XTB-IIR High-Power X10 Transmit Booster / Repeater

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The XTB-IIR is a high-power X10 repeater with additional capabilities, such as providing direct X10 Boost, and providing a digital port that emulates the X10 TW523 / PSC05 powerline interface. It incorporates AGC to deal with the high levels of powerline noise generated by the electronic devices that populate today's homes. Its enhanced firmware will properly handle sequential bright/dim and extended commands, and deal with many of the problems that can effect powerline communication. We believe the XTB-IIR is the best X10 repeater available today.

The X10 protocol was developed back in the 70's by Pico Electronics. Many of us got started in home automation using those early X10 devices. In the decades since our homes have become filled with various electronic devices, some of which are downright hostile to X10 powerline communications. People often blame the X10 devices when their system does not work perfectly. But maybe the blame should be redirected at the manufacturers who developed these new devices without any regard for other equipment that might share the same powerline. The series of XTB X10 Transmit Boosters was developed to give X10 systems a means to fight back.

X10 powerline control signals are sent as a series of 120KHz bursts coupled onto the powerline. Our electrical systems were designed to distribute 60Hz AC power, and are very efficient at that task. Unfortunately, they don't do as well distributing the 120KHz X10 signal bursts. Combined with the various "signal suckers" spread throughout our electrical systems, X10 signal levels fall off rapidly as they propagate away from the transmitter. Many X10 transmitters utilize inexpensive transformerless power supplies. While small and cheap, transformerless supplies cannot deliver much energy. Because most X10 transmitters cannot supply much current, any "signal suckers" on the powerline will compound the attenuation.

The normal approach is to isolate the problem devices with filters. However, many loads are dynamic, and the powerline environment is always changing. It becomes impractical and expensive to isolate all potential signal suckers with filters. The XTB-IIR provides an alternate means to deal with these problem devices by boosting X10 signals to much higher levels.

The original XTB (X10 Transmit Booster) was developed as a convenient plug-in way to boost X10 signal levels. With its 6-watt transformer power supply, the XTB generated a strong signal on its own phase, but a good passive coupler was still required to propagate that signal to the other phase. The XTB-IIR has an even more powerful transmitter with twin coupling networks to drive both phases directly. These coupling networks also act as a passive tuned-circuit coupler when the XTB-IIR is not transmitting, eliminating the need for any additional coupling device. Connecting the XTB-IIR to both phases near the distribution panel will deliver much stronger X10 signals throughout the electrical system, and possibly even eliminate the need to isolate any of the "signal suckers" with individual filters.

OVERVIEW

The XTB-IIR is an evolution of the discontinued XTB-II, and enhances the capabilities of that unit. A PIC microcontroller was included in the XTB-II to gate off the superfluous X10 bursts produced for 3-phase systems. Because that allows it to concentrate all its energy into the zero-crossing X10 burst, the XTB-II could produce a stronger output than the XTB. Having the PIC on board provided the means to develop a much more elaborate unit.

The XTB-IIR accepts inputs from just about any X10 transmitter. A control module such as the CM15A can be plugged directly into the X10 input, and the XTB-IIR will drive boosted outputs to both phases. The XTB-IIR also includes built-in TW523 emulation. A digital I/O line can be run from an automation controller directly to the XTB-IIR. The opto-isolated digital interface on the XTB-IIR is functionally similar to that of the TW523. Unlike its predecessor, the XTB-IIR can support TW523 communication while directly boost the output of a plug-in X10 transmitter and operating as a high-power repeater without requiring any mode changes.

Since the original function of the XTB-II PIC was just to gate off unnecessary 3-phase bursts, an 8-pin PIC was all that was needed. That PIC had sufficient resources to add TW523 emulation. However, its single comparator made it difficult for the XTB-II to monitor the powerline and function as a repeater while configured to directly boost the output of an X10 transmitter. Note that a firmware update is available for the XTB-II to bypass this limitation.

The XTB-IIR incorporates a 14-pin PIC to avoid this limitation entirely. While similar in internal architecture to PIC used in the XTB-II, the larger PIC provides two comparator inputs to monitor the powerline and the X10 Input receptacle simultaneously. The additional I/O pins also provide the ability to control other functions.

