X10 Collisions

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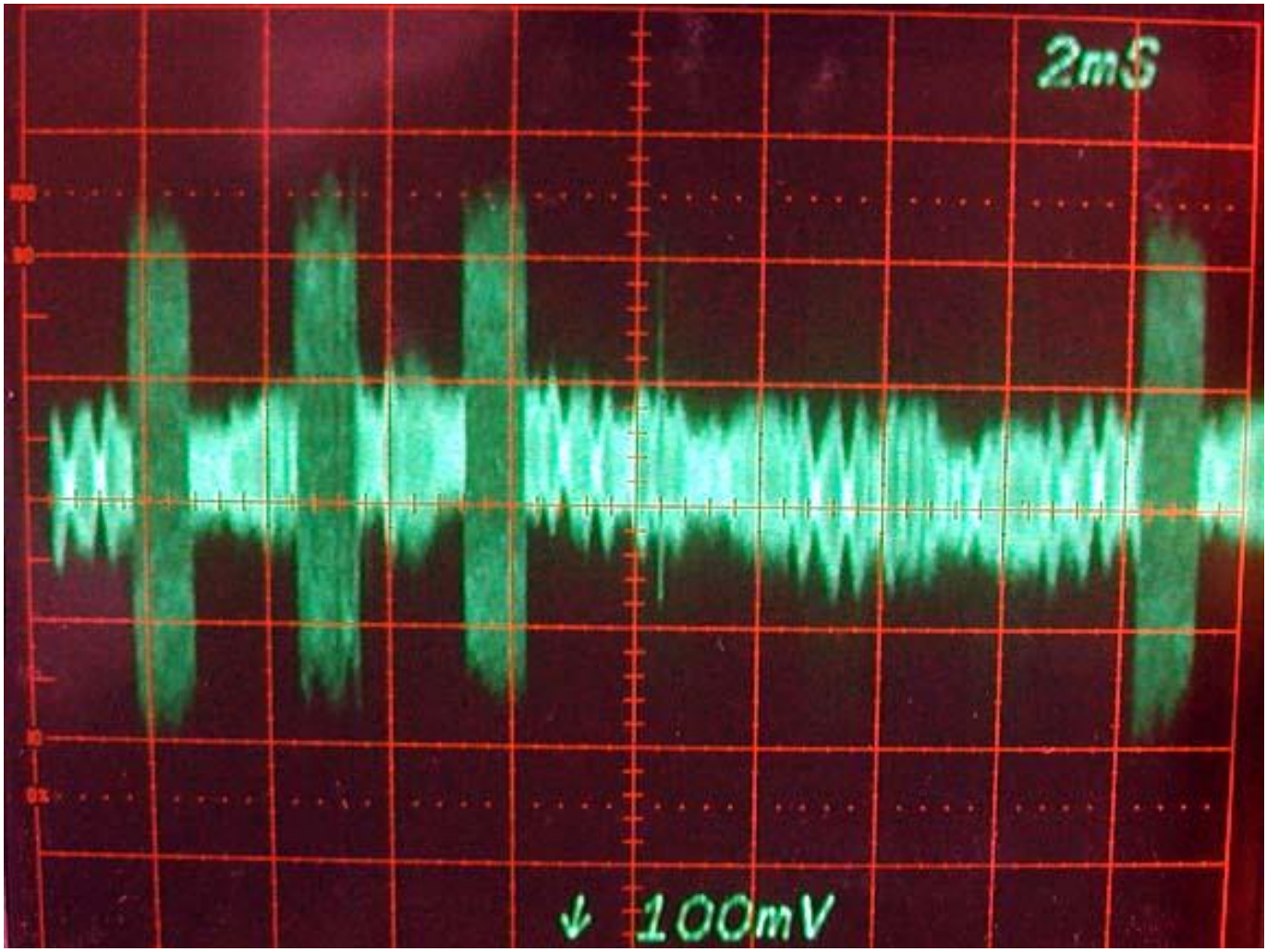
Some people report random difficulties with their X10 systems. If signal strength issues have already been addressed through couplers, filters, or a signal booster, the remaining problems are often a result of powerline noise or collisions between X10 signals sent over the powerline. This tutorial will explore this problem, and offer a few suggestions on how to minimize it.

