

How to Power Your Thermostat Using Solid State Relays



Tattiana Davenport

If you read my previous blog post, “[Click! Clack! What’s the setback in your thermostat?](#)” about the interaction between a [thermostat](#) and a heating, ventilation and air conditioning (HVAC) system, you know how the thermostat controls HVAC loads. But where does the thermostat get the power to operate and how can you make it more efficient?

Two power sources are available for the thermostat: batteries and the 24VAC. Batteries are required for the thermostat to operate without interruption. It is very important that the energy consumed by the batteries is as low as possible, but even if you minimize consumption, this still isn’t a user-friendly option because batteries will require replacement from time to time. To reduce the replacement frequency, you can use the 24VAC supply. In systems where the C wire is not available, the bridge rectifier shown in [Figure 1](#) converts the alternating current (AC) voltage through the load into a direct current (DC) voltage.

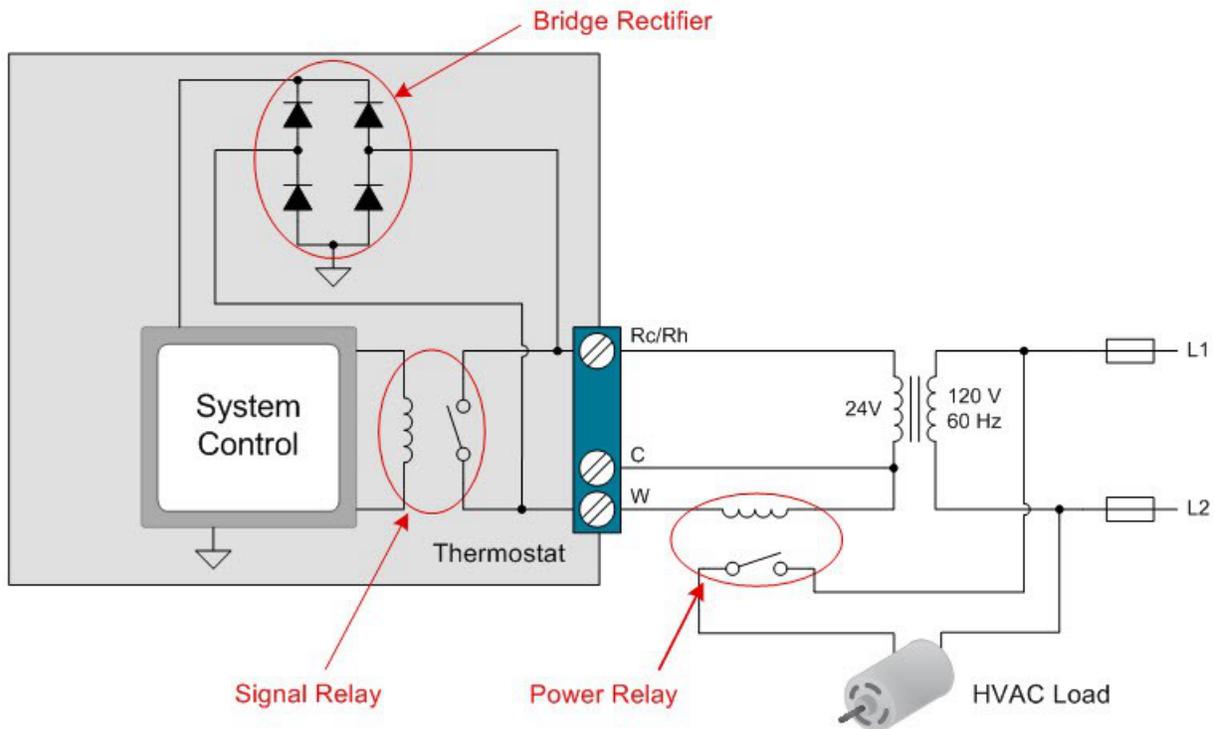


Figure 1. Single Thermostat Signal-relay Connection with HVAC Load

During the HVAC load (compressor, fan, gas valve, etc.) off-time, the contact of the signal relay is open. When the contact is open the terminals of the rectifier bridge see the 24VAC voltage of the HVAC transformer and convert the AC power to DC power, as previously described. This resulting DC voltage is used to power the thermostat or sub-circuits.

During the HVAC load on-time, the contact of the signal relay is closed. When the contact is closed the voltage across the rectifier bridge terminals drops to zero. This eliminates the option of using the 24VAC as a power source, so the thermostat’s battery power must control the circuit. The required current to operate an electromechanical relay can range from tens to hundreds of milliamps, which can have a significant effect on battery life.

What if there was a way to power the relay without using the thermostat's batteries? Battery life would increase and replacement frequency would drop even further. One method is to open the relay for short periods during the on-time (signal-relay contacts closed) of the HVAC load and charge the control system. The period of charge time needs to be very small in comparison to the power relay's turn-off time as to not deactivate the power relay and its corresponding load. Unfortunately, this isn't possible with electromechanical (signal) relays because of their switching speeds. The time it takes for a contact to move to the desired position is in the range of milliseconds and will interrupt HVAC load operation.