TW523 emulation in both the XTB-II, and the XTB-IIR differ from an actual TW523 in several ways. Normally, the XTB-IIR error checks all incoming data, and does not produce any output when a collision is detected. Error detection in the XTB-IIR is enhanced because it not only checks for the correct number of "1" bits in a command, it also checks that all bits are received in complimentary pairs. That should improve rejection of erroneous messages caused by noise from compact fluorescent lights and similar electronic devices. Both units do not need a gap to separate X10 messages, and they will recognize each pair of bright/dim commands. They will also transmit and receive extended commands through both the X10 Input receptacle and the digital port. The XTB-IIR now includes the ability to repeat the "doublet" extended commands produced by the CM15A, HomeVision, and possibly some other controllers. Standard "simplex" extended commands are not repeated because of the overlap issue. A special diagnostic mode is included in the XTB-IIR that returns all bits in real-time with no error checking. The repeater will function normally even in the diagnostic mode.

Both the XTB-II, and the XTB-IIR include a bandpass amplifier for X10 return signals. The XTB-II used the cost-effective workhorse LM318 for that amplifier, but the XTB-IIR uses a significantly more expensive Analog Devices AD817 to obtain the best possible performance. In addition, the XTB-IIR includes a gain switch to allow it to receive very weak signals in a relatively noise-free environment, while providing the ability to recover stronger X10 levels in the presence of high background noise. The bandpass filter will attenuate out-of-band noise, but line transients can still make it through, and are amplified. Devices sensitive to noise, such as the PowerLinc 1132, may not work well with any of the XTB units.

The major 1.20 firmware update included the ability to prevent repeating selected housecodes. That feature may be helpful in certain situations, or when two homes sharing the same utility transformer both incorporate X10 automation systems.

The XTB-IIR includes almost double the number of programmable mode options are available on the XTB-II. They will allow the user to tailor the XTB-IIR for optimum performance in each installation. The options include various repeater and signal reception modes, error checking, command storm shutdown level, and 3-phase operation.

XTB-IIR PERFORMANCE

A typical X10 transmitter, such as the TW523 / PSC05 interface used by many high-end automation controllers, is specified to deliver 5Vpp into a 5 ohm load. The XTB-IIR was measured delivering just over 30Vpp into a 4.8 ohm resistive load. Since power increases with the square of voltage, the XTB-IIR can deliver over 30 times the power of a typical X10 transmitter. That will go a long way to combating the many "signal suckers" found in a typical home today.

DETAILED HARDWARE DESCRIPTION

It all starts with the power supply. Most X10 transmitters use a transformerless power supply that limits their output capability. The XTB-IIR has a 6-watt transformer supply that provides the high peak currents necessary to deliver high energy X10 signal bursts to the powerline. It also includes a PIC to mask the superfluous 3-phase bursts so all its power can be concentrated into the zero crossing burst. Depending on line characteristics, the XTB-IIR can output over 20Vpp at 120KHz onto the AC line.

The XTB-IIR evolved from the simple plug-in XTB. That unit just boosts the output from a standard X10 transmitter plugged into its X10 Input receptacle. The XTB-IIR still supports that feature, but it adds an opto-isolated digital port for TW523 emulation, and can also repeat signals received over the powerline. Power stage component values have been optimized to drive the lower impedance load presented by 2 coupling networks directly into the main distribution panel.

The XTB-IIR originally used a 14-pin PIC16F684 instead of the 8-pin PIC12F683 in the XTB-II. That was changed to a new PIC16F1823 with even more capabilities in firmware version 1.20. The other significant change from the XTB-II is that the XTB-IIR includes a higher performance amplifier and a gain switch in the return signal path. The increased gain allows it to recover low-level X10 signals in a quiet environment. The gain switch in the XTB-IIR provides more dynamic range with more AGC resolution, allowing it to recover X10 signals in the presence of significant line noise from CFL and LED lights as well as other powerline noise sources.

The larger PIC gave direct control of the LED, which will flash when a signal is transmitted or received, and also flicker in the presence of line noise. The LED will pulse a number of times to identify different error conditions, and beginning with firmware version 1.20, it will glow dimly whenever the unit is powered and operating correctly.

DETAILED FIRMWARE DESCRIPTION

XTB-IIR mode options are programmed by sending a 9-8-2-X sequence via a Maxi Controller plugged into the X10 Input receptacle. Mode programming is accepted only on one selected housecode (P by default). The "ALL-OFF" is still accepted on any housecode at power-on to restore the default configuration. The housecode for mode commands is selected by sending a **9-8-2-2-ON** sequence on the desired housecode immediately after an “ALL-OFF” default.

The XTB-IIR offers up to 16 mode options. Because of the additional capabilities, several of the 9-8-2-X mode sequences are not the same as for the XTB-II. The XTB-IIR will always receive extended commands, and the option that disabled that capability has been eliminated. The "TW523" mode has also been eliminated because the XTB-IIR will accept inputs from any source without requiring a mode change. Please refer to the XTB-IIR Mode Options document for more detailed information. That document can be downloaded here: http://jvde.us/xtb/xtb-iir_modeoptions.pdf

Since the XTB-IIR is intended for repeater applications, a fundamental change was made to the operating system so it can operate as a repeater regardless of what other inputs are used. The XTB-IIR is capable of accepting X10 input, digital input, and powerline signals without mode changes. This allows it to directly boost the output of a plug-in controller, such as the CM15A, while simultaneously acting as a repeater. When multiple inputs overlap, the first source received will have priority, and other inputs will be ignored until transmission is completed. There are also options available to abort a transmission when commands overlap, and to re-transmit a repeated command when the line has cleared.

All XTB-IIR transmissions are sent using its internal 120KHz frequency generator. That is frequency locked to the 60Hz powerline, and will normally be within 1% of the standard frequency. While the utility company maintains the 60Hz frequency with very precise regulation (even short term), that might be a consideration for people running off independent generators with poor frequency regulation. However, it is doubtful that a generator would deviate enough in frequency to cause a problem with X10 communication. The LED will glow dimly when the XTB-IIR is locked to the powerline frequency.

Another significant advancement of the XTB-IIR is the enhanced AGC loop. The second comparator input of the XTB-IIR PIC eliminates a possible feedback loop, and incoming signals no longer have to be limited in amplitude. Combined with the gain switch, the AGC loop has much more resolution than the AGC loop in the XTB-II. This allows the threshold to be maintained just above the background noise level, providing the ability to receive weaker signals. The variable AGC level and alternate AGC sample point provide the ability to deal with noise that will totally block X10 reception by ordinary X10 modules.

Bright and Dim commands are a problem for most repeaters because they deviate from standard X10 protocol. They are often sent in sequence with no gaps between. This is a problem for some repeaters, but the XTB-IIR was designed to repeat sequential bright and dim commands. Since it is impossible to listen to the powerline while the XTB-IIR is transmitting, the sequence will be repeated copies of the first bright/dim command in the sequence. Like all commands, the first half of the initial bright/dim command is not transmitted because that is received and decoded. The second half is transmitted, as is every subsequent command in the sequence until a gap is received. Because the first half of the initial bright/dim command is not transmitted, the actual number of transmissions in the sequence is always one fewer than the number sent by the remote transmitter. One additional command is not tacked onto the end of the sequence because it could step on another transmission following the bright/dim sequence. Note that a short button press on a maxi-controller produces a half length (ll-cycle) bright/dim command, and the XTB-IIR will repeat that during the "missing" second half as though it was a standard 22-cycle long command.

The XTB-IIR will receive and transmit all extended commands through both the X10 Input and digital ports. It will also repeat the "doublet" extended commands produced by the CM15A, HomeVision, and perhaps some other controllers. It will not repeat "simplex" extended commands due to the overlap issue. Since extended commands have become a standard part of the protocol, the XTB-IIR does not require a mode option to enable them to be processed.

The XTB-IIR is designed for a 240V split-phase distribution system, and will normally mask the extra bursts produced by some controllers for 3-phase systems. This allows the transmitted power to be concentrated in the essential zero crossing burst. On receiving, the XTB-IIR always monitors just the zero-crossing signal bursts, but there are options to enable 3-phase transmit and repeat if necessary. Transmitted power is automatically reduced to limit excessive drain on the power supply when driving all three phases. There is also a mode option to reduce the output power if the signal strength produced by the XTB-IIR is too strong for a given installation. A special 3-phase version of the XTB-II is available with a larger power supply to drive all phases at full amplitude.

The XTB-IIR provides complete error checking on incoming signals, requiring not only the correct number of 1's, but also that all received bits be complimentary pairs. This is done to fight the modulated noise produced when the noise from multiple compact fluorescent lights sums together. Note that when sending sequential dims, only the first command is error checked because subsequent commands are transmitted copies of that command recalled from memory.

