

X10, Noise Generators, Signal Suckers, and Filters

Jeff Volp (Links updated 04/22/2015)

In this day and age, most people with anything more than a minimal X10 system often encounter some type of signal reliability issue. This is often due to the interaction between the X10 signals and the various "Signal Suckers" and "Noise Generators" that are found in a typical home today.

Background

The X10 protocol was developed back in the 70's by a Scottish firm called Pico Electronics. Data is sent over the powerline as a series of 1 mS bursts of 120KHz just after each zero crossing of the 60Hz waveform. Presence or absence of a burst signifies a logic "1" or a logic "0" respectively. A standard transmission is comprised of 44 bits spread over 22 cycles of 60Hz. This is organized as a 4-bit "1110" start pattern followed by 9 data bits transmitted in complimentary pairs. That same 22-bit pattern is then transmitted again for the second half of the command. More detailed information is available in this document: [X10 Technical Note](#). (It is 1.3MB, and may take time to download.)

When the X10 protocol was developed, there was little in a typical home to interfere with the 120KHz signal bursts. We had incandescent lamps and fluorescent lamps with magnetic ballasts. Computers were barely on the horizon. Almost all home entertainment equipment used large transformer-based power supplies. Some of that equipment did include bypass capacitors on the AC power input, but they were to prevent the fellow next door with the CB rig from broadcasting on your stereo speakers. The values were chosen to attenuate signals in the megahertz range. They usually worked pretty well unless your neighbor with the handle "PileDriver" was running a big linear on his CB output.

Many X10 transmitters use inexpensive transformerless power supplies. These take advantage of capacitive reactance at 60Hz to drop the line voltage to usable levels while dissipating very little power. These supplies are cheap to produce, but there are a couple of factors that make them not the best choice for the intermittent loads posed by X10 transmitters. For capacitors of reasonable size, the amount of energy available is limited to a couple of watts. For example, the 2.2uF dropping capacitor in the TW523/PSC05 will provide less than 30 mA at 30 volts. The other factor is that this type of supply ALWAYS delivers that much energy, and the module must dissipate that power as waste heat whenever it is not transmitting. So there is a tradeoff between the amount of power available for the transmitter, the amount of energy dissipated as waste heat, and the physical size and cost of the dropping capacitor. The transformerless power supply is one of the reasons why most X10 transmitters can only deliver 5Vpp into a 5-ohm load, or just over 0.6 watt. For those of you interested in details: $((5V_{pp} / 2) \times .707)^2 / 5$ ohms

On the other hand, transformer power supplies are large, heavy, and expensive. But, transformer supplies have the ability to deliver high current when needed, and dissipate little energy at other times. That makes transformer power supplies a more suitable choice for X10 transmitter applications. For comparison, the transformer supply in the [XTBR](#) provides enough energy to transmit bursts in excess of 20Vpp into a 5-ohm load, or about 10 watts. Its bigger brother, the [XTB-IIR](#), can deliver even more. And the quiescent power of both of those units measures about 1 watt on a "Kill A Watt" meter, the same as a typical X10 module with a transformerless power supply.

“Signal Suckers”

In a quest to make electronics smaller, lighter, and cheaper, many manufacturers have been adopting switching power supplies. These work by rectifying the 120V powerline directly, and feeding the resulting DC voltage to a high-frequency chopper that drives a small high-frequency transformer to produce the various voltages needed by the equipment. That high-frequency chopper can produce electrical noise that will radiate out onto the powerline. There are FCC regulations that limit conducted interference from devices like that, and manufacturers use various means to reduce the radiation. Since capacitors are cheap, many manufacturers just add a filter capacitor directly across the power input to shunt the interference signal to ground.

