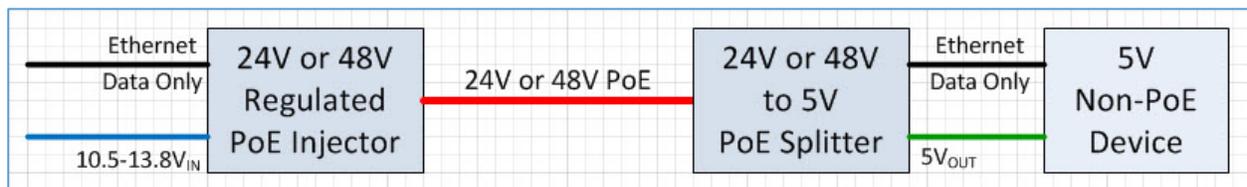
## Using PoE with Non-PoE Devices

Some low-end, consumer-grade phones and cameras have a separate DC power jack and do not support PoE natively. In other words, their Ethernet jacks are not designed to accept power on the Ethernet cable. These devices can still be powered using a single PoE cable by using a PoE splitter at the device end.

Many IP phones and cameras operate at 5 or 12 volts. But such a low voltage is not conducive to being distributed on Ethernet cables due to voltage drop considerations. For a given power requirement at the device, the lower the voltage, the higher the current required. And the higher the current, the higher the voltage drop will be on the PoE cable.

The way to overcome this problem is to use a higher voltage, such as 24V or 48V, on the Ethernet cable to reduce voltage drop. The injector provides Ethernet data and power on the PoE cable. A PoE splitter located at the device end of the cable separates the data and power, delivering the data connectivity via Ethernet, while stepping down the voltage and delivering power to a separate power connector.

The following diagram shows a 5V device, such as a camera or phone, powered by a PoE connection of 24V or 48V. The injector accepts unregulated 12V power, such as from a battery, and produces a regulated PoE output at a higher voltage. The splitter separates the data from the power, steps down the voltage, and produces a regulated 5V output for the device.



Commercially available splitters are available from several vendors. Following are just a few references to provide an example of the options available.

- Tycon Power Systems splitters:
  - POE-MSPLT-4805: IEEE 802.3af/at or 48V passive PoE Input; 5V, 2.5A Output
  - POE-MSPLT-4812: IEEE 802.3af/at or 48V passive PoE Input; 12V, 1A Output
  - POE-MSPLT-4824: IEEE 802.3af/at or 48V passive PoE Input; 24V, 0.5A Output
- WiFi Texas splitters:
  - WS-POE-5v10W: 12-28V passive PoE Input; 5V, 2A Output
  - WS-POE-12v: 18-24V passive PoE Input; 12V, 1A Output

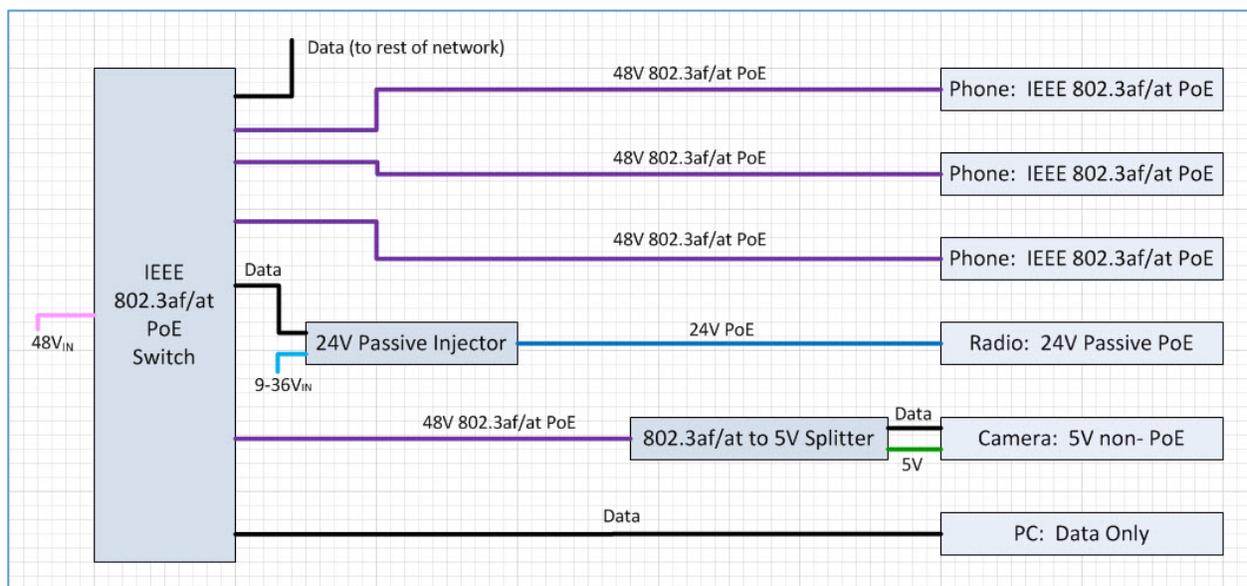
## Mixed PoE Environments

Most station designs will involve a variety of PoE types. Some devices will support standard IEEE 802.3af/at PoE. Some devices will require passive PoE. Some devices need power but won't support PoE at all. Still other devices have their own power source (such as laptops or servers). There are many ways to connect all of these device together. The choice of design is dependent upon a variety of factors, including: powered device requirements, cost, component count, component availability, cabling simplicity, and personal preference.

Consider a typical command post or headquarters site at a field event. The device connectivity requirements might include:

- Three (or more) IEEE 802.3af/at phones: One or two for the served agency; one or two for technical support and testing.
- WiFi radio using 24V passive PoE
- Camera using 5V, no PoE. The camera will be mounted on a mast so a single cable to feed both power and data is preferable.
- One or more PCs: served agency PCs, servers, etc.
- Ethernet switch to connect them all together

Of course, a separate power injector could be used for each individual PoE device. But the cost and cabling complexity adds up quickly. Since multiple devices support standard 802.3af/at PoE, a multi-port (“midspan”) injector could be used to reduce cost and device count. But an even simpler approach is to use an 802.3af/at Ethernet switch. Such a switch will supply 802.3af/at power and data to 802.3af/at devices and data only to non-802.3af/at devices. The following diagram summarizes the connectivity:



Each of the phones receives power and data directly from the PoE switch using standard IEEE 802.3af/at PoE. The WiFi radio uses 24V passive PoE. So a separate injector is used. Since neither the injector nor the radio is detected as an 802.3af/at device, the PoE switch supplies only data. The camera needs 5 volts but is not PoE capable. An 802.3af/at splitter can be used to draw standard 802.3af/at PoE from the switch and present the camera with separate data and regulated 5V power connections. This allows the camera to be easily positioned far from the Ethernet switch without worry about voltage drop. The PC and the connection to the rest of the network don't need power from the switch and aren't detected as 802.3af/at devices, so the switch sends only data.

Note that two different input voltages are required. The PoE switch requires 48VDC, which can be supplied from a 12V battery using a 12V to 48V step-up converter/regulator. The 24V Passive PoE injector has a wide input range which can draw power directly from a 12V battery.

The above example is just one of many possibilities. To understand the trade-offs of one design vs. another, a more detailed understanding of the specific requirements and capabilities of the devices involved is needed. The following sections should provide the reader with more device-specific details.

## Linksys Power Considerations

### Linksys Current and Power Requirements

The Linksys WRT54 series of wireless routers are nominally rated as 12 VDC devices. Anecdotal evidence and some experimentation has shown that these devices work over an input voltage range of 10 to 15 volts. This means they can be powered directly from a typical 12 volt sealed lead-acid (SLA) battery which has a useful output voltage range of approximately 10.5-13.8 volts.

The following table summarizes the input current ( $I_{IN}$ ) and power ( $P_{IN}$ ) drawn by a Linksys WRT54G for a given RF output power and different input voltages. The typical value was measured after the device booted up and was sitting idle with little to no network traffic. The maximum value occurred when the device was booted up or rebooted.

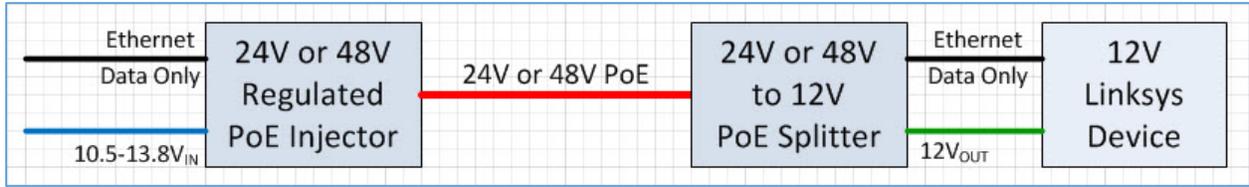
RF Pwr (dBm)	$V_{IN}$ (volts)	$I_{IN}$ (mA) Typical / Max	$P_{IN}$ (W) Typical / Max
19	15	221 / 231	3.3 / 3.5
	14	236 / 242	3.3 / 3.4
	13	251 / 262	3.3 / 3.4
	12	272 / 295	3.3 / 3.5
	11	297 / 306	3.3 / 3.4
	10.5	309 / 319	3.2 / 3.5
	10	325 / 345	3.3 / 3.4

For purposes of planning how long a battery in a field station will last, use the average typical current and compare to the discharge curves on the battery datasheet to estimate the run time. Since the typical at-rest voltage of a 12V battery is about 13.2 volts and it's best not to discharge the battery lower than 10.5 volts, the approximate average typical current can be calculated from the above data using the 13V and 10.5V typical current values:  $(251+309)/2=280$  mA. The Linksys will require peak power of about 3.5 watts.

### Powering the Linksys Device with PoE

If the Linksys device will be used in a real network deployment, it would be best to get the antennas up above the local clutter of people, equipment, pop-up tents and other items that can attenuate the signal and cause multi-path problems. Rather than suffering a lot of signal loss by using a long coax run to a remote antenna, it would be better to locate the Linksys device at the top of a mast (in a suitable enclosure to protect it from the elements).

The above data shows that the Linksys device needs about 3.5 watts of power (plus a safety margin), which is easily supported by PoE. The Linksys device does not support PoE natively. But the injector/splitter combination described previously could be used to provide both power and data connectivity to the Linksys using a single Ethernet cable. The following diagram summarizes the connectivity.



## Ubiquiti Power Considerations

### Ubiquiti Current and Power Requirements

Most of the Ubiquiti 10/100 Mbps AirMax products use passive PoE. The Ubiquiti AirMax devices such as the Rocket, NanoStation, Bullet and PicoStation are advertised as 24 VDC devices. The actual input voltage tolerance band is not listed on the product datasheets. But, according to some postings by Ubiquiti employees on the company's user forums, the units will be stable over the input voltage range of 10.5 VDC to 25 VDC.

This input voltage range is important when considering the use of batteries to power the Ubiquiti devices. The useful voltage range of a 12 volt sealed lead-acid (SLA) battery is typically from about 13.8 volts down to 10.5 volts. If two SLA batteries are connected in series to achieve 24 volts, then the fully charged series battery voltage of about 27.6 volts ( $\sim 13.8 \text{ V} \times 2$ ) will far exceed 25 volts and might damage the device. Alternatively, if a single 12 volt SLA battery is used, the input voltage would be starting near the lower end of the Ubiquiti input voltage tolerance range and the battery could not be discharged all the way down to 10.5 volts due to the voltage drop that will occur on the Ethernet cable.

The input current drawn by the Ubiquiti radio varies depending on the configured RF output power and the input voltage. For a given RF output power, the lower the input voltage, the higher the current drawn by the Ubiquiti device.

To understand the current requirements of the Ubiquiti devices, a variety of measurements were taken using four devices: a Rocket M2, a NanoStation M2, a Rocket M5, and a Bullet M5. The maximum RF output power of the Bullet M5 is 25 dBm. So all devices were measured at that RF output power level. The other devices were also measured at their maximum RF output level. Two current values were measured: Typical and Maximum. The typical value was measured after the device booted up and was sitting idle with little to no network traffic. The maximum value occurred when the device boots up or reboots.

The table below summarizes the typical and maximum current drawn by several Ubiquiti devices for several combinations of RF output power and input voltage. For each row, the input voltage is multiplied by the highest input current (bolded) and the result is shown as the maximum power.

RF Out (dBm)	V <sub>IN</sub> (volts)	Input Current: Typical (mA) / Maximum (mA)				Maximum Power (W)
		Rocket M2	NanoStation M2	Rocket M5	Bullet M5	
25	24.0	133 / <b>274</b>	127 / 262	140 / 190	121 / 177	6.6
	18.0	170 / <b>399</b>	164 / 307	179 / 244	154 / 228	<b>7.2</b>
	12.0	245 / <b>512</b>	235 / 492	259 / 357	221 / 328	6.2
	11.0	265 / <b>561</b>	255 / 541	281 / 396	239 / 354	6.2
	10.5	277 / <b>577</b>	265 / 543	292 / 430	250 / 368	6.1
27	24.0			140 / <b>190</b>		4.6
	18.0			180 / <b>255</b>		4.6
	12.0			260 / <b>359</b>		4.3
	11.0			282 / <b>390</b>		4.3
	10.5			294 / <b>409</b>		4.3
28	24.0	135 / <b>268</b>	130 / 262			6.4
	18.0	173 / 347	167 / <b>396</b>			<b>7.2</b>

	12.0	249 / 496	239 / <b>509</b>			6.1
	11.0	270 / <b>580</b>	258 / 522			6.4
	10.5	282 / 585	270 / <b>594</b>			6.3

For purposes of planning how to power a field station, these number can be used as follows:

- Design a power source that meets the worst case of all of the above measurements, plus a safety margin, to ensure it is flexible enough to use with any of the above radios.
- Use the highest maximum current value listed above (594 mA) when calculating voltage drop on the Ethernet cable. This will ensure that the Ubiquiti device always gets whatever power it needs, including during boot-up/reboot.
- Use the average typical current and compare to the discharge curves on the battery datasheet to estimate the run time.
- Use the highest of the maximum power calculations (plus a safety margin) to plan the PoE power requirements. The above test results show that the typical Ubiquiti device will consume up to approximately 7.2 watts of power.

### Powering the Ubiquiti Device with PoE

Since the Ubiquiti device has a broad input voltage tolerance, passive PoE injectors of either 18V or 24V will work. The experimental data above shows that the Ubiquiti device draws less current, and the voltage drop on the Ethernet cable will be lower, if the input voltage is higher. So, a 24 volt injector might seem preferable. But the 24 volt injector has to draw more current for itself than an 18 volt injector does in order to boost the voltage higher than the 18 volt injector does. In contrast, at 18 volts the Ubiquiti device will draw more current and there will be more voltage drop on the Ethernet cable. But the 18 volt injector draws less current for itself because it doesn't need to boost the voltage as high as the 24 volt injector.

To see which combination is better, a Ubiquiti Rocket M2 set to 28 dBm RF output power was connected to each injector and allowed to boot and reach steady state. Then measurements of the injector input current were made at different input voltages using two different lengths of 24 AWG Ethernet cable.

The following table summarizes the steady state input current vs. input voltage and Ethernet cable length for both of the above models of DC-to-DC regulated PoE injectors.

$V_{IN}$ (volts)	TP-DCDC-1218 $I_{IN}$ (mA)		TP-DCDC-1224 $I_{IN}$ (mA)	
	3 ft Cable	100 ft Cable	3 ft Cable	100 ft Cable
24	161	162	163	163
23	167	169	171	170
22	174	177	178	178
21	181	186	186	187
18	214	217	219	218
12	325	333	331	332
11	358	366	366	367
10.5	377	384	387	388

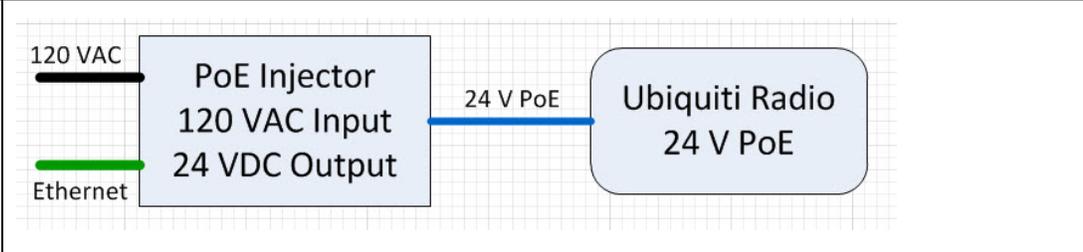
For short Ethernet cable runs, the 18 volt injector has a very small (essentially negligible) advantage at lower voltages because it draws slightly less current. For example, at 11 volts input and using a 3 ft cable, the 18 volt injector draws 358 mA vs. the 366 mA drawn by the 24 volt injector. For longer cable runs, there is no significant difference in the input current. The 24V injector has the added advantage of possibly being used with a 24V PoE splitter to provide power to for lower voltage, non-PoE devices.

### Ubiquiti Passive Power over Ethernet Wiring Options

There are a variety of ways to deliver passive PoE to the Ubiquiti radios. This section provides details for several methods, including a connectivity diagram and specific details for example components.

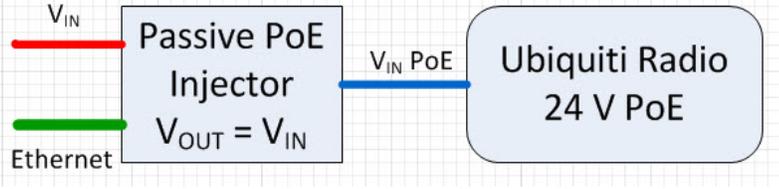
#### 120 VAC Power Injector

This method uses the standard power injector that comes with most of the Ubiquiti AirMax products. The 120 VAC could be supplied by either a generator or an inverter. Ubiquiti makes several power injectors. The 10/100 Mbps NanoStation comes with, and the Bullet devices can be used with, a 24 VDC 12 W (0.5 A) injector (Ubiquiti part number POE-24-12W). The 10/100 Mbps Rocket devices typically come with a 24 VDC 24 W (1.0 A) injector (Ubiquiti part number POE-24-24W).

<p>Diagram:</p>		
<p>Example:</p>		<p>Manufacturer: Ubiquiti                  Part Number: POE-24-12W, POE-24-24W                  Source: Amazon, Streakwave, ...                  Approximate price: \$15-20</p>

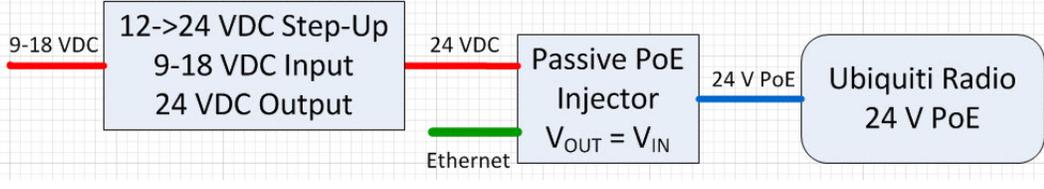
#### Passive Power Injector

This is a purely passive device. It applies the positive input voltage to pins 4 and 5 and the negative/ground/return to pins 7 and 8. This type of device can be used if you are sure that the input voltage will be sufficient for the needs of the PoE device.

<p>Diagram:</p>		
<p>Example:</p>		<p>Manufacturer: Alpha                  Part Number: APOE01                  Source: Amazon                  Approximate price: \$1.99                  Notes: Accepts standard 2.1mm DC power cable</p>

12 to 24 VDC Step-Up with Passive Power Injector

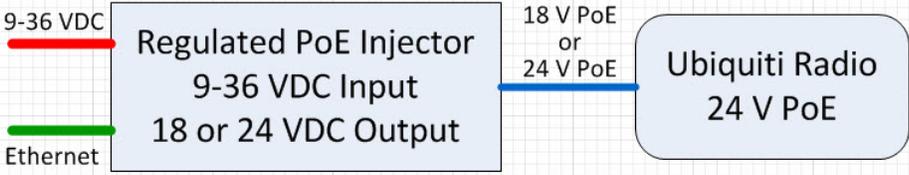
In order to regulate the DC input from a single 12V battery to the passive power injector, a 12V to 24V step-up converter can be used. This ensures a constant 24 VDC input to the passive injector while allowing the battery to be discharged to lower voltages. Maintaining the higher PoE voltage minimizes the voltage drop on the Ethernet cable (see discussion above).