There is an optional mode that passes ALL received bits back to the automation controller in real time without any error checking. This allows an automation controller to actually do collision detection itself. Some controllers may also be able to provide diagnostic information from the raw data bits. While the diagnostic mode is enabled, the XTB-IIR will still continue to function normally as a repeater.

Since the XTB-IIR was developed for use as a repeater, it includes a feature to automatically disable its transmitter whenever there is an X10 “command storm” on the powerline. That can occur when something causes a remote button to become stuck in the “on” position. Some X10 modules like the CM15A have also been known to lock up in a continuous transmit mode. Since continuous traffic is almost always a result of some error condition, the XTB-IIR shut off its transmitter to prevent overheating. There is a mode option to increase the shutdown limit for those installations that have a lot of normal X10 traffic. The default allows a burst of about 120 commands, with 20 per minute average. (The default was increased to 30 per minute average in firmware 1.20.) The higher threshold allows a burst of about 400 commands, and an average of 60 per minute. That should be adequate for even the most complex X10 installations. While the transmitter is disabled, the XTB-IIR will still monitor traffic on the powerline, and output valid commands to the digital port. The LED flashes continuously while the transmitter is disabled due to a command storm, and the transmitter will automatically be re-enabled after 10 seconds of clear line. The delay is longer following a second shutdown. Note that the flash mode of the X10 PowerFlash module exceeds even 1 per second, and the XTB-IIR will go into command storm shutdown after several minutes of continuous flashing.

In addition to flashing continuously during a command storm, the LED will provide several other indications. It normally flashes during every received or transmitted X10 command. It can also flicker when line noise manages to peek above the AGC threshold. That normally only happens in the first few seconds after a sudden increase in noise level. The LED will flash 3 times when an error is detected on an incoming signal. That means the XTB-IIR did recognize a valid start pattern, but there was an error in the data pattern that caused the command to be rejected. The LED will flash 4 times when a collision is detected from overlapping X10 commands on the powerline. Sometimes that can also be caused by a high noise level on the powerline if noise manages to peek above the AGC threshold during a transmitted “0” slot. The LED will flash 5 times if an error occurs during mode programming.

Beginning with firmware version 1.20, the XTB-IIR now includes the ability to query the AGC detection threshold as a pre-set dim command. This provides the means for a smart controller to monitor the background noise level, and issue an alert when that level increases significantly.

ELECTRICAL CONNECTION

The XTB-IIR does not simply plug into a standard receptacle like the XTB. It should be installed adjacent to the electrical distribution panel where it can drive both phases directly. Connections to the distribution panel are made through one of the two internal terminal strips. The other terminal strip is normally connected to the X10 Input receptacle on the cover. Most X10 transmitters have a 2-prong plug, and the XTB-IIR cover was revised to accept a 2-prong polarized receptacle. Ground is not used internally, and switching to a polarized receptacle allows a less expensive plug and socket to be used to connect it to the distribution panel.

The XTB-IIR should normally be wired to both phases and neutral either directly or through a 240V plug & receptacle fed from a double-pole 15A or 20A circuit breaker. A standard power cord can be connected to Phase I and Neutral for single-phase operation. Ground is not used internally. A solid connection to neutral is essential for proper operation.

The locking strain relief on the XTB-IIR will accept up to .4-inch diameter wire. #18 gauge wire is sufficient because the XTB-IIR is internally fused at 2 amps maximum. When using heavy gauge solid wire it is easier to connect the terminal strip with the board removed from the case. Check the electrical connections carefully before applying power. It is recommended that the terminal strip screws be re-torqued (with power switched off) to insure solid connections.

INTERNATIONAL 240V 50Hz VERSION

A single-output 240V 50Hz version of the XTB-IIR is available. The PCB and all components are now ordered in RoHS compliant versions. Lead-free solder is also used in the assembly of all 240V 50Hz units, so that version is totally RoHS compliant.

3-PHASE VERSION

The XTB-III is a special three-phase version with 3 coupling networks and a larger 12-watt power supply for use on 3-phase "Y" electrical distribution systems. A 240V 50Hz version of the XTB-III is also available.

NOTE: The XTB-III is intended to be a high-power powerline interface for high-end controllers, such as the JDS Stargate or HomeVision. Because the XTB-III has just a single processing channel referenced to its Phase I power input, it can only be used to repeat commands from external transmitters connected to that same phase. Commands from transmitters on other phases will be received, but those commands cannot be repeated because of transmission overlap. The repeater function is disabled by default to prevent it repeating commands produced by external transmitters connected to the other phases.

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