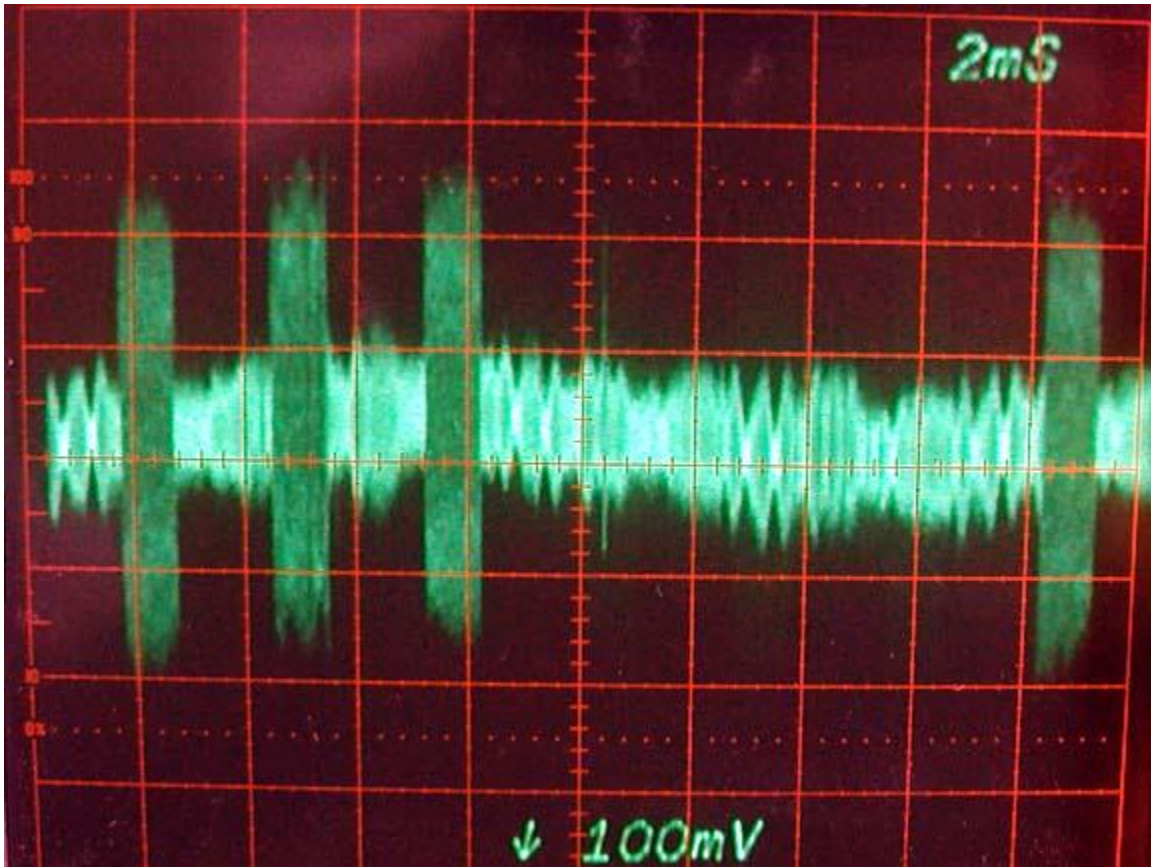
That cheap fix works well for the manufacturer, but it may become an obstacle for other devices that share the same powerline. Unless the manufacturer included some series inductance on the AC input (unlikely because that might cost a dime), any incoming high-frequency signal on the powerline will also be shunted to ground. These devices are what we commonly call “Signal Suckers”. They range in their ability to attenuate X10 signals, but the worst of them – computer power supplies and some UPSs – will pretty much kill any X10 signals on the circuit they are connected to. “Signal Suckers” also impact other electronic devices that rely on powerline communication, such as wireless intercoms, and baby monitors.

While testing the XTB prototype, most outlets in our house read 1Vpp or better. There were several receptacles at the far end of the house that read only 0.1Vpp. One of those supplied power to an APC “Office 280” UPS. The X10 signal on that receptacle jumped up to 1Vpp with that UPS unplugged. That shows how much impact just one “Signal Sucker” can have.

“Noise Generators”

The other common obstacle for reliable X10 operation is from “Noise Generators”. These are electronic devices that are inherently noisy, and do not contain line filters to prevent that noise from reaching the powerline. Common culprits are generic compact fluorescent and newer LED light bulbs, and some of the newer “wall-wart” switching power supplies. Another significant source of noise is from devices that actually communicate over the powerline, such as wireless intercoms and baby monitors.

Below is a photograph of that type of noise coming in over the powerline while I was working on the XTB-II AGC loop. In addition to the four X10 signal bursts, you can see a background carrier containing amplitude modulation. This type of signal can cause a problem because it is directly in the X10 bandpass, and its amplitude measured about 100mVpp. Even X10 modules with AGC will have a problem detecting weaker X10 signals in the presence of background noise such as this. In this case, the X10 bursts were about 4 times the background noise level, which was still adequate for reliable operation. I was curious about what information was being carried by the modulation, but the signal was intermittent, and it finally disappeared completely after several days. The X10 bursts being generated by the XTB-II probably caused an intermittent buzzing sound in whatever audio device was being used, and its use may have been discontinued because of that.



Fixing the Problem:

OK, so we have “Signal Suckers” and “Noise Generators”. What can we do about them? **FILTERS!**

There are really two approaches to this. I recommend investing the time to take the methodical approach to solving this problem. However, there is a simple alternative that can work almost as well. We know that most computers are “Signal Suckers”, so the first step is to isolate any computer and related monitor in your home with an X10 filter, such as the XPPF. You will probably still have a few more “Signal Suckers” scattered throughout your home. To combat those, you can use a high power signal source, such as the [XTBR](#) or [XTB-IIR](#) to deliver much more energy to the powerline. Many people report this simple approach has worked well for them.