<p>Diagram:</p>		
<p>Example:</p>		<p>Manufacturer: Supernight, SMAKN, others ...                  Part Number: varies                  Source: Amazon                  Approximate price: \$23 to \$33                  Notes: Allowable input voltage and output current varies by manufacturer.</p>

		<p>Manufacturer: Alpha                  Part Number: APOE01                  Source: Amazon                  Approximate price: \$1.99                  Notes: Accepts standard 2.1mm DC power cable</p>
--	---	--

### 18 or 24 VDC Regulated Power Injector

Power injectors are available which accept a wide range of input voltages such as 9 to 36 VDC and output a regulated 18 or 24 VDC. These could be used with either a single or dual battery source to provide a consistent output voltage throughout the full useful range of battery voltages (typically about 13.8 volts down to about 10.5 volts, per battery). Maintaining the higher PoE voltage minimizes the voltage drop on the Ethernet cable (see discussion above).

<p>Diagram:</p>		
<p>Example:</p>		<p>Manufacturer: Tycon Power Systems                  Part Numbers:</p> <ul style="list-style-type: none"> <li>• 18 VDC PoE: TP-DCDC-1218</li> <li>• 24 VDC PoE: TP-DCDC-1224</li> </ul> <p>Source: Streakwave                  Approximate price: \$37                  Notes: The 18 volt version has a small advantage of using slightly less current on short cable runs. For longer cable runs, there is no significant advantage.</p>

### 802.3af Injector and “Instant IEEE 802.3af” Adapter

The IEEE 802.3af/at standard specifies how Power over Ethernet devices can negotiate power requirements with and draw power from an injector. The standard specifies 48 VDC. Ubiquiti markets an adapter called “Instant 802.3af” which adapts standard 802.3af 48 VDC PoE to passive PoE used by Ubiquiti. The output voltage of the “Instant 802.3af” is 18 VDC, which is plenty to drive the Ubiquiti radios. The device is inserted into the PoE line, between the 802.3af source and the Ubiquiti device. Two models are available: one for indoors (Ubiquiti model number INS-8023AF-I), and a weather

resistant model for outdoors (Ubiquiti model number INS-8023AF-O). Voltage drop on the PoE cable can be minimized by using the outdoor model and placing the Instant 802.3af device at the radio end of the cable.

Diagram:		
Example:		Manufacturer: Ubiquiti Model Name: Instant 802.3af (Outdoor) Part Numbers: <ul style="list-style-type: none"> <li>• INS-8023AF-O (Outdoor)</li> <li>• INS-8023AF-I (Indoor)</li> </ul> Source: Amazon, Streakwave Approximate price: \$19

### 24 VDC Passive PoE Switch

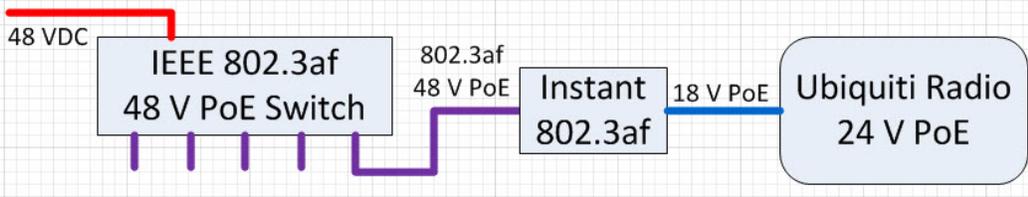
Ubiquiti markets a line of switches call the ToughSwitch which can supply 24 VDC passive PoE to Ubiquiti devices. They come in 5, 8, and 16 port flavors. The 5 port version runs on 24 VDC. The 8 and 16 port versions run on 120 VAC. Similar switches are available from other vendors.

Diagram:		
Example:		Manufacturer: Ubiquiti Model Name: ToughSwitch 5-port Part Number: TS-5-POE Source: Amazon, Streakwave Approximate price: \$95

### 802.3af 48 VDC PoE Switch and “Instant 802.3af” Adapter

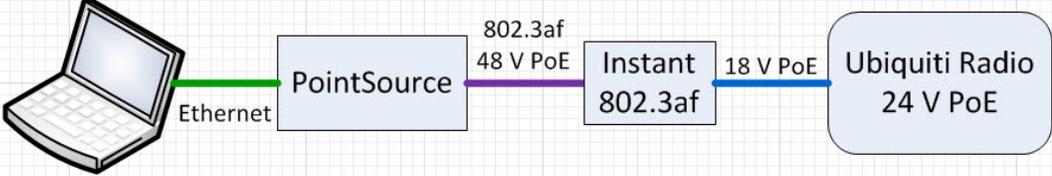
Most enterprise and carrier Power over Ethernet switches implement the IEEE 802.3af or 802.3at standard. When adding a Ubiquiti 24 volt device to an existing 802.3af/at infrastructure, the simplest

approach is to enable power on the Ethernet switch port which feeds the Ubiquiti device and then use the “Instant 802.3af” adapter to adapt the power to Ubiquiti passive PoE voltage requirements.

Diagram:		
Example:		<p>Manufacturer: Ubiquiti                  Model Name: Instant 802.3af (Outdoor)                  Part Number: INS-8023AF-O                  Also available: INS-8023AF-I                  Source: Amazon, Streakwave                  Approximate price: \$19</p>

Portable PoE for Roof-top or Tower Installation/Alignment

When installing a WiFi device with a directional antenna on a roof or tower, it is convenient to have a local power source and LAN connection so that a laptop can be used near the device to monitor the alignment utility while adjusting the antenna alignment. The Veracity Pointsource (Veracity model number VAD-PS) is perfect for this purpose. The Pointsource has an Ethernet port to which the laptop is connected. The device then outputs 802.3af Power over Ethernet from an onboard battery to a second Ethernet port. The Ubiquiti “Instant 802.3af” adapter is used to convert to passive PoE for use with the Ubiquiti device. The device comes with a charger and shoulder strap. The strap is convenient for attaching to a tower.

Diagram:		
Example:		<p>Manufacturer: Veracity                  Model Name: Pointsource                  Part Number: VAD-PS                  Source: Amazon, Streakwave                  Approximate price: \$225</p>

	 A white, cylindrical PoE injector with a black Ethernet cable attached to one end and a metal mounting bracket on the other. The injector is shown against a light gray background.	<p>Manufacturer: Ubiquiti Model Name: Instant 802.3af (Outdoor) Part Number: INS-8023AF-O Also available: INS-8023AF-I Source: Amazon, Streakwave Approximate price: \$19</p>
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## Power Considerations for Other Station Components

The WiFi radio is just one part of the field station that must be powered. This section discusses the power options for other devices that make up a typical field network station.

### Power over Ethernet vs. Separate Power Cords

The principal advantage of using Power over Ethernet is ease of deployment. PoE devices don't require a separate power cord so they can be more easily located in a convenient location than a device that needs both an Ethernet cable and a power cable. As explained earlier, even 5V and 12V non-PoE devices can be located 25, 50, or more feet away by using a higher voltage PoE injector and a PoE step down splitter. Examples are a camera which might be mounted on top of an outdoor mast, or multiple phones distributed within a shelter or incident command post. To simplify station design, consider using PoE for as many devices as possible.

### DC Voltage Step-Up/Down Regulators

Sealed DC voltage regulators are readily available. They are extremely easy to integrate into a field station and their circuitry is protected from anything touching it. All that is required is to attach connectors to their input and output power leads and then connect them between the battery and the device(s) to be powered. The following table shows just a few examples for delivering different regulated DC voltages from a 12V battery.

<p><b>5 VDC Regulated Output</b>                  Source: Amazon                  Description: 12V/24V to 5V 5A/25W Car Regulator Power Supply Module                  Manufacturer: Kimdrex                  Input: 9-35 VDC                  Output: 5 VDC / 5A                  Approximate price: \$16</p>	
<p><b>12 VDC Regulated Output</b>                  Source: Amazon                  Description: 8V-40V Step Down to 12V 6A 72W                  Manufacturer: SUPERNIGHT                  Approximate price: \$24                  Input: 8-40 VDC                  Output: 12 VDC / 6A                  Approximate price: \$24</p>	

<p><b>24 VDC Regulated Output</b>  Source: Amazon  Description: DC/DC Converter Regulator 12v Step up to 24v 3a 72w  Manufacturer: SUPERNIGHT  Approximate price: \$23  Input: 8 – 18 VDC  Output: 24 VDC / 3A</p>	
<p><b>48 VDC Regulated Output</b>  Source: Amazon  Description: Generic 144W 12V to 48V 3A DC-DC Converter Boost Step-up Car Power Module Waterproof  Manufacturer: Unknown  Input: 10-15 VDC  Output: 48 VDC / 3A  Approximate price: \$32</p>	
<p><b>Adjustable DC Regulated Output</b>  Source: Amazon  Description: DROK 5V/12V/24V Adjustable 5-32V to 1-27V DC Volt Converter Regulator Step-down Power Supply  Input: 5-32 VDC (at least 2V above desired output voltage)  Output: 1-27 VDC adjustable / 5A Max  Approximate price: \$15  Note: Can be used to delivery uncommon voltages such as 7.5V or 9V from a 12V battery system. But be careful to protect the adjustment screw on the underside of the device from being bumped in the field. It might be wise to keep a volt meter handy in case the output voltage needs to be checked or adjusted in the field.</p>	

## Ethernet Switches

Most WiFi radios have a single Ethernet port. But most field stations will have two or more devices to be connected, such as: at least one PC, at least one Voice over IP (VoIP) Phone, a camera, and possibly a printer. Therefore, an Ethernet switch will most likely be needed.

## Non-PoE Switches

Most small, 5 to 10 port Ethernet switches operate on 5, 7.5 or 12 volts DC. There are many brands of switches and trying to determine the true input voltage tolerance for all of them would be a never-ending (and costly) project. The most straight-forward approach is to plan to deliver a regulated input voltage to the switch. When choosing a switch, select one with an input voltage that can easily be supplied by commercial, off-the-shelf voltage regulators such as those shown above.

## Standard IEEE 802.3af/at PoE Switches

A variety of 5 to 10 port PoE switches are available which operate on 48 volts DC. It is a simple matter to use a 12V to 48V step-up converter/regulator to provide power to these switches. The switch then

provides power to the attached 802.3af/at devices using PoE. So, a single DC power connection can power the switch and several attached devices.

#### Passive PoE Switches

Small, 5 to 8 port passive PoE switches are available from a few vendors who specialize in WiFi network equipment. Some switches can even provide different voltages on each port. These switches typically require a DC input voltage of at least the highest voltage to be supplied on any port. Other switches provide a single output voltage on all ports. For example, Ubiquiti offers a 5-port, 24V passive PoE switch which operates on 24 VDC input. According to a post from a Ubiquiti employee on the Ubiquiti user forums, the officially recommended input voltage range is 22-25 VDC. The switch can power multiple Ubiquiti radios with 24 volt PoE. The input voltage to the switch will be passed to the PoE devices minus about a 0.4 volt drop. Use of this switch would require a 24 VDC output from the station power system.

#### Voice over IP (VoIP) Phones

Some inexpensive, consumer-grade Voice over IP (VoIP) phones typically operate using a separate 5 or 12 volt power supply. For ease of deployment, it is advantageous to run a single PoE cable to the phone, especially if it might be moved around on the desk. Use a PoE injector at the Ethernet switch and a PoE splitter at the device.

Business/enterprise-class phones typically cost only a little more but usually offer the advantage of accepting standard IEEE 802.3af/at PoE at 48 volts. For a field station with only one or two phones, individual power injectors could be used. For a command post with multiple phones, a PoE switch can be cheaper and easier to deploy. Phones with displays and lighted buttons, can draw significantly more power than non-display, voice-only phones.

#### IP Cameras

Many inexpensive, consumer-grade IP cameras typically operate using a separate 5 or 12 volt power supply. Some cameras operate on 24V passive PoE. Higher-end cameras typically use standard IEEE 802.3af/at PoE at 48 volts. Check the device to see which type of power it will accept. Pan/Tilt/Zoom cameras and cameras which feature infrared illumination can draw significantly more power than fixed cameras.

#### PC and Printer

One or more PCs and, perhaps, a printer can be useful at many types of field stations. PCs and printers usually require much more power than any of the other devices mentioned here and will probably be powered separately. Most modern PCs can operate for several hours on their own internal batteries. Some mobile printers can operate on their own batteries.

## Field WiFi Station Power System Examples

In the examples that follow, only the power requirements of the network components are considered. Small servers running on 5 or 12 VDC are widely available and can easily be added to these configurations. Power for individual user PCs and printers is outside the scope of this document.

The reasoning behind the configurations shown below is described in each example.

### Example 1: Linksys Node Only

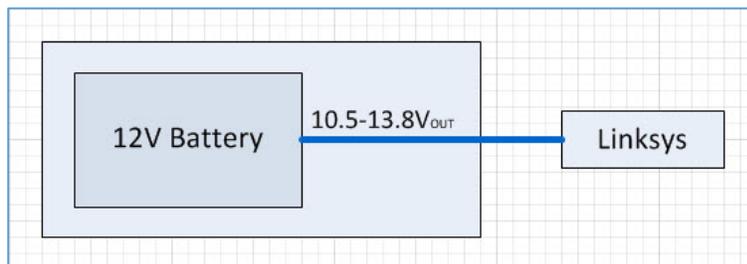
#### Requirements

- Location
  - All devices are indoors (the Linksys device is not weather resistant)
  - All devices are fairly close to the Linksys node (the Ethernet switch is in the node itself)
- Devices to be powered:
  - Linksys node: 10-15 VDC @ <500 mA

#### Design Considerations

- The Linksys input voltage tolerance (10-15 VDC) is wider than the useful operating voltage range of an SLA battery (10.5-13.8 VDC). So the Linksys can be connected directly to the battery.

#### Diagram



#### Components

The example system can be constructed using the following components.

- 12 volt, 7Ah SLA battery
- Small plastic box to protect battery and prevent terminals from being shorted

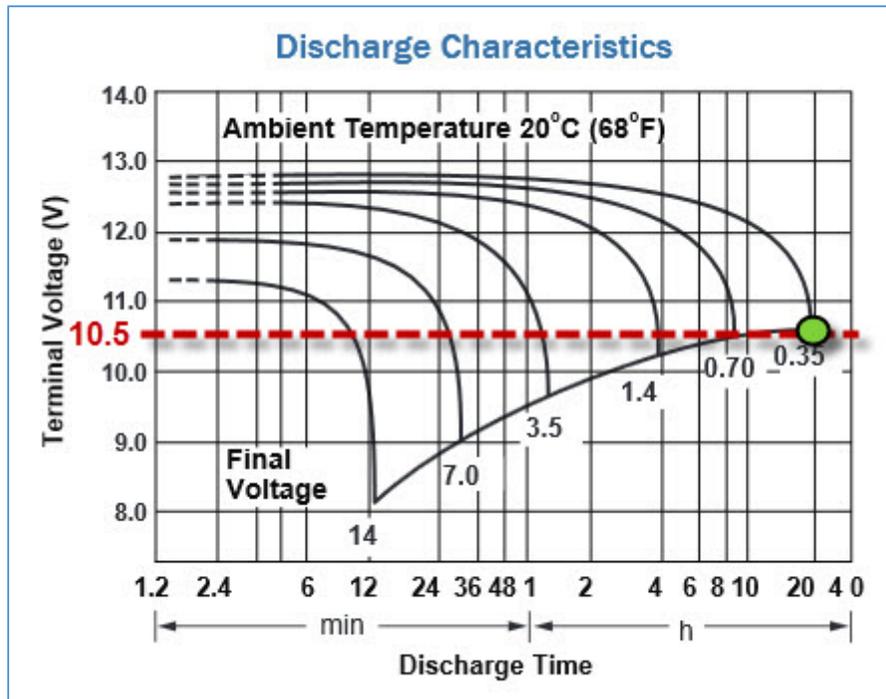
#### Lab Testing

As described earlier, the current used by the Linksys device was measured at its maximum RF output power (19 dBm) and several different input voltages. The resulting table of values shown earlier is repeated here.

RF Pwr (dBm)	V <sub>IN</sub> (volts)	I <sub>IN</sub> (mA) Typical / Max
19	15	221 / 231
	14	236 / 242
	13	251 / 262
	12	272 / 295
	11	297 / 306
	10.5	309 / 319
	10	325 / 345

Analysis

The following discharge curves are from the datasheet for a Power-Sonic 12 volt, 7 Ah battery, model number PS-1270. Each curve represents the output voltage over time for a different discharge current. The red line was added to show the minimum safe discharge voltage of 10.5 volts. The green dot was added to show where the curve would end for the worst case current in the above results (345 mA).



Power-Sonic PS-1270, 345mA discharge, 10.5V cutoff

Reading down from the green dot to the X-axis shows that a brand new battery used in the above configuration should last approximately 20 hours. Adding some safety margin to account for an older, less than perfectly maintained battery, and to account for the additional current from a camera and more network traffic, it is clear that the battery should last for at least 16-18 hours.

Conclusion

This configuration using one 12 volt, 7 Ah batteries is portable, affordable, and should easily support field operations for at least a full 8 hour shift, possibly two shifts.

## Example 2: Linksys Node with Additional Devices

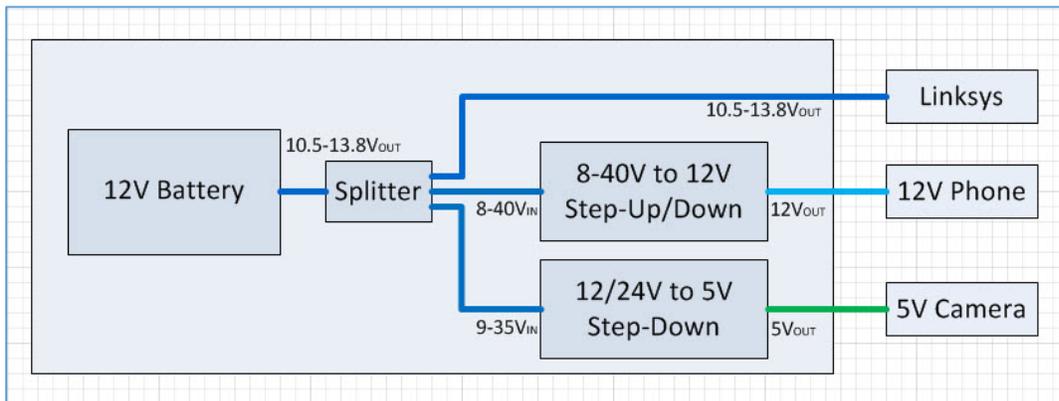
### Requirements

- Location
  - All devices are indoors (the Linksys device is not weather resistant)
  - All devices are fairly close to the Linksys node (the Ethernet switch is in the node itself)
- Devices to be powered:
  - Linksys node: 10-15 VDC @ < 1 A
  - Phone: 12 VDC @ < 600 mA
  - Camera: 5 VDC @ < 200 mA

### Design Considerations

- The Linksys input voltage tolerance (10-15 VDC) is wider than the useful operating voltage range of an SLA battery (10.5-13.8 VDC). So the Linksys can be connected directly to the battery.
- The intent of the design is to support commercially available, off-the-shelf products. So regulated DC voltage will be provided to all other network components.
- Given that a 12 VDC regulated output will need to exist, the Linksys could be connected to that or corrected directly to the battery, depending on the current capacity of the regulator.
- No Ethernet switch is needed since the Linksys contains a 5 port switch

### Diagram



### Components

The example system can be constructed using the following components.

