Current Sensing in No-Neutral Light Switches

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TEXAS INSTRUMENTS

Light switch boxes can be broken down into two major topologies: switch boxes that have a neutral wire run through them, and those which do not. Traditionally in light switches, a switch in the "On" position closes a switch in the line, creating a path for current to flow to a light bulb. In the "Off" position, this switch is opened, thus breaking the current loop. Figure 1 shows a light switch box which has a neutral wire run through it. Figure 2 shows a switch box without a neutral wire running through it.

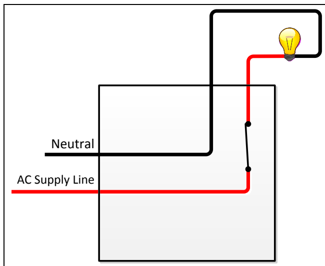

Figure 1. Neutral Wire Present

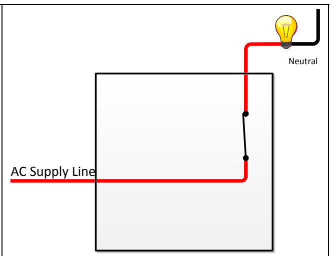

Figure 2. No-Neutral Wire Present

A problem arises with the introduction of "Smart" switches designed to allow a user to control lighting through various devices like smartphones. For these switches to operate, there are internal components which require constant power, even when the light is turned off. This is necessary so that the switch can still be controlled remotely. In switch boxes with a neutral wire in them, this is not a problem as the neutral wire can be used to create a path for current to flow through even when the switch is in the off position. In switch boxes without a neutral wire, there must be a constant flow of current through the bulb as this is the only path for the current to flow. This challenge means special consideration must be taken when designing a smart switch for no-neutral switch boxes. It is important to use components that require as little current as possible. If the internal components require too much current, it will cause the light bulb to illuminate even when it is turned off. Figure 3 demonstrates the path that is possible in switch boxes with a neutral wire. Figure 4 shows the current path for a switch box without a neutral wire. It is still possible to have a physical switch in a no-neutral setup in the event that the user wants to prevent any current from flowing through the path. However this would also prevent any power from being delivered to the components of the switch as well.

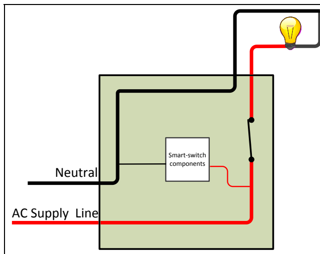

Figure 3. Smart-Switch With Neutral Wire

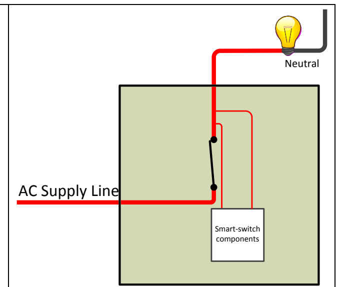

Figure 4. Smart-Switch With No-Neutral Wire

One important internal component of a smart switch is the current-sensing chain. As many smart switches allow the user to set various brightness levels it is important for the microcontroller in the switch to know how much current is being delivered to the bulb to determine its brightness. Current sensing is a technique that is performed by placing an op-amp across a low-resistance shunt resistor that is in series with the bulb. Ohm's Law tells us that the voltage drop across a resistor is directly related to the current flowing through this resistor. This voltage difference across the resistor is gained up by the op-amp which outputs to an analog to digital converter that is communicating with a microcontroller. The microcontroller uses this input to determine of the current flowing through the bulb.

One very suitable device for this application is the LPV821. The LPV821 is the Industry's first nanopower zero-drift precision amplifier, with a quiescent current of only 700 nA. The ultra-low current consumption of the LPV821 helps to solve the problem of allowing the internal components of the switch to operate as needed while minimizing current draw. Lower current draw from this device also opens up more overhead for the other components to utilize more current without exceeding a threshold that would cause the bulb to illuminate, or cause the bulb to flicker from the leakage current of the other components.

The zero-drift aspect of the LPV821 also makes it an excellent fit for this application. The LPV821 has an offset voltage of ±20 µV, allowing the amplifier to have a high accuracy output with only a small voltage drop across the shunt resistor. This means that a very small resistance shunt resistor can be used while still generating enough of a voltage drop to be detected by the op-amp. As the power dissipated in a resistor is equal to the current squared times the resistance, being able to use a smaller resistor means less power dissipation.

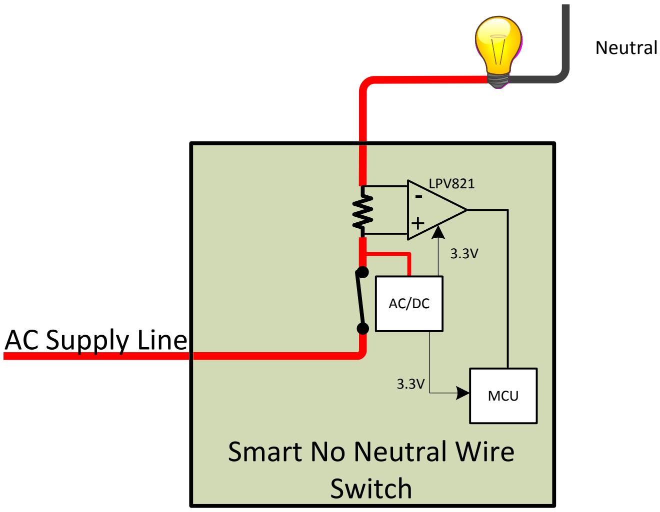

Figure 5. No-Neutral Switch Block Diagram With the LPV821

Figure 5 contains a basic block diagram for using the LPV821 in a Smart No-Neutral switch. Here the LPV821 is placed across a shunt resistor and is feeding information to an analog-to-digital converter that communicates with the microcontroller. There is also an AC to DC converter that steps the 220-V AC down input to a 3.3-V DC signal. This signal is within supply voltage range of the LPV821, and is also used to provide power to the microcontroller.

Another way the LPV821 can be used in a no neutral light switch is as part of a current protection string. By using the output of the LPV821 as the positive input node of a comparator, with a reference voltage on the negative input node the output of the comparator will shift to the positive rail of the comparator once the voltage on the positive node surpasses the reference voltage. This can be used to raise a flag on the microcontroller to alert of overcurrent as is shown in Figure 6. In this diagram a TLV3691 comparator is used. The TLV3691 is a nanopower comparator making it an ideal fit for low-power applications such as this. The output of the comparator could also be connected to a FET that would create an open circuit if an overcurrent scenario occurs.

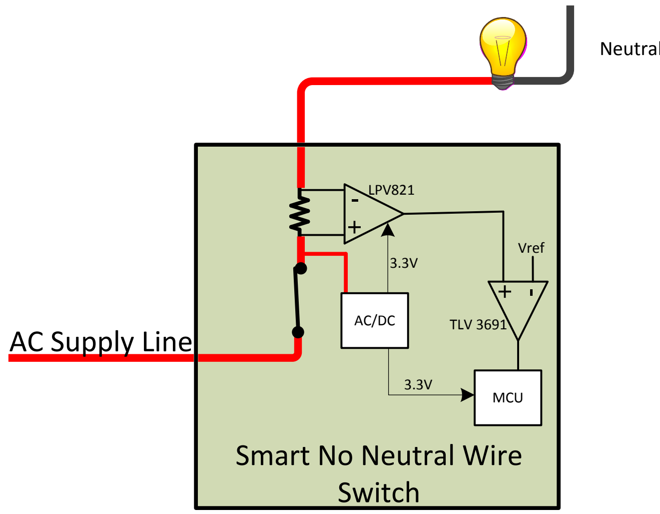

Figure 6. Configuration With TLV3691 Comparator

Alternate Device Recommendations

For applications where quiescent current must be reduced even further the LPV521 is a suitable alternate device offering a quiescent current of only 325 nA, but has a higher offset voltage at 1 mV.

Table 1. Alternate Device Recommendations

DEVICE	OPTIMIZED PARAMETERS	PERFORMANCE TRADE-OFF
OPA333	Supply Voltage Range, Precision	Quiescent Current
LPV811	Quiescent Current	Precision
LPV521	Quiescent Current	Precision

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