The Methodical Approach

Since many electronic devices do not cause any problems at all, I recommended that you methodically identify the problem loads before installing filters. This effort will take some time, but it will give you a comprehensive map of your entire power distribution system, and it should identify the problem loads. The procedure below outlines the steps I used myself at our last house when we began to encounter some X10 reliability issues.

A step-by-step approach begins with purchasing an X10 signal level meter. Previously I recommended the Elk ESM1 as a good affordable signal meter. I used one myself, but it and all the other X10 meters in the same price class have been discontinued. To fill the gap I designed the [XTBM](#) and [XTBM-Pro](#). The XTBM kit is similar in price to the discontinued ESM1, but it provides digital readouts of signal and noise with much better resolution. The assembled XTBM and XTBM-Pro are more expensive, but still much more affordable than the other available units, such as the Monterey and ACT testers.

Assuming you have an X10 signal strength meter available, the next step is to map the electrical circuits throughout your home. This will take some work unless your distribution panel is very well labeled. Breakers or fuses are generally labeled well enough to give you an idea of what they control. It is very helpful to start by drawing a floor plan of your house. Several of the breakers will probably control individual loads, such as dishwasher, furnace, and other major devices. Those are easy to confirm by tripping those breakers one-by-one, and checking that power was removed from the corresponding device.

After these individual circuits are confirmed, go through the remaining breakers by tripping them off one-by-one. Use a small portable light to plug into each receptacle in the area of the house that is supposed to be supplied by that breaker. Also, exercise all wall switches in that area to identify what circuits they are on. Label each receptacle or switch on your floor plan with the number of the breaker that controls it. All receptacles and switches should be identified when you are done. If you still have unidentified circuits, those last few can be traced by tripping breakers in sequence until that circuit goes off. This is easiest done with two people, but you can use a plug-in radio turned up loud or a long extension cord run from the receptacle under test to a lamp that can be seen from the breaker panel. Whatever method you use, it is important to map out ALL receptacles before proceeding further.

Now that you know which circuits power which loads, the next step is to identify the problem loads. You will need a transmitter connected near your main distribution panel to do this. I will assume you already have a signal coupler to propagate the signal over to the opposite phase. Another tutorial covers that topic if you don't know what a coupler does. I used a RR501 transceiver plugged into an outlet near the main distribution panel when I mapped our house. Then it was easy to wander around checking receptacles while using a Palmpad to trigger X10 commands. If you don't have a wireless link, a second person can issue the commands from a command console plugged in near the panel. I previously suggested using a long extension cord to send commands from your location as you move around, but signal loss in the extension cord will impact the measurements. The important thing is that you want the transmitter connected near the distribution panel to minimize corruption from any problem loads on its own circuit.

There are several methods you can use to identify the problem loads. The procedure I used was to concentrate on just one circuit at a time. However, since computers are known to be major signal suckers, it is wise to unplug all of them first. Then, on each circuit, unplug all electronic loads. That includes any modular power supplies, entertainment equipment, and just about anything other than standard incandescent lights. With all potential problem loads unplugged (they must be unplugged – not just switched off), send a few X10 commands while monitoring the signal levels at a few receptacles on that circuit. With no problem loads on that circuit, all readings should be similar – perhaps varying at most by a factor of two. There is a rare special case where wire inductance and distributed capacitance can combine to create a local “Black Hole”, but we will ignore that for now. While doing this test, also note the background noise level at each receptacle if your meter has that capability. Then begin plugging in the loads. For each load reconnected, recheck the signal level at its receptacle. There should be little difference. Any load that causes a significant reduction in signal strength should be isolated with a filter.

When using a meter with a multi-segment LED bar, even a slight reduction in signal level can cause the next lower bar to light at transition points. When this happens, it is worth repeating the test a few times both plugged in and unplugged to confirm there really is a repeatable reduction in signal level. If so, that may also be a candidate to isolate with a filter. If your meter is capable of indicating noise, turn on the device under test to see if the noise level increases. Also check for error conditions if your meter can indicate that. Any device that increases the noise level or causes errors should be isolated with a filter. It will take time to methodically go through your home like this, but the effort invested will save much more time in the future that can be wasted by the usual trial and error approach to X10 troubleshooting.

Once you have identified your problem loads, they should all be isolated from the powerline with filters. It is important to use filters designed for this application. Most problem loads can be isolated with the X10 Pro XPPF 5-amp plug-in filter. Just be careful to stay within its ratings because it will get hot and stink when overloaded. SmartHome and ACT offer higher current filters. The [XTB-F10](#) and [XTB-F15](#) are also excellent filters that are conservatively rated. The big 20 amp X10 Pro XPF can be used to isolate an entire circuit. Two of them can be used to isolate a 240V circuit. Unfortunately, the small Leviton 6287 filter that could be installed in-line between X10 switches and ceiling fixtures has been discontinued, and is no longer available.