<p><b>12 V Battery</b>                  Manufacturer = various                  Quantity = 1</p>	
--	--

<p><b>8-40V to 12V Step-Up/Down</b>          Manufacturer: SUPERNIGHT          Description: 8V-40V Step Down to 12V 6A 72W          Source: Amazon          Approximate price: \$24          Note: This is a 6A unit. It has the advantage of accepting input from either a single or dual battery configuration.</p>	
<p><b>12/24V to 5V Step Down</b>          Manufacturer: Kimdrox          Description: 12V/24V to 5V 5A/25W Car Regulator Power Supply Module          Source: Amazon          Approximate price: \$16</p>	
<p><b>Box</b>          Manufacturer: Really Useful Boxes          Size: 3.0 Liter (for CDs, DVDs)          Source: Amazon, Office Depot, etc.          Approximate price: \$6</p>	

### Example 3: Ubiquiti Node Only

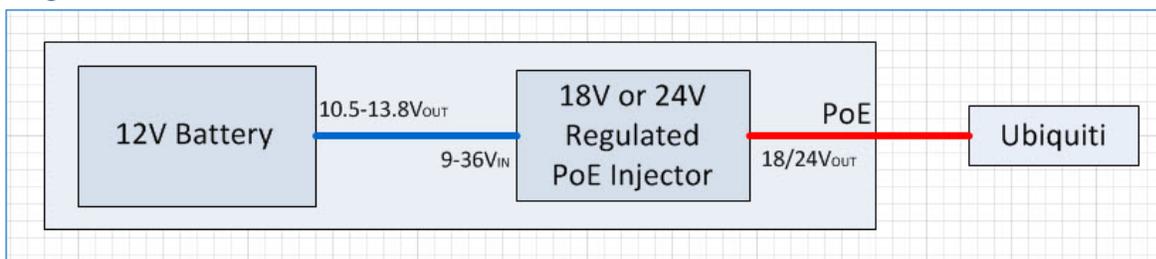
#### Requirements

- Location
  - Radio/antenna located outdoors on a 20 foot pole as a fill-in node/repeater. The node will bridge the coverage between other nodes, but will not have any local devices connected to it.
  - Battery will be located at the base of the pole for ease of maintenance and so that the pole doesn't need to support the weight of the battery.
- Devices to be powered
  - Ubiquiti radio: 10.5-25 VDC @ < 1 A passive PoE using 25 ft of 24 AWG wire

#### Design Considerations

- A very short PoE cable would introduce negligible voltage drop and a passive PoE injector could be used to power the Ubiquiti device directly from a battery. But the 25 foot PoE cable in this example will introduce a significant voltage drop of 0.38 volts. That means that the battery cannot be discharged any lower than 10.88 volts, reducing the available battery capacity. That may be sufficient for most needs. If not, a regulated PoE injector can be used. This example uses the regulated PoE injector.

#### Diagram



#### Components

The example system can be constructed using the following components.

<p><b>12 V Battery</b>                  Manufacturer = various                  Quantity = 1</p>	
--	--

<p><b>18 or 24 volt PoE Injector</b> Manufacturer: Tycon Power Systems Part Numbers:<ul style="list-style-type: none"><li>• 18 VDC PoE: TP-DCDC-1218</li><li>• 24 VDC PoE: TP-DCDC-1224</li></ul>Source: Streakwave Approximate price: \$37 Notes: The 18 volt version has a small advantage of using slightly less current on short cable runs. For longer cable runs, there is no significant advantage.</p>	
<p><b>Box</b> Manufacturer: Really Useful Boxes Size: 3.0 Liter (for CDs, DVDs) Source: Amazon, Office Depot, etc. Approximate price: \$6</p>	

## Example 4: Ubiquiti Node with Additional Devices (12V)

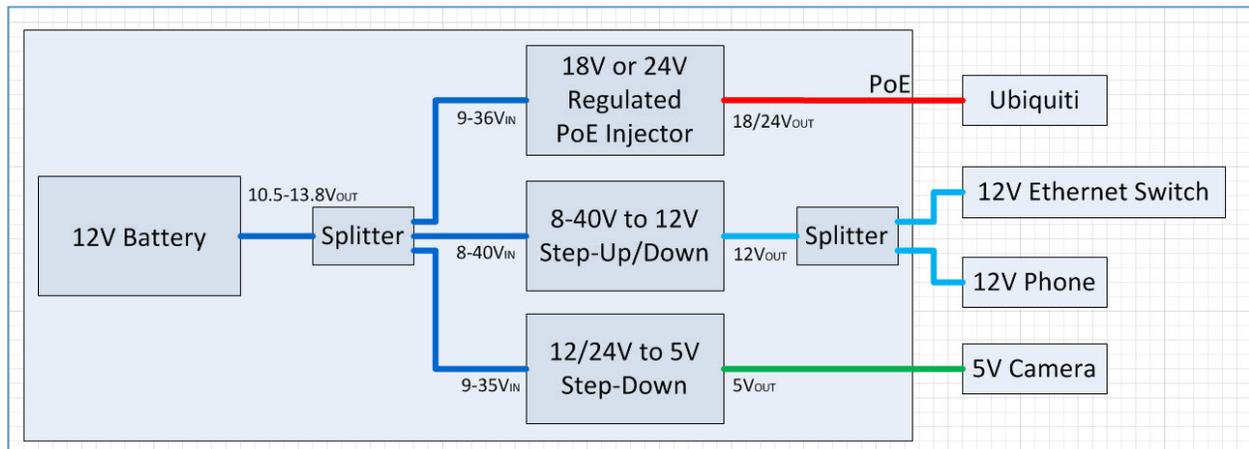
### Requirements

- Location
  - Radio/antenna are located outdoors (Ubiquiti devices are weather resistant)
  - Operating station is indoors, 100 cable feet away from the radio
  - Power system is located indoors, at operating station
- Devices to be powered:
  - Ubiquiti radio: 10.5-25 VDC @ < 1 A passive PoE using 100 ft of 24 AWG wire
  - Ethernet switch: 12 VDC @ < 1A
  - Phone: 12 VDC @ < 600 mA
  - Camera: 5 VDC @ < 200 mA
- Power Source:
  - Single 12V battery

### Design Considerations

- Due to the voltage drop on the 100 ft PoE cable, a regulated PoE injector will be used
- An Ethernet switch is needed because the Ubiquiti radio has only a single Ethernet port
- The Pan/Tilt camera draws considerable power for its motor

### Diagram



A regulated PoE injector is used to provide power to the Ubiquiti radio and reduce voltage drop on the 100 ft cable. An 8-40 volt to 12 volt converter is used to provide a regulated 12 volts for other devices such as an Ethernet switch and a telephone. A 12/24V to 5 volt step-down converter is used to provide a regulated 5 volts for a camera.

Components

<p><b>12V 7Ah Battery</b>                  Manufacturer = various                  Quantity = 1</p>	
<p><b>18 or 24 volt PoE Injector</b>                  Manufacturer: Tycon Power Systems                  Part Numbers:  <ul style="list-style-type: none"> <li>• 18 VDC PoE: TP-DCDC-1218</li> <li>• 24 VDC PoE: TP-DCDC-1224</li> </ul>                 Source: Streakwave                  Approximate price: \$37                  Notes: The 18 volt version has a small advantage of using slightly less current on short cable runs. For longer cable runs, there is no significant advantage.</p>	
<p><b>8-40V to 12V Step-Up/Down</b>                  Manufacturer: SUPERNIGHT                  Description: 8V-40V Step Down to 12V 6A 72W                  Source: Amazon                  Approximate price: \$24                  Note: This is a 6A unit. It has the advantage of accepting input from either a single or dual battery configuration.</p>	
<p><b>12/24V to 5V Step Down</b>                  Manufacturer: Kimdrex                  Description: 12V/24V to 5V 5A/25W Car Regulator Power Supply Module                  Source: Amazon                  Approximate price: \$16</p>	
<p><b>Splitters</b>                  Manufacturer: PowerWerx                  Model Name: Red-Dee-2 Connect                  Source: HRO, PowerWerx                  Approximate price: \$20</p>	

**Box**

Manufacturer: Really Useful Boxes  
 Size: 3.0 Liter (for CDs, DVDs)  
 Source: Amazon, Office Depot, etc.  
 Approximate price: \$6



### Lab Testing

The system was connected as shown in the above diagram except that a bench supply was used instead of the battery. The Ubiquiti Rocket M2 radio was configured for 28 dBm RF output power.

Measurements of the typical and maximum current were taken at various voltages ranging from the fully charged voltage (13.8V  $\approx$  28V) down to the fully discharged voltage (10.5V).

The maximum current varied from 1.9 to 4.8 Amps and occurred when the power was turned on and all devices started booting. This value is import when considering the rating of the fuses to be used in the system. The maximum value varied in each test, regardless of input voltage. Presumably the variation is due to very slight differences in how quickly devices started their boot cycles.

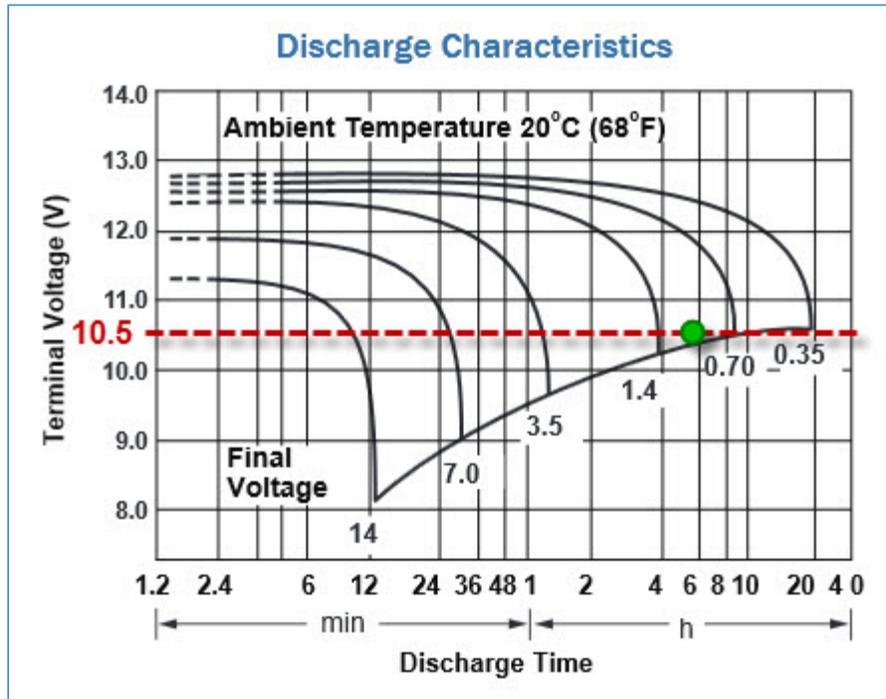
The typical current was measured after all devices had booted and reached steady state. There was little to no network traffic and the phone was on hook. The following table summarizes the typical observed current vs. input voltage.

$V_{IN}$ (volts)	$I_{IN}$ (A) Typical
14	0.95
13	1.03
12	1.12
11	1.25
10.5	1.31

As mentioned above, the typical current shown above does not include any live traffic on the network. Adding traffic to the network causes the processors in the network devices to do more work and draw slightly more current. So the actual current for a real deployment will be somewhat higher than the typical numbers measured above.

### Analysis

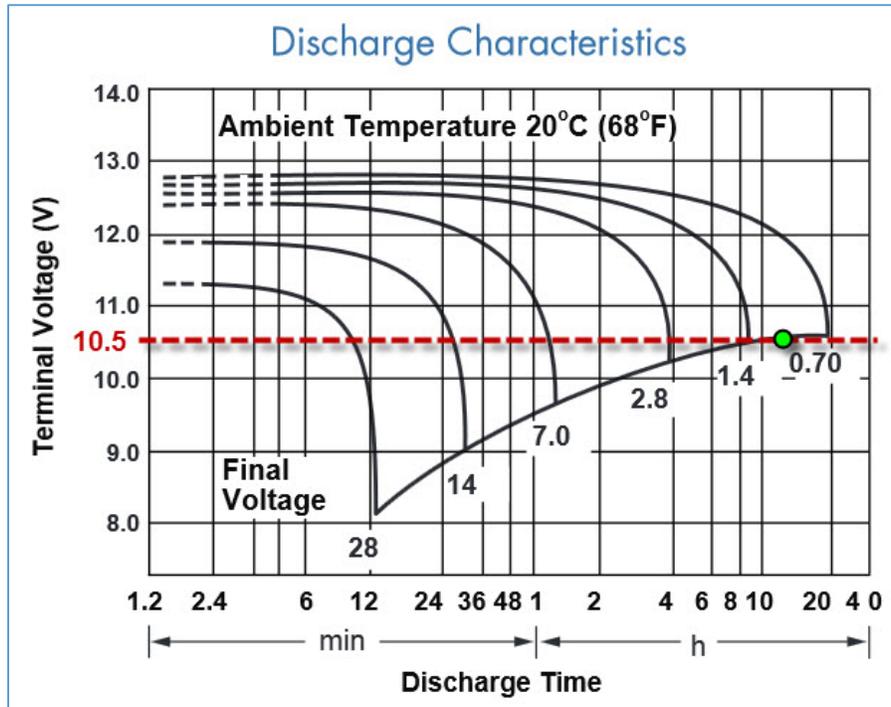
The following discharge curves are from the datasheet for a Power-Sonic 12 volt, 7 Ah battery, model number PS-1270. Each curve represents the output voltage over time for a different discharge current. The red line was added to show the minimum safe discharge voltage of 10.5 volts. The green dot was added to show where the curve would end for the approximate average current in the above results. Since the voltage steps above are not equally spaced, the average was computed as:  $[high+low]/2 = [1.31+0.95]/2=1.13A$ .



*Power-Sonic PS-1270, 1.13A discharge, 10.5V cutoff*

Reading down from the green dot to the X-axis shows that a brand new battery used in the above configuration should last approximately 5.5 hours. Adding some safety margin to account for an older, less than perfectly maintained battery and to account for more network traffic, it is clear that the battery should last for at least 4-5 hours.

In order to supply power for an entire 8-10 hour shift, a larger battery will be needed. The following discharge curves are from the datasheet for a Power-Sonic 12 volt, 14 Ah battery, model number PS-12140. The red line and green dot were added in the same way as the previous diagram.



*Power-Sonic PS-12140, 1.13A discharge, 10.5V cutoff*

Reading down from the green dot to the X-axis shows that a brand new battery used in the above configuration should last approximately 13 hours. Adding some safety margin to account for an older, less than perfectly maintained battery and to account for more network traffic, it is clear that the battery should last for at least 8-10 hours.

It is instructive to compare these results with the next example which uses two batteries connected in series. A major advantage of using a single 12 volt battery is the ability to use a single battery charger. After gaining the experience of building and charging several field systems, the author can attest that this advantage cannot be overstated. In addition, a simple AC power failover system could be added using a single, small DC supply and a single West Mountain Radio Super PWRgate PG40S.

It is instructive to compare these results with the next example which uses two 7 Ah batteries.

### Conclusion

This configuration using one 12 volt, 14 Ah battery is portable, affordable, and should support field operations for at least 8-10 hours. The use of a single battery makes charging much easier than a two-battery solution.

## Example 5: Ubiquiti Node with Additional Devices (24V)

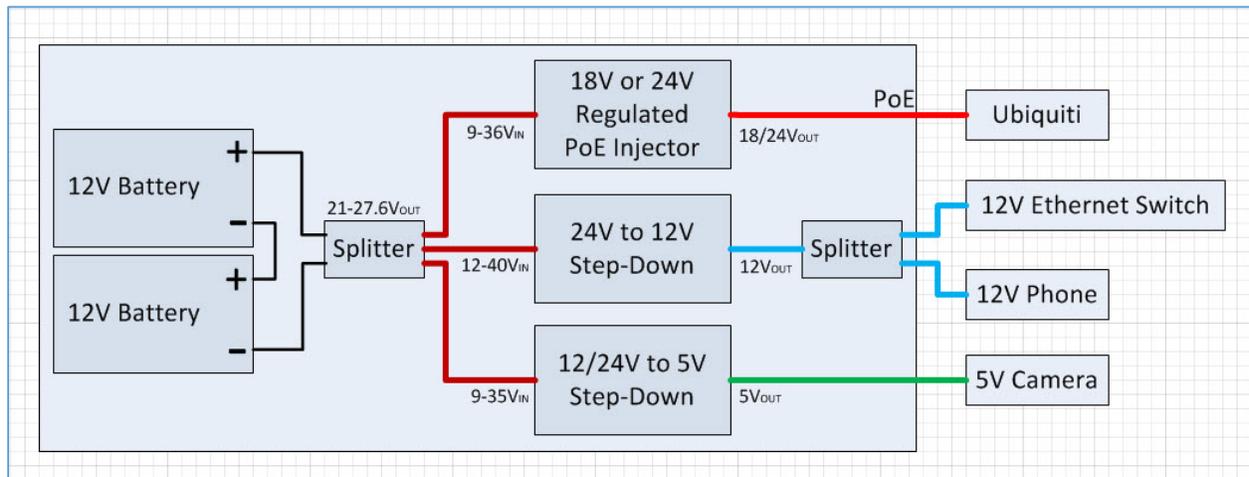
### Requirements

- Location
  - Radio/antenna are located outdoors (Ubiquiti devices are weather resistant)
  - Operating station is indoors, 100 cable feet away from the radio
  - Power system is located indoors, at operating station
- Devices to be powered:
  - Ubiquiti radio: 10.5-25 VDC @ < 1 A passive PoE using 100 ft of 24 AWG wire
  - Ethernet switch: 12 VDC @ < 1A
  - Phone: 12 VDC @ < 600 mA
  - Camera: 5 VDC @ < 200 mA
- Power Source:
  - Two 12V batteries

### Design Considerations

- To protect the radio from overvoltage, a regulated PoE injector will be used
- An Ethernet switch is needed because the Ubiquiti radio has only a single Ethernet port
- The Pan/Tilt camera draws considerable power for its motor

### Diagram



The diagram shows two batteries are connected in series to produce an unregulated 24 volts. A regulated PoE injector is used to provide power to the Ubiquiti radio. A 24 volt to 12 volt step-down converter is used to provide a regulated 12 volts for other devices such as an Ethernet switch and a telephone. A 12/24V to 5 volt step-down converter is used to provide a regulated 5 volts for a camera.

### Components

The example system can be constructed using the following components.

<p><b>12V 7Ah Battery</b>                  Manufacturer = various                  Quantity = 2</p>	
<p><b>18 or 24 volt PoE Injector</b>                  Manufacturer: Tycon Power Systems                  Part Numbers:</p> <ul style="list-style-type: none"> <li>• 18 VDC PoE: TP-DCDC-1218</li> <li>• 24 VDC PoE: TP-DCDC-1224</li> </ul> <p>Source: Streakwave                  Approximate price: \$37                  Notes: The 18 volt version has a small advantage of using slightly less current on short cable runs. For longer cable runs, there is no significant advantage.</p>	
<p><b>24V to 12V Step Down</b>                  Manufacturer: KEEDOX/HOSSEN                  Description: DC/DC Converter Regulator 24V Step down to 12V 20A 240W                  Source: Amazon                  Approximate price: \$20                  Note: This is a 20A unit. That's way more than is needed. But it is highly rated, while smaller units were not highly rated.</p>	
<p><b>12/24V to 5V Step Down</b>                  Manufacturer: Kimdrex                  Description: 12V/24V to 5V 5A/25W Car Regulator Power Supply Module                  Source: Amazon                  Approximate price: \$16</p>	
<p><b>Splitters</b>                  Manufacturer: PowerWerx                  Model Name: Red-Dee-2 Connect                  Source: HRO, PowerWerx                  Approximate price: \$20</p>	

**Box**

Manufacturer: Really Useful Boxes  
 Size: 3.0 Liter (for CDs, DVDs)  
 Source: Amazon, Office Depot, etc.  
 Approximate price: \$6

**Lab Testing**

The system was connected as shown in the above diagram except that a bench supply was used instead of the batteries. The Ubiquiti Rocket M2 radio was configured for 28 dBm RF output power.