Fortunately, there is a device that can achieve the proper switching speeds: the solid-state relay (SSR). An SSR is a semiconductor-based relay using thyristors or power transistors to perform on/off control.

This recharging method requires an SSR with a dual MOSFET configuration because then it is possible to turn off MOSFET-based SSRs whenever necessary. In addition, the body diode of each MOSFET can assist in the rectification of the 24VAC. MOSFET body diodes combined with two additional diodes create a full-wave rectification bridge, shown in [Figure 2](#).

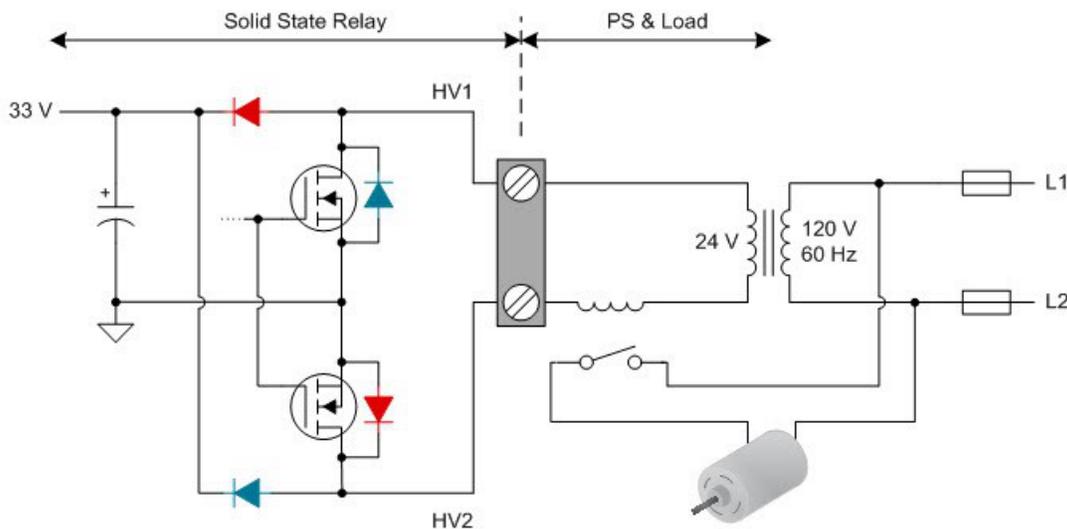


Figure 2. Power Supply of an SSR in an HVAC System

[Figure 3](#) shows the resulting rectification waveforms that correspond to the color-coded diodes in [Figure 2](#). Connecting a properly sized capacitor at the output of the rectifier bridge will smooth out the voltage ripple of the final waveform. You can then step this DC voltage down to your desired voltages for the control system.

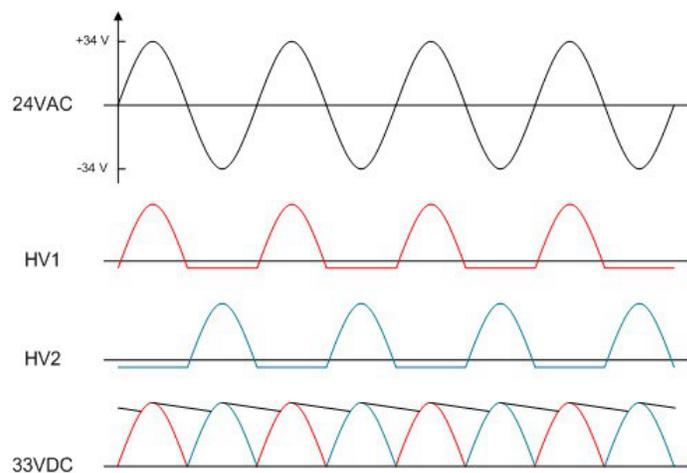


Figure 3. Full-wave Rectification Waveforms

Using an SSR enables the HVAC system to fully power the thermostat, reducing the power usage of the batteries. When the SSR is off, the HV1 and HV2 lines will see the full 24VAC voltage and provide a constant 33VDC at the output of the rectification bridge. When the SSR is on, it is still possible to cycle through open and closed states for short periods of time, enabling the supply capacitor to recharge. This design can dramatically reduce energy requirements from thermostat batteries and thus battery-replacement frequency.

Want to learn about the component selection process for SSRs in thermostat end equipment? Stay tuned for another blog post, in which I will provide an overview of a low-cost SSR design.

Additional Resources:

- Learn about SSRs in the blog post, [“Modern approach to solid state relay design.”](#)
- Download the Solid State Relay 24V AC Switch with Galvanic Isolation Reference Design ([TIDA-00751](#))
- Check out these data sheets:
 - NexFET™ power MOSFET [CSD19537Q3](#).
 - FemtoFET MOSFET [CSD18541F5](#).



IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated