Solve 3.3-V relay design issues

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A relay is defined as an electrically operated switch; it is either open or closed. When the relay is open no current passes through the relay, so the load that is connected to the relay receives no power. When a relay is closed, the circuit is completed and current passes through the relay and delivers power to the load. Typical relays use an electromagnet to operate a switching mechanism mechanically. Additional relay switching methodologies also are used across various industrial applications. A typical application of relays comes out of the necessity to control a given circuit by a low-power signal where a complete electrical isolation between control and controlled circuits is needed. A secondary need for relays is in applications where several circuits must be controlled by one signal.

The first switching relays were developed over a hundred years ago for use in long distance telegraph circuits, where a repeating signal coming in from one circuit had to be re-transmitted to another adjoining circuit. This application made relays ubiquitous and used extensively in telephone exchanges, and then in early computers to perform logical operations.

A contactor is a type of relay that can handle the high power required to directly control an electric motor or other loads. Most telecom and consumer electronics applications use low-power relays. Two typical types of low-power relays are solid state and electromechanical relays. Solid state relays are electronic switches that control power circuits with no moving parts, wherein a small control signal controls a larger load current or voltage. Electromechanical relays use an electromagnet to open and close a relay. When the coil controlling the electromagnet is given a voltage, the electromagnet causes the contacts in the relay to connect and thus transfer current through the relay. In both cases a sensor responds to an appropriate input (control signal): a switching device that switches power to the load circuitry; and some coupling mechanism to enable the control signal to activate this switch. The relay may be designed to switch either AC or DC to the load.

Need for 3.3-V relays

In consumer electronics like air-conditioners, washing machines and printer spoolers, relays are used to interface low-voltage electronic controllers with high-voltage and high-power equipment. Relays also are widely used in automated test equipment when very low resistance and inexpensive switches are required. Lowering the supply voltage rails to achieve higher speed and higher power efficiency is a common theme across various analog and digital integrated circuit components and their end applications. The 5-V power rails were very common until the last decade. Now 3.3-V rails can be found everywhere, with 1.8-V power rails catching up fast. Relay usage is tracking the same trend, albeit at a slower rate. The 12-V relays have been replaced by 5-V relays over the last decade and are still very common. However, the 3.3-V relays are catching up fast as well.

Requirements and challenges for 3.3-V relay designs

Current 12-V relay drivers are still amenable to their application in driving 5-V relays. However, owing to a higher VOL or VCESAT, the old generation relay drivers are not amenable to driving 3-V relays. Due to lack of availability of low-voltage relay drivers, the end applications have resorted to discrete components. A typical discrete component implementation uses a single or multiple MOSFETs in a paralleled array along with diodes and resistors. MOSFETs have an inherent substrate diode that conducts in the reverse direction, so a single MOSFET cannot block current in both directions. For AC (bi-directional) operation, two MOSFETs are arranged back-to-back with the source pins tied together and drain pins connected to either side of the output. The substrate diodes are alternately reverse-biased to block current when the relay is off. When the relay is on, both gates are biased positive relative to the source by the photo-diode. Typical practice is to provide access to the common source so that multiple MOSFETs can be wired in parallel, if switching a DC load. Usually a network is provided to speed up the MOSFET's ON/OFF when the control input is removed.

Using a discrete component has inherent issues, mainly due to higher cost and limited printed circuit board (PCB) space. Unwanted power dissipation results when low-voltage applications are overwhelmed by the large number of discrete components, very much against the original motivating factors for using the low-voltage relays. Telecom or consumer electronic applications usually need four to seven relays to switch and driven either in series or in parallel. This penalizes the PCB even further. Designers have to estimate the final number of relays needed while still in the design process, making the number of required components unpredictable. This process of estimation can result in designing for all possible permutations of number of relay channel voltages and could increase the complexity of required design combinations needed to cover all possible applications. The need for simultaneous AC/DC applications further complicates the design process. The designer either makes multiple designs to support many applications, or one extensive and complicated design to support all potential applications. The simultaneous need for AC/DC applications requires a built-in control for inductor noise reduction, and possibly includes a capacitor. Finally, the question of whether the discrete components will support only one or multiple voltages tied together drives the design complexity exponentially. Designers must decide upfront what voltage transistors, diode ratings and resistors values, all of which will determine voltage, power and AC/DC design applicability.

All these problems faced during the 3.3-V relay switch and driver design, along with future needs for even lower voltages and green initiatives, is driving towards a more integrated solution that can support both solid state and electromechanical relays in simultaneous AC/DC applications. To eliminate these design challenges, using an integrated chip (IC) capable of an all-in-one application implementation is recommended.

Operational and manufacturing issues with discrete components

In addition to complex design challenges and cost penalties, designers have to consider and resolve upfront several other issues. Two main issues are: time needed to manufacture the PCB; and built-in discrete component reliability. As more components are needed, more board connections are required; plus cross-checks performed for quality assurance purposes; and increased time to design and build multiple combinations. Moreover, discrete components do not have the option or flexibility to have the built-in electrostatic discharge (ESD) protection. This could result in field application failures, risk of increased early failure rates (EFR), or higher mean time between fails (MTBF). Finally, a designer also must consider any operational issues that may result from the supply chain needed to keep the variety of discrete components readily available for initial design, further modifications or enhancements, and the ability to sustain continuous manufacturing.

Identifying and implementing the right integrated chip

For an integrated chip to be an all-in-one implementation and to eliminate the design challenges described, the following capabilities are necessary:
* support multiple voltage relay ranges (1.8 V, 3.3 V, 5 V) with low output VOL (0.4 V) required for low-voltage rails
* compatible with microcontroller and logic interfaces
* internal inductive kick-back protection along with the ability to eliminate spurious operation noise (associated with low-voltage inductive relay loads).
* multi-staging capability for parallel use of multiple input and output voltages
* low input and output leakage currents for low-power consumption (Energy Star Compliant / CE ERP-Lot 6 compatible)
* built-in ESD protection.

A typical integrated functional implementation for each relay driver channel is shown in Figure 1.

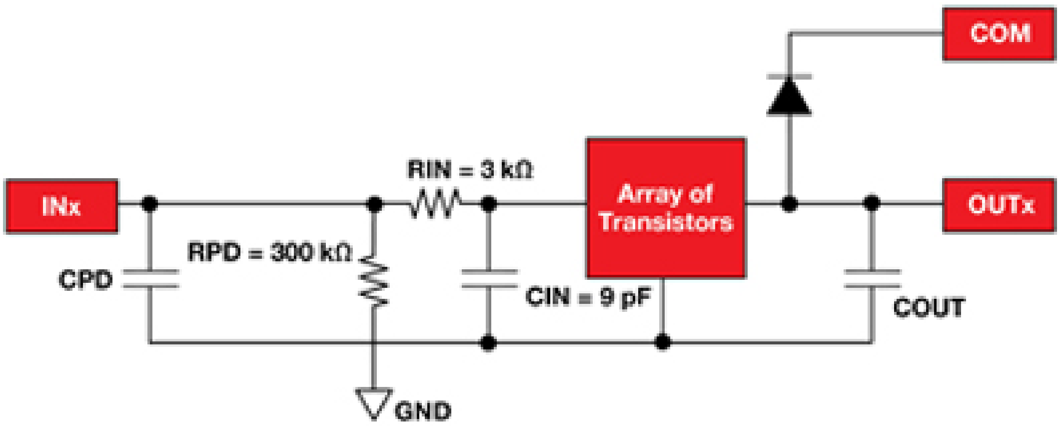

Figure 1. Functional diagram of an integrated chip showing a single channel relay driver. A typical application integrates seven to eight channels in one IC.

A typical application for 3.3-V or 1.8-V relays is shown in Figure 2.