Measurements of the typical and maximum current were taken at various voltages ranging from the fully charged series voltage (13.8V x 2 = ~ 28V) down to the fully discharged series voltage (10.5V x 2 = 21V).

The maximum current varied from 1.9 to 4.8 Amps and occurred when the power was turned on and all devices started booting. This value is important when considering the rating of the fuses to be used in the system. The maximum value varied in each test, regardless of input voltage. Presumably the variation is due to very slight differences in how quickly devices started their boot cycles.

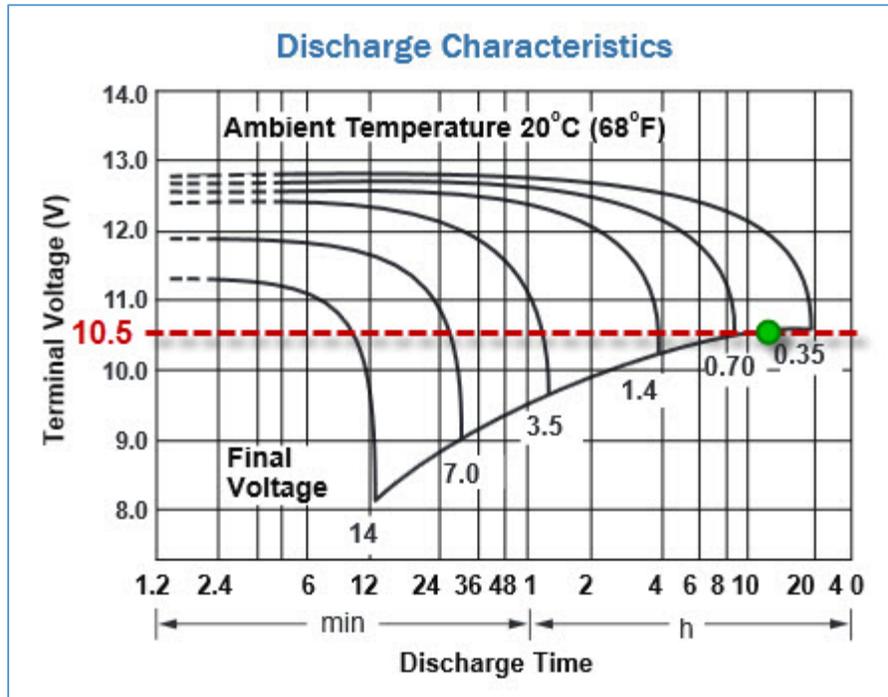
The typical current was measured after all devices had booted and reached steady state. There was little to no network traffic and the phone was on hook. The following table summarizes the typical observed current vs. input voltage.

$V_{IN}$ (volts)	$I_{IN}$ (mA) Typical
28	501
27	516
26	533
25	550
24	567
23	587
22	610
21	634

As mentioned above, the typical current shown above does not include any live traffic on the network. Adding traffic to the network causes the processors in the network devices to do more work and draw slightly more current. So the actual current for a real deployment will be somewhat higher than the typical numbers measured above.

**Analysis**

The following discharge curves are from the datasheet for a Power-Sonic 12 volt, 7 Ah battery, model number PS-1270. Each curve represents the output voltage over time for a different discharge current. The red line was added to show the minimum safe discharge voltage of 10.5 volts. The green dot was added to show where the curve would end for the average current in the above results (562 mA).



*Power-Sonic PS-1270, 562mA discharge, 10.5V cutoff*

Reading down from the green dot to the X-axis shows that a brand new battery used in the above configuration should last approximately 13 hours. Adding some safety margin to account for an older, less than perfectly maintained battery and to account for more network traffic, it is clear that the battery should last for at least 10-12 hours.

It is instructive to compare these results with the previous example which uses a single battery. An advantage of this solution is that 7 Ah batteries are usually easy to find at local electronics stores. But the added difficulty of charging two batteries makes this solution less desirable than a single battery solution.

### Conclusion

This configuration using two 12 volt, 7 Ah batteries is portable, affordable, and should support field operations for a full 10-12 hour shift. But the need to charge two batteries makes this solution less desirable than a single battery solution.

## Example 6: Incident Command Post for Public Service Event

This configuration was deployed at the field headquarters site of a public service event for a city in Santa Clara County.

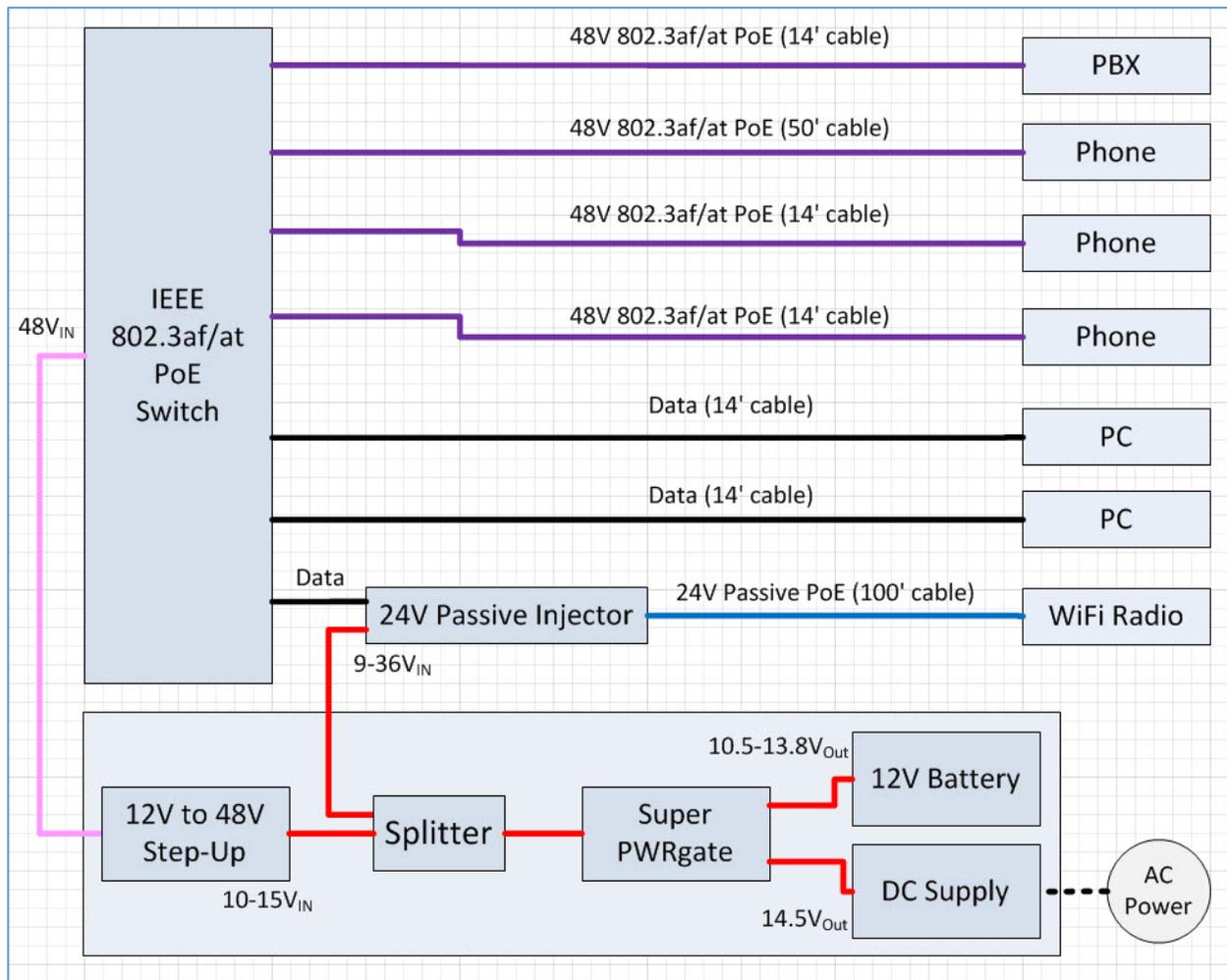
### Requirements

- Location
  - Radio/antenna are located outdoors (Ubiquiti devices are weather resistant)
  - Operating station is police command vehicle, 100 cable feet away from the radio
  - Power system is located inside the command vehicle
  - Phones, PBX, and PCs will all be located inside the command vehicle
- Devices to be powered:
  - WiFi radio: 10.5-25 VDC @ < 1 A passive PoE using 100 ft of 24 AWG wire
    - Radio: Ubiquiti Rocket
    - Antenna: Ubiquiti AirMax 10 dBi omni (dual-polarity)
  - PoE Ethernet switch: 48 VDC @ < 1.5A
    - Netgear GS110TP
  - 1 VoIP PBX: IEEE 802.3af/at PoE
    - Grandstream UCM6102
  - 3 multiline phones with displays: 5 VDC or IEEE 802.3af/at PoE
    - Grandstream GXP2130 (3 line phone with display and station busy lights)
    - Grandstream GXP2200 (6 line phone with display)
    - Grandstream GXP1625 (2 line phone with display)
  - 2 PCs
    - One PC for managing and monitoring the mesh network.
    - One PC to run the network video recorder to display and record two cameras deployed at other locations.
  - No camera at this site.
- Power Source:
  - One 12V battery
  - 120 VAC power may be available from a generator in the command vehicle.

### Design Considerations

- To protect the radio from under-voltage, a regulated PoE injector will be used
- An Ethernet switch is needed because the Ubiquiti radio has only a single Ethernet port
- Since multiple standard PoE devices will be used, an 802.3af PoE switch will be used to reduce the number of power injectors needed and simplify the wiring
- The power source will be configured to use AC power when available and switch to DC power when/if the AC power fails.

Diagram



A West Mountain Radio Super PWRgate PG40S was used to allow interrupt-free switching between AC power and battery. While AC power is available, the Super PWRgate draws power through the DC supply to run the station and charge the battery. If AC power fails, the Super PWRgate switches to battery power. The output voltage supplied by the Super PWRgate to the load can vary, depending on whether it is supplying power from the DC supply or the battery.