An alternate solution is the [XTB-ANR](#) Active Noise Reducer. It is a small plug-in module that will significantly reduce even in-band noise on its circuit. It continually monitors the powerline for PLC signals, and will switch off its attenuator when an X10 or Insteon signal is detected. One plugged into each phase near the distribution panel will significantly reduce the overall noise levels throughout the home, including any coming in over the utility feed. If there is a known strong noise source inside the home, best results may be obtained by plugging an XTB-ANR into the same circuit.

Think twice about using surplus filters for this application. Many are designed to prevent line noise from entering a device, and are actually “Signal Suckers” themselves. A good X10 filter uses a “T-network” to block transfer of 120KHz X10 signals from the input to the output, and shunt noise safely to ground.

An Optimum Approach for X10 Reliability

For those of you who have the ability to “clean sheet” your X10 installation, here are a series of steps I recommend that can provide virtually 100% reliability:

- 1) Install a whole-house signal block, such as the X10 PZZ01 or Leviton 6284, at the main distribution panel to prevent X10 signals from coming in over the powerline from your neighbors. An alternative is the Smart Meter Rejection Kit that is comprised of a set of large clamp-on ferrite filters that go over the service entrance cables, and a shunt that severely attenuates any noise straddling the 240V line. It doesn't hurt to also install an X10 compatible whole house surge protector, such as the Leviton 51110, at the same time. **Since the whole-house signal block slips over the main feed into the distribution panel, this work MUST be done by a qualified electrician.**
- 2) Even in our house fewer than half the circuits power devices controlled by X10. With some careful planning at the main distribution panel, it is likely that all X10 circuits can be moved to the same phase. If that can be done, only that one phase must be driven by X10 transmitters, and there is no need for any X10 signal coupler at all. **For your safety, this work should also be done by a qualified electrician.**

3) While our house was under construction, I had one circuit run to locations that would be later used for electronic devices. That circuit powers one or two additional receptacles in each room. Those particular receptacles are color coded differently than normal receptacles, and that one circuit is fed through the 20 amp XPF filter. That circuit is used to power computers and most other loads known to cause problems for X10 powerline traffic. As a result, we are using only a few other filters to isolate particularly nasty devices that could not be plugged into that circuit.

4) In this energy conscious era, I planned that most ceiling lights would use compact fluorescent bulbs. Every X10 lighting circuit that could possibly use CF bulbs has a Leviton 6287 filter installed behind the X10 switch. We specified that deep electrical boxes be used throughout the house, so fitting in the filters was not much of a problem. It is unfortunate that Leviton discontinued production of this filter because there does not appear to be a suitable substitute available

5) The inexpensive X10 wall switches can work well. We used them at our last house. However, here we upgraded to Leviton switches that include AGC. They have worked flawlessly since their installation a decade ago. The older Leviton “red line” switches we used have been discontinued, but their newer “green line” switches should still be an excellent choice for a new installation.

6) Locate your primary X10 transmitter near the main distribution panel. This reduces the series inductance in that run, and provides the maximum signal at the distribution point. And adding the [XTBR](#) or [XTB-IIR](#) near the panel would deliver the strongest possible X10 signals throughout your home.

7) While not unique to X10, dimmer switches must dissipate about 1% of the delivered power as waste heat. I specified that metal wall boxes be installed where dimmer switches would be used to dissipate that waste heat, but that is only something to consider if you are planning to still use incandescent lights.

We use X10 not only for lighting, but also irrigation, hot water recirculation, auxiliary ventilation, and other conveniences. We have a number of Leviton 16400 four-button wall transmitters distributed throughout the house to access various control functions. After taking the previously listed steps during the construction of this house, we had virtually 100% reliability of the X10 automation system even without the XTB. The only problem we had was one compact fluorescent bulb in a living room table lamp would miss its OFF command several times a year. While we did note its occasional misbehavior, it was not enough of an issue to bother with a filter.

One central circuit with a large number of X10 loads, including several transmitters, did have low signal levels as read by the ESM1. There were no electronic “Signal Suckers” on that circuit other than the X10 devices themselves. As electronic devices continue to proliferate in our homes, I was concerned that the sheer number of electrical loads could eventually cause signal levels on that circuit to drop low enough to become a reliability issue. Installing the original XTB at the distribution panel increased signal levels on that circuit tenfold, and reliability concerns were no longer a factor. Even that cranky living room lamp hasn’t missed its OFF command since. That original XTB has been replaced by prototypes of more recent signal boosters as these products continue to be developed.

I hope sharing my experience in these tutorials will help others obtain the same level of reliability that we have here. X10 has been with us for over 3 decades. Its low cost and rich selection of devices still makes it a cost-effective solution. Installations today can certainly be more challenging than they were decades ago, but investing some time and effort up front will give a big payoff in the years to come.