Background

X10 data is sent over the powerline as a series of 1 millisecond bursts of 120KHz beginning just after each zero crossing of the 60Hz waveform. Presence or absence of a burst signifies a logic "1" or a logic "0" respectively. Some X10 transmitters output three bursts, aligned with all zero crossings of a 3-phase power distribution system. (This photo was captured without the XTB boosting signal levels.)



X10 3-Burst Complimentary Pair with some background noise (120V AC waveform removed)

A standard X10 transmission is comprised of 44 bits spread over 22 cycles of 60Hz. That is organized as a 4-bit start pattern followed by 18 data bits sent as complimentary pairs for a total of 22 bits. This pattern is identically repeated for the second half of the transmission to form a "doublet". More detailed information on the protocol is available in the X10 Technical Note.

Each half of the standard X10 doublet is comprised of twelve "1" bits and ten "0" bits. When two X10 commands are transmitted at nearly the same time, portions of those commands can overlap, resulting in some of the otherwise blank bit positions containing signal bursts from the second transmitter. A collision is defined as there being more than twelve "1" bits in either half of the X10 doublet.

Years ago, about the only way there could be any extra "1" bits was when two X10 transmissions overlapped. Today our homes are filled with all sorts of electronic devices, some of which can radiate noise out onto the powerline. When that noise is near the 120KHz X10 bandpass, it can result in additional "1" bits being detected, particularly if the receiving module does not incorporate some form of AGC to raise its detection threshold above the noise level. So while the normal cause for collisions is the overlap of two X10 transmissions, that error can also be due to bursts of powerline noise.

The X10 protocol does not include any error correction codes, and even a single extra "1" bit makes it impossible to properly decode that half of the doublet. The only savior is that the bit pattern is transmitted twice. So even if one half is corrupted, it may still be possible to decode the other half.

Collisions from X10 motion detectors:

As defined above, collisions result when two X10 transmissions overlap. That often happens when using X10 wireless motion detectors.

There are two X10 RF transceivers in general use. Many people use the inexpensive TM751, which has often been included in kits because of its low price. Unlike the RR501, the TM751 transceiver does not contain a powerline receiver, and cannot verify there is no X10 traffic on the powerline before transmitting. As a result, it will retransmit any wireless X10 command as soon as it has been received. If the home contains multiple motion detectors working through more than one TM751, overlapping transmissions are likely if motion can be sensed in more than one location at the same time.

The more expensive RR501 transceiver does check the powerline before transmitting. While it is still possible for collisions to occur, the RR501 will delay until after a transmission already in process has completed. The reason why collisions can still occur is that many X10 transmitters, such as the inexpensive Mini and Maxi Controllers, do not include receivers to check for X10 traffic, and begin transmission immediately when a button is pressed. So, even though the RR501 has waited for a clear line before beginning its transmission, another "impolite" controller can still step on that transmission.

A side issue that I noticed with the RR501 is strong powerline noise can prevent it from making any transmission. I often use a remote RR501 to send weak signals over the powerline. While testing AGC response, I noticed the remote RR501 transmission would be inhibited if enough noise was injected onto the powerline. The transmission would occur when the noise was reduced, indicating the RR501 was waiting for X10 traffic to clear.