The 12V battery was an AGM battery, which has an ideal charging voltage of 14.2V. There is a 0.3V drop across the Super PWRgate. Therefore, the DC supply was set to 14.5V output.

An Anderson Powerpoles splitter fed the output from the Super PWRgate to the 12V to 48V step-up regulator and the 24V passive PoE injector. Both units were capable of handling the range of output voltages supplied by the Super PWRgate. The 12V to 48V step-up provided a regulated 48 VDC to the PoE switch. The 24V passive PoE injector provided a regulated 24 VDC to the WiFi radio.

The phones and PBX could be powered by 5V and 12V, respectively, or by PoE. Powering by PoE simplified the power system by eliminating DC splitters, power cables, and step-down converters/regulators for 5V and 12V. It also allowed the phones to be located far from the power source. So, the PoE switch was used to provide power and data connectivity to the PBX and the PoE

phones. One phone was located in the back of the command vehicle, requiring a long cable. The other two phones and the PBX were located near the Ethernet switch, so shorter cables could be used.

The WiFi radio was located on a mast outside of the command vehicle. A 100 foot long cable was routed out one of the vehicle windows, over to the mast, and up to the radio.

### Components

The actual deployed system was constructed using the following components.

<p><b>12V 18Ah Battery</b>                  Manufacturer = Power-Sonic                  Quantity = 1                  Part Number: PS-12180                  Source: AtBatt.com                  Approximate price: \$40</p>	
<p><b>Super PWRgate PG40S</b>                  Manufacturer: West Mountain Radio                  Part Number: PG40S                  Source: Ham Radio Outlet                  Approximate price: \$140</p>	
<p><b>24 volt Passive PoE Injector</b>                  Manufacturer: Tycon Power Systems                  Part Numbers:  <ul style="list-style-type: none"> <li>• 24 VDC PoE: TP-DCDC-1224</li> </ul>                 Source: Streakwave                  Approximate price: \$37</p>	

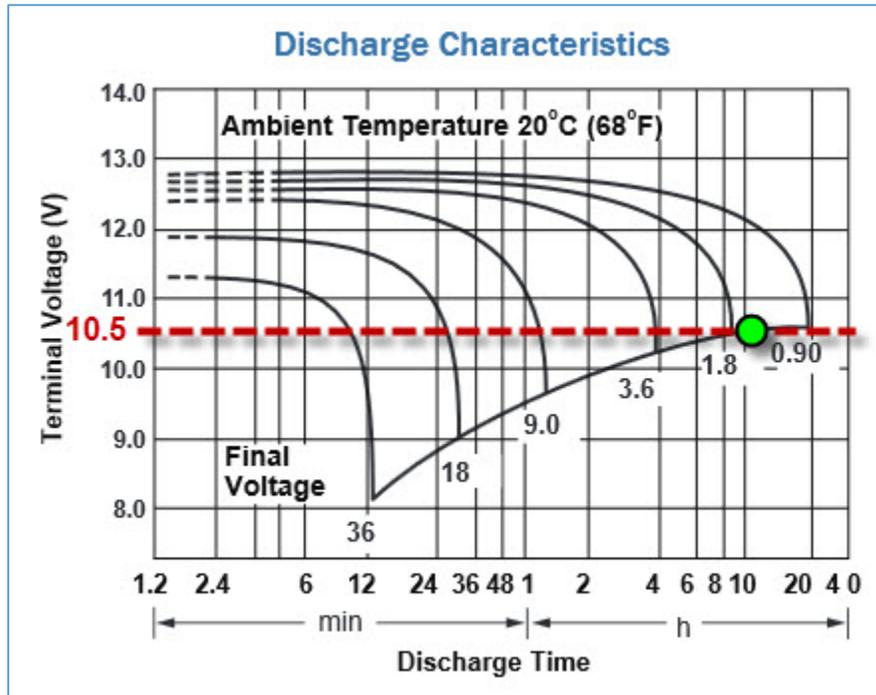
<p><b>12V to 48V Step-Up Regulator</b>                  Source: Amazon                  Description: Generic 144W 12V to 48V 3A DC-DC Converter Boost Step-up Car Power Module Waterproof                  Manufacturer: Unknown                  Input: 10-15 VDC                  Output: 48 VDC / 3A                  Approximate price: \$32</p>	
<p><b>Splitter</b>                  Manufacturer: PowerWerx                  Model Name: Red-Dee-2 Connect                  Source: HRO, PowerWerx                  Approximate price: \$20</p>	
<p><b>Toolbox</b>                  Manufacturer: Husky                  Size: 22 in.                  Source: Home Depot                  Approximate price: \$15                  Notes: This size was sufficient to hold the entire power system plus the PBX and PoE switch.</p>	

**Field Deployment**

The use of PoE simplified the deployment of all devices. Ethernet cables were run to the WiFi radio, the PBX, and each of the phones and PCs. The battery was connected. The WiFi radio booted up and provided DHCP addresses to all devices. The PBX booted up and the phones connected. Everything came up without a problem. Current draw of the station, including WiFi radio, PBX, phones, and PoE switch was approximately 1.6 Amps. Later, when the generator was turned on, the station was able to run off AC power, with the battery serving as a backup. This can in handy at one point when the station needed to be moved. The AC plug was disconnected, the system was moved, and then the AC was reconnected, all without losing any network connectivity. The station ran continuously from about 09:30 to about 17:30 – a total of about 8 hours.

**Analysis**

The following discharge curves are from the datasheet for the Power-Sonic 12 volt, 18 Ah battery used in the above system. The model number is PS-12180. Each curve represents the output voltage over time for a different discharge current. The red line was added to show the minimum safe discharge voltage of 10.5 volts. The green dot was added to show where the curve would end for the average current observed during deployment (1.6A).



*Power-Sonic PS-12180, 1.6A discharge, 10.5V cutoff*

Reading down from the green dot to the X-axis shows that a brand new battery used in the above configuration should last approximately 11 hours. Adding some safety margin to account for an older, less than perfectly maintained battery and to account for more network traffic, it is clear that the battery should last for at least 8-10 hours.

### Conclusions

The use of PoE whenever possible greatly simplified the deployment of end devices. The use of a PoE switch instead of separate power injectors greatly simplified the construction of the power system. The 18Ah battery was properly sized for the expected run time and, at about 13 lbs, is a nice size for handling either a larger, headquarters configuration or a small field station.

## Field WiFi Station Power System Construction

Following are some general recommendations to take into account when constructing a power system for a field WiFi station.

### PoE is Preferred

Devices which operate using Power over Ethernet are much simpler and more flexible to deploy than devices which require both a network cable and a power cable. Even if a device doesn't support PoE directly, the use of a PoE injector and a PoE splitter is often easier and more flexible to deploy than separate Ethernet and power cables.

### Limited Number of Output Voltages

For simplicity of design, construction and maintenance, it's best to limit the number of different output voltages that the station power system must support. Plan on supporting at least regulated 12 volt DC for components such as switches, phones and cameras. Regulated 5VDC may also be necessary. When using Ubiquiti radios, add support for 18 or 24 volt PoE. Other PoE devices will likely use standard IEEE 802.3af/at 48 VDC.

In the end, practicality should prevail. That is, if most devices of a particular type use a particular voltage, then add that voltage to your system so it is flexible enough to support the most commonly available devices of that type. Remember that many different device types may be pressed into service during an emergency. So the power system should be as simple as possible yet retain flexibility and adaptability to different voltage and current requirements.

### Modular Components

Networking equipment in general, and WiFi equipment in particular, continues to drop in price, size, and power requirements. Product release cycles are short and getting shorter. Rather than spending a lot of time on a complicated, custom-designed, custom-assembled system in a box, consider using a generic toolbox to hold commercial, off-the-shelf (COTS) components that can easily be swapped out if they fail or are upgraded as requirements change.

### Standardize Connectors

For maximum interchangeability and ease of replacement of a failed component, consider using a standard connector between all devices. Anderson Powerpoles are commonly used in amateur radio and are excellent for this purpose. Powerpoles hoods come in a variety of colors and the different colors can be used for different voltages to help lessen the chance of cross-connect errors. Be sure to follow any common conventions regarding color and polarity.

### Label all Connectors

When constructing a multi-voltage system, using colored connectors alone is probably not sufficient. Some devices have very wide input voltage ranges. For example, some of the voltage regulators and PoE injectors used in the above examples can accept voltages from as low as 9V to as high as 35V. A color scheme that would be able to match those device inputs to outputs of different voltages within that range would need to be quite elaborate (and confusing). Therefore, it is critical that all connections be labeled with their respective input and output voltages. Even if different color connectors are used, label the connectors to avoid errors by someone else who may not be familiar with the chosen color scheme.

### Voltage, Current and Polarity Protection

Some of the step-up, step-down, and regulation devices include protection against over-voltage, over-current and reverse polarity, but some do not. The power system should be properly protected against these types of errors. Use fuses, diodes and other mechanisms as appropriate.

### Plan for Expansion

If your station works well, you will probably be asked to provide more services. Perhaps an extra phone or camera, or more Ethernet jacks for more PCs. Be sure to size the battery system, the number of Ethernet switch ports, the current capacity of voltage regulators and PoE injectors, and the box that contains it all so that moderate expansion is easy to accommodate.

## Vendors

The following vendors are mentioned above. There are many more. Pick one that works best for you.

- Amazon: [www.amazon.com](http://www.amazon.com)
- Ham Radio Outlet: [www.hamradio.com](http://www.hamradio.com)
- Home Depot: [www.homedepot.com](http://www.homedepot.com)
- Office Depot: [www.officedepot.com](http://www.officedepot.com)
- Power-Sonic: [www.power-sonic.com](http://www.power-sonic.com)
- PowerWerx: [www.powerwerx.com](http://www.powerwerx.com)
- Streakwave: [www.streakwave.com](http://www.streakwave.com)
- Tycon Power Systems: [tyconpower.com](http://tyconpower.com)
- Ubiquiti Networks: [www.ubnt.com](http://www.ubnt.com)