

HomePlug Alliance (<http://www.homeplug.org/>) is the governing group that reviews, ratifies, and approves powerline devices that can send internet signals through electrical conductors. The HomePlug AV2 is the latest standard that utilizes the Multi-Input Multi-Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) as the modulation technique that can improve channel capacity due to its adaptability in the presence of frequency selective channels, resilience to narrow band interference, and robustness to impulsive noise.

Other technologies from HomePlug include HomePlug AV1.0, HomePlug AV, and HomePlug Green PHY. The latest HomePlug AV2 technology is compatible with previous HomePlug technologies.

The HomePlug AV technology utilizes only the Physical Layer and Media Access Control (MAC) or Data Link Layer (DLL) of the 7-Layer in Open System Interconnection (OSI) Model.

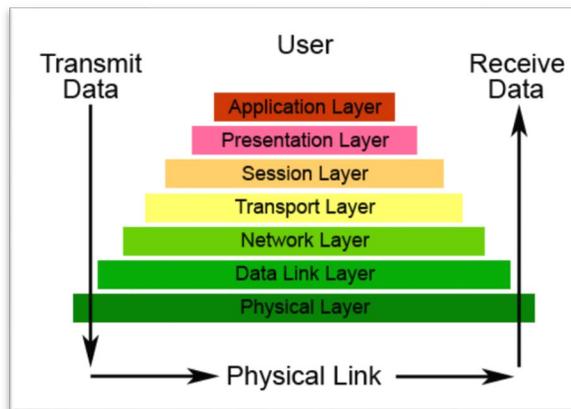


Figure 1: The Seven Layers of OSI

The Physical Layer conveys the bitstream in the forms of electrical impulse, light or radio signal through the network at the electrical and mechanical level. It provides the hardware a means of sending and receiving data on a carrier including defining cables, cards and physical aspects.

The Data Link Layer (DLL) is a layer where data packets are encoded and decoded into bits. It furnishes transmission protocol knowledge and management, and handles errors in the physical layer, flow control and frame synchronization. The data link layer (DLL) consists of Media Access Control (MAC) and logical link control (LLC). The MAC sub-layer controls how a computer on the network gains access to data and permission to transmit data. The LLC sub-layer controls the frame synchronizations, flow control and error checking.

## 02 Objectives

- Determine if running power and data concurrently within the same circuit creates interference.
- Determine if harmonics causes signal degradation. If so, how to minimize signal degradation?
- Determine if surge protector devices are compatible.
- Determine if circuit breaker impacts powerline adapter and/or degrades data signal.

## 03 How Does Powerline Work

The electrical 120V signal travels to an electrical circuit using the 60Hz frequency in the United States One of the greatest challenges with combining data and power on the same line is the electrical sensitivity created by the electrical noise present on the power conductor. HomePlug Alliance resolved this challenge

by increasing the carrier frequency (ranges from 2-30Mhz). The data signal is then conveyed through the neutral conductor which is common to all phases.

The two signals are combined with the power using the 60Hz at high amplitude and data signal with a high frequency (MHz) at low amplitude. The two signals can be combined by the powerline adapter and then separated at the receiver by using a high pass filter.

The data signal from the 'sender' adapter is modulated using OFDM technique then sent to the 'receiver' adapter on the other end, which is demodulated back to original data signal.

## 04 Data on Electrical Circuit

When conveying data signal using the existing electrical wiring, there is a good chance that power equipment connected to the same circuit will radiate harmonics, noise, and/or energy forms that may interfere or obstruct the transmitted data signal. The system may also be susceptible to radiate radio frequencies or the presence of other external signals.

The HomePlug Alliance requires each node/adapter a 'Tone Maps' updates during operations to avoid troubled frequencies and to put more data onto those frequencies that exhibit low losses. HomePlug also added filters to mitigate noise from adjacent motors or other high-rated power equipment.

The use of the BusSTRUT busway technology is a good application to isolate the electrical noises from equipment such as HVAC, elevators, motors and other non-linear loads. It is our opinion that the HomePlug adapters will work seamlessly with the receivers within the same busway. Testing will be conducted in a later phase to verify hypothesis.

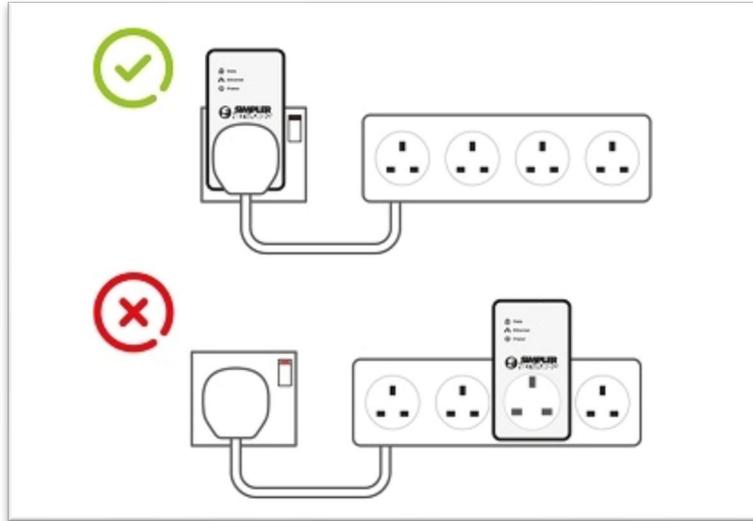
## 05 Powerline adapter on Surge Protector Device

The HomePlug Alliance and adapter manufacturers do not recommend connecting the Powerline adapter to surge protectors or uninterruptible power supplies (UPS) with surge protection due to internal filters that remove a portion or all of the high frequency signals used in powerline communications. Powerline adapters work best when plugged directly to the wall outlet as recommended by the manufacturer.

The busSTRUT system does not utilize surge protectors in the busway system eliminating or greatly reducing the impact to end devices plugged into the HomePlug adapter within the busway system.

Netgear Support stated the following on their FAQ webpage:

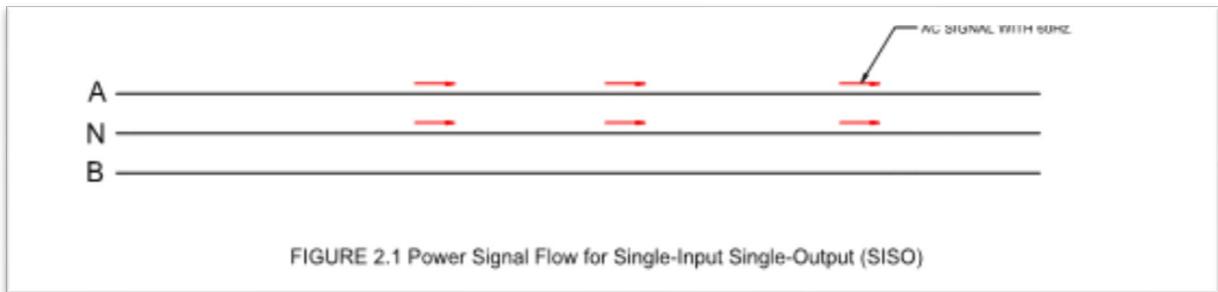
*NETGEAR does not recommend using power strips, surge protectors, UPS and extension cords with Powerline products. These devices filter out some or all the high frequency signals used in Powerline communications. Connecting a Powerline to one of these devices can greatly reduce the data rate of transfers, or block communications entirely. See illustration on following page.*

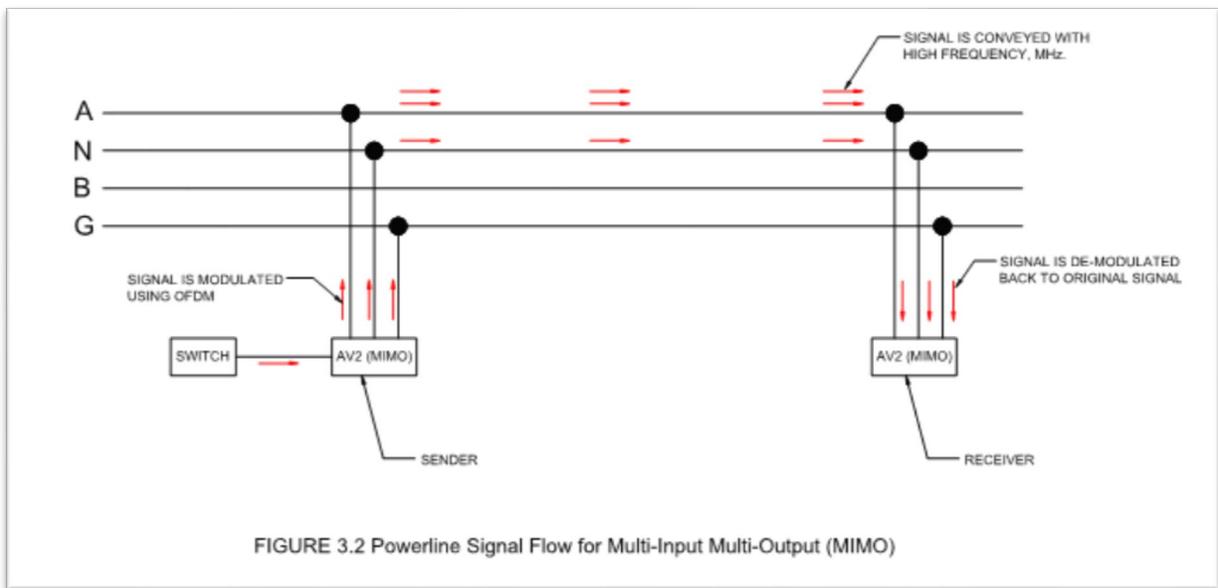
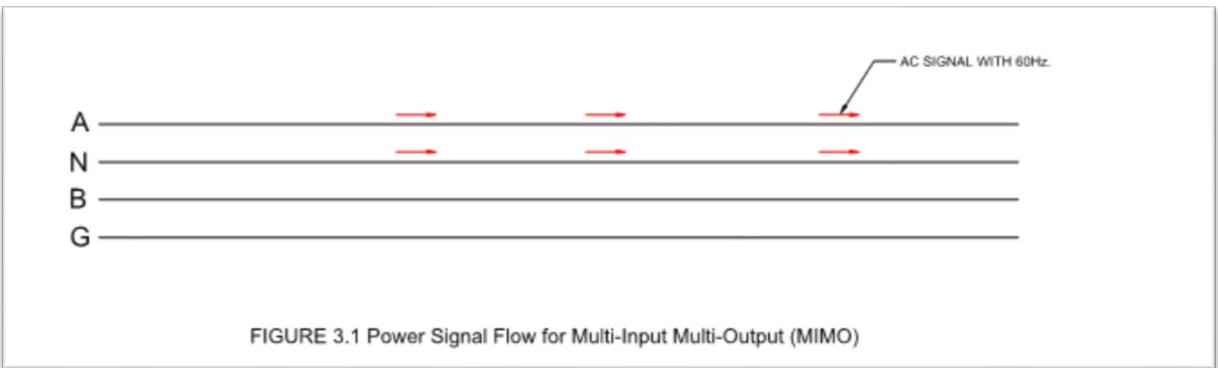
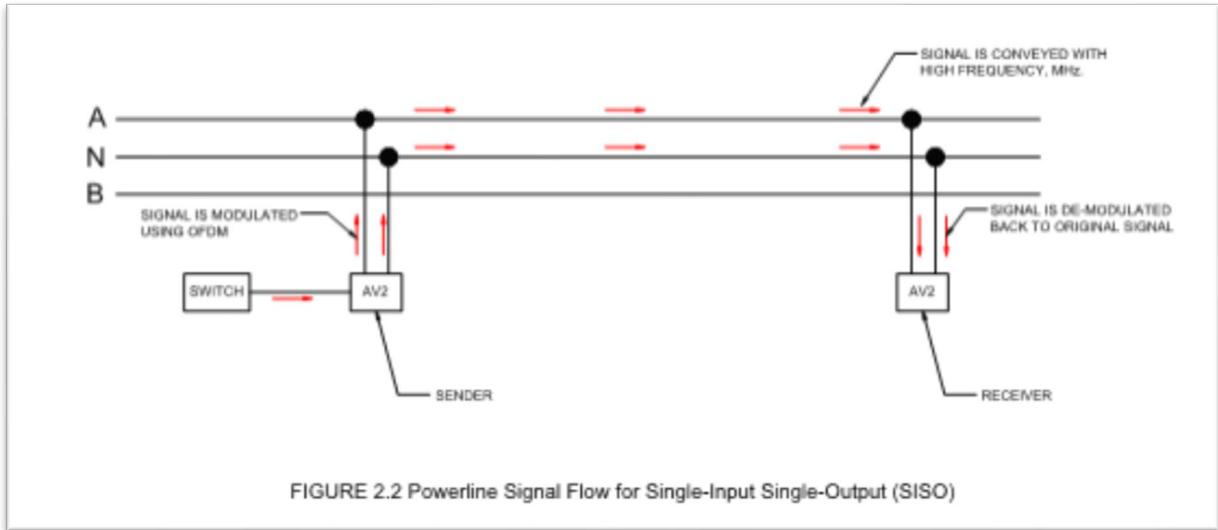


## 06 Effect of Circuit Breaker (CB) with Powerline Device

Currently there are no known issues with using a circuit breaker on the circuit, as long as the CB is in the closed position. The powerline adapter utilizes the neutral conductor to convey signals across different phases or circuits. Additional investigation is needed to determine if the powerline device can be used on multiple phases, and will be continued in phase 3 of this study.

The HomePlug AV2 sends the data signal on neutral and travels to the receiver adapter whether on the same circuit or different circuits. The Integrity of the existing electrical wiring plays a major role in the data speed that adapter can provide. Damaged wiring, and/or loose connections on any wire, neutral, or ground will affect the signal transmission. See figures 2.1 – 3.2 below.





07 Conclusion

The power companies have been using powerline communications since 1920 allowing them a way to control power by sending signals over the main transmission lines. They also utilize this technology to instruct the power meters when to switch to peak/ off-peak rates.

The wiring in most residences can be used to convey signals in variety of frequencies. The electricity in the US uses 60Hz signal, so another information signal can be transported along the same wires at a higher frequency without causing interference. The HomePlug AV2 uses this technique to mitigate noise, harmonics, and other forms of energy interference.

The most recent HomePlug AV2 has a high bandwidth capability compared to other technologies making it ideal for internet, streaming video, multi-room IPTV, online gaming and other high demand networking uses. It uses the MIMO feature that doubles the rate coverage, complete interoperability with HomePlug AV and Green PHY, and power save with three modes of operation (active, standby and idle). The HomePlug AV2 provides the throughput and coverage that is required to support the most demanding multimedia applications.

Even though the powerline adapter is designed for residential applications, our research indicates the powerline adapter may be suitable for light commercial or commercial use with the proper design and compatible end devices at each node. The busway is a great application to employ the HomePlug AV2 technology to isolate the harmonics, electrical noise, and voltage spikes from other equipment. We believe there are networking techniques available to help optimize the transmission of signals by creating a sub-network dedicated for HomePlug AV2 use.

Summary responses to the Task on Phase 1:

- HomePlug Alliance has developed a standard for powerline device that converts the data signal using OFDM, a modulation technique. HomePlug Alliance has solved the problem by using high frequency carrier, in MHz, to send data signal using the same electrical wiring. This solve the noise issues.
- Connecting to a surge protector is not recommended by the HomePlug Alliance and Manufacturers
- There are no known issues with the circuit breaker. The signal utilizes the neutral conductor as main carrier that is common to all phases.

## 08 Appendices

- HomePlug AV Specification Version 2.1
- HomePlug AV2 Technology
- tp-Link User Guide
- tp-Link TL-PA9020P User Guide