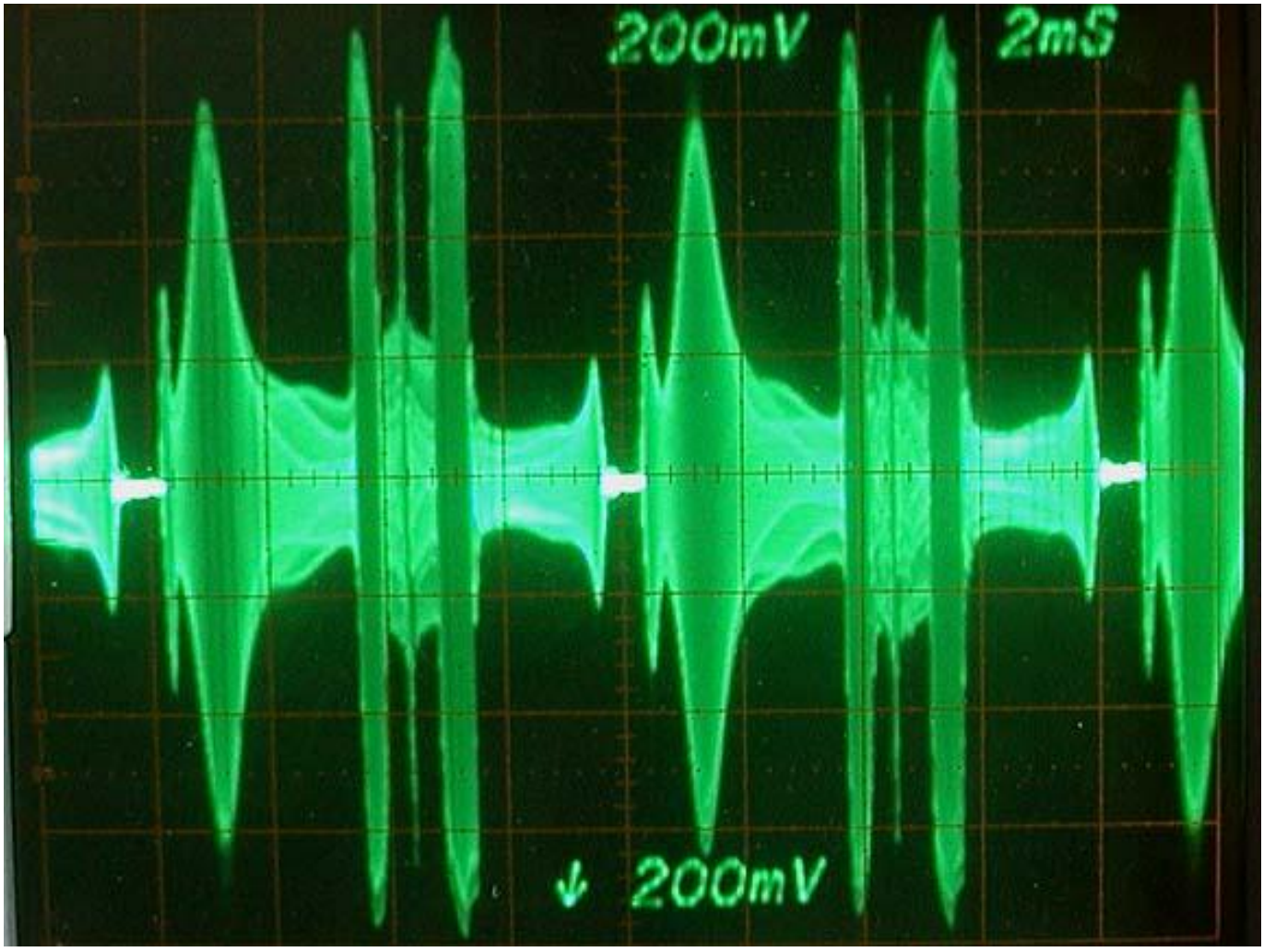
Collisions from two-way X10 traffic:

Some collisions are caused by macros initiating a series of commands that could trigger responses from other X10 devices while the macro is still issuing commands. One instance involved a sunlight detector responding when a nearby light was turned off. With just a single controller, collisions can only happen in special circumstances. Some X10 devices have two-way capability to transmit their status when it changes. Some devices may also request reconfiguration following a power interruption. If the transmitter does not incorporate collision avoidance, a status change could conflict with another X10 command.

Of course, collisions can also be caused by someone issuing a manual command just as the automation controller was sending its own command. Some systems issue a lot of X10 traffic to monitor the status of X10 modules, and random collisions become more likely as the command density increases.

Collisions from poweline noise:

This photograph shows the noise produced by an inexpensive cellphone charger. The noise bursts are clearly stronger than the X10 signal bursts in the prior photo, and would be detected as collisions by any X10 module that did not incorporate AGC.

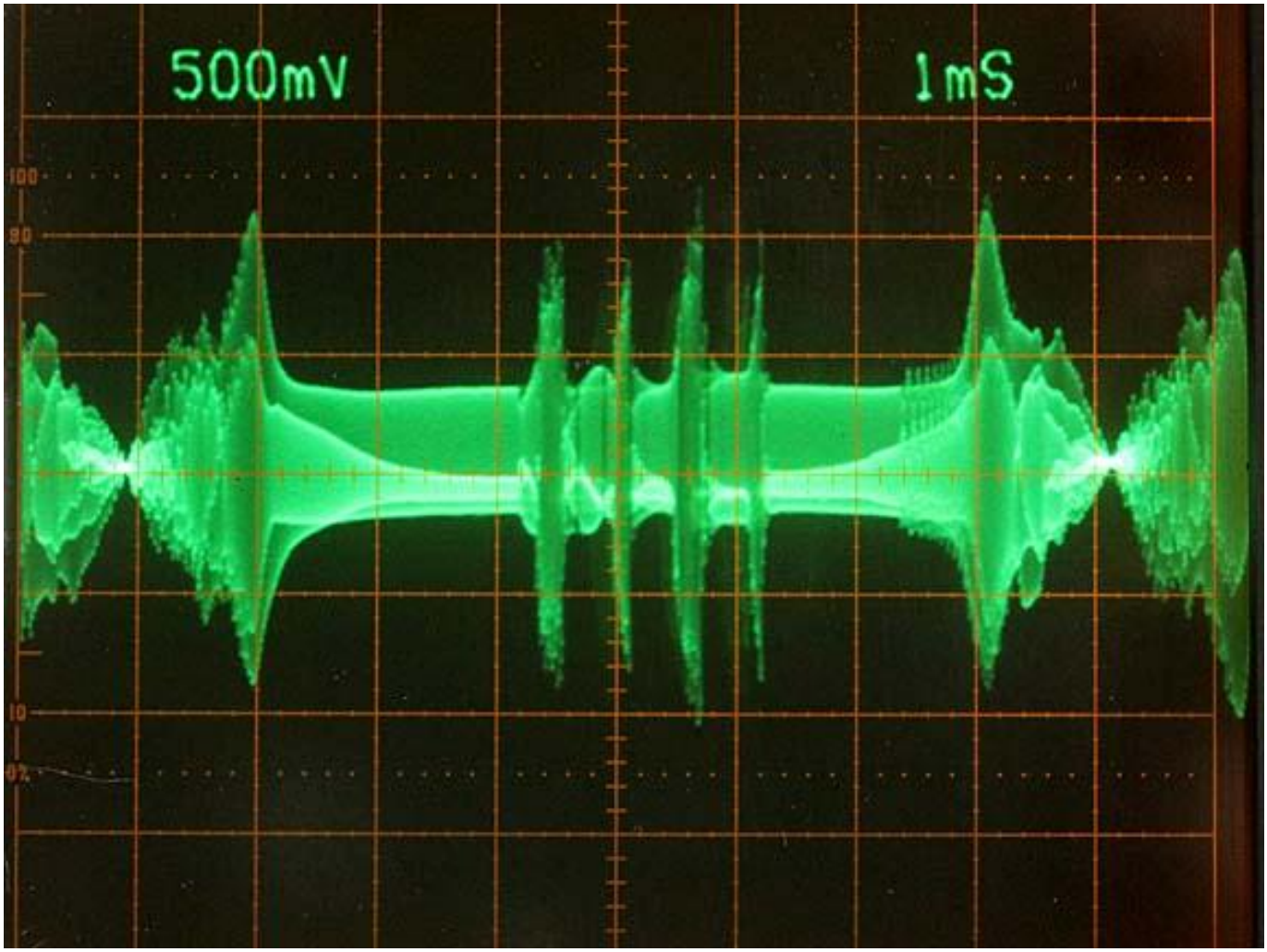


The XTB-ANR – an alternate way to deal with powerline noise.

With CFLs and LED lights proliferating, isolating all noise generators with filters can be cumbersome, and I developed the XTB-ANR (Active Noise Reducer) as an alternate approach. The XTB-ANR will significantly reduce even in-band powerline noise.

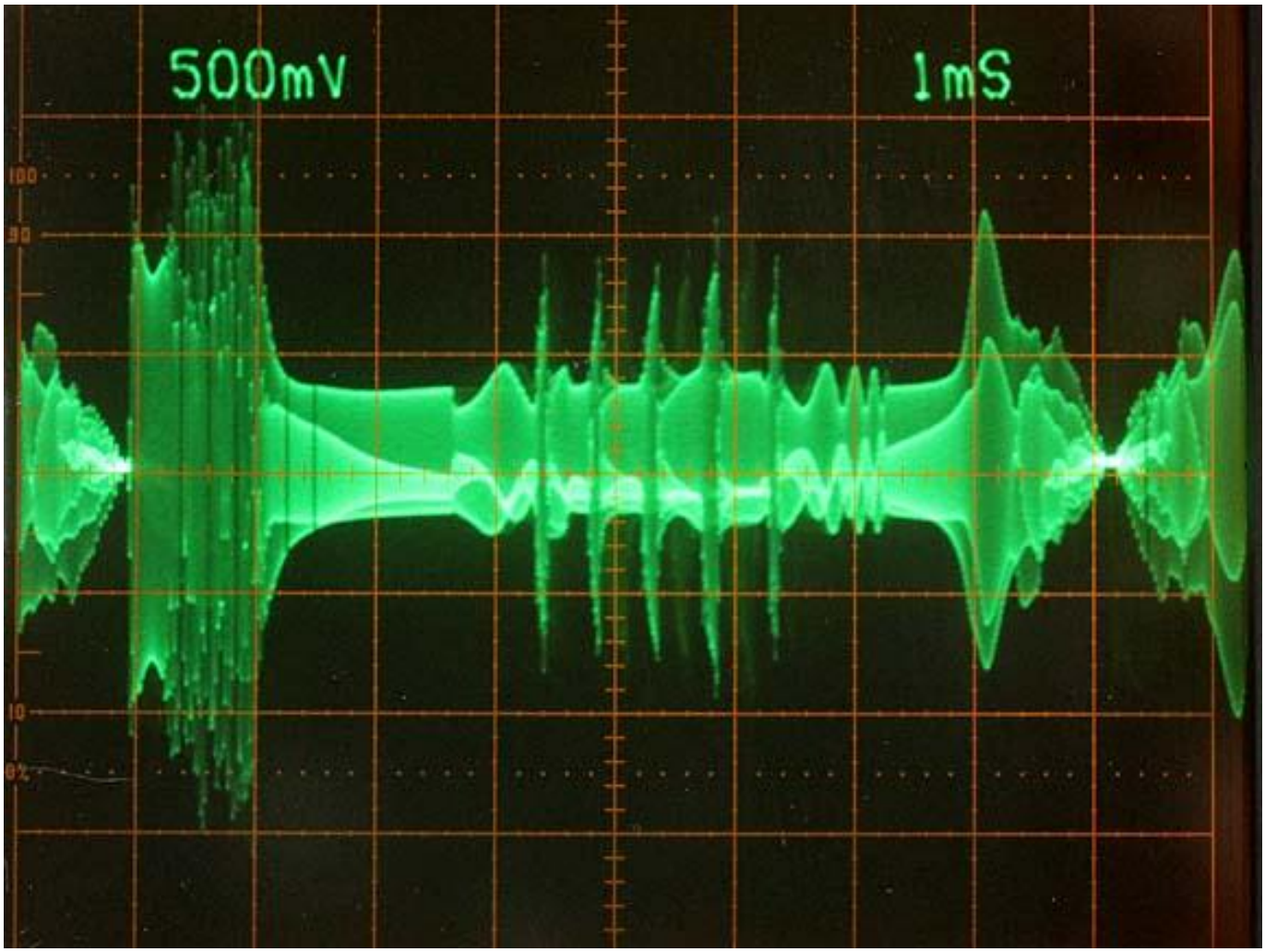
I took some time to record what the XTB-ANR can do to powerline noise. Below are a series of photos showing how the XTB-ANR deals with the noise produced by the Lumoform LED light that is the worst powerline noise generator I have encountered.

The first photo shows the raw powerline signal measured through an X10 Pro XPCP passive coupler. You can see the noise peaks at almost 2Vpp. Zero crossings of the AC waveform are at the two points on the left and right of the trace where the noise level drops to zero.



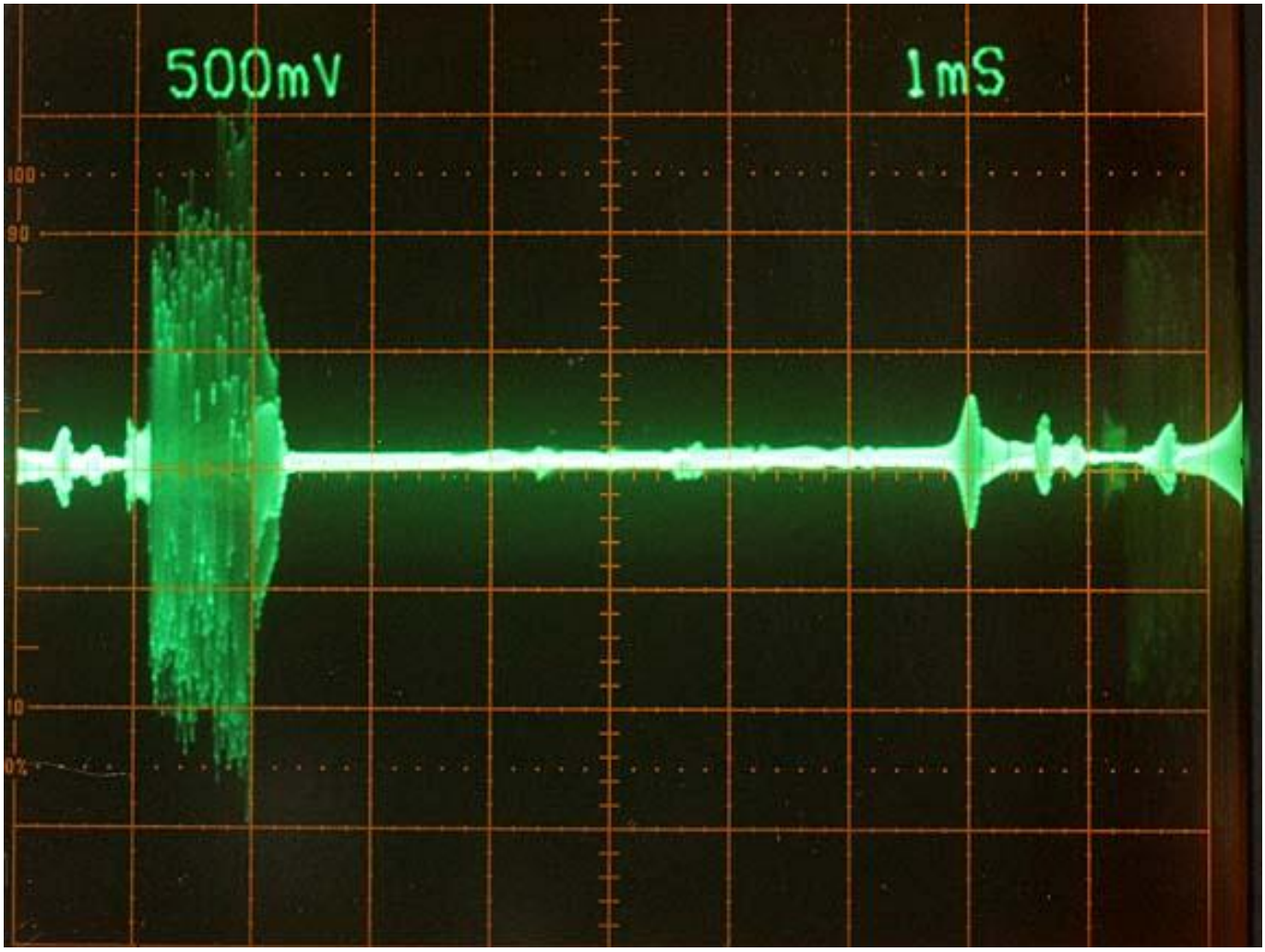
Noise from Lumoform 4W 120V LED bulb

The second photo shows a 2Vpp X10 signal being added to the powerline. You can see it begins just after the left zero crossing. The variation in amplitude is due to the noise and the X10 signal summing together. Even with a signal this strong, there is virtually no way an X10 device could extract that signal. Both the X10 signal burst and the noise burst on the right would be decoded as a logic "1", resulting in a collision.



X10 signal added to noise from Lumoform 4W 120V LED bulb

The last photo shows the effect of plugging the XTB-ANR into this circuit. The overall noise level has been substantially reduced. You can see that the first portion of the X10 signal burst is attenuated until the XTB-ANR recognizes it is a valid X10 signal. At that point it switches off the attenuation, allowing the full X10 signal to come through. As in the second photo, the variation in amplitude is do to the noise and the X10 signal summing together. The faint shadow off to the right is a prior X10 signal burst that can be seen due to the persistence of the scope's CRT.



XTB-ANR passing X10 signal while reducing noise

Here the difference between a logic "0" (no signal burst) and a logic "1" (with the burst) is about a factor of five. An X10 module incorporating AGC should have no trouble decoding this command. It might be marginal for a standard X10 module if the noise frequency is near the X10 passband. But remember, this is the worst noise source I have found. Noise from a more typical noise source is reduced even more.

It is possible for noise having the same signature as a valid X10 signal to confuse the XTB-ANR, and cause it to switch off its attenuation. In that case the only option is to isolate that particular noise source with a standard X10 filter. The X10 XPPF filter works very well for isolating noise sources that consume up to several amps.

Recommendations:

There are several steps that can be taken to reduce or eliminate X10 powerline collisions.

1) Be careful with the deployment of X10 wireless motion detectors. When needing multiple transceivers to provide adequate RF coverage, consider using either the more expensive X10 RR501 transceivers or a single WGL transceiver to cover the entire house.

2) When using macros that request status information from remote X10 devices, be sure to allow sufficient time for that unit to respond before issuing another command.

3) Keep in mind how much X10 traffic will be required as you design your automation system. With the required inter-command gap, each X10 command takes almost half a second to transmit. A complete two-part command that selects a module and tells it what to do takes almost a second. If that was a status request, the total round-trip time would approach two seconds – and even more if extended commands are involved. Try to keep X10 traffic relatively low to reduce the chances of overlapping transmissions.

4) Maintain a noise-free powerline environment. Powerline noise is becoming a major factor causing X10 systems to malfunction. Consider purchasing some sort of signal meter that can measure powerline noise so you can track down offending devices and either isolate or eliminate them. The basic ESM1 was discontinued a couple of years ago, but it can sometimes be found on eBay. The XTBM has better resolution, and is worth the investment if you have a large X10 system.

5) If you are using a lot of potential noise generators, you might consider installing a pair of XTB-ANRs, one on each phase near the distribution panel to reduce overall background noise levels.

Following these steps should reduce or eliminate any problems with X10 powerline collisions.

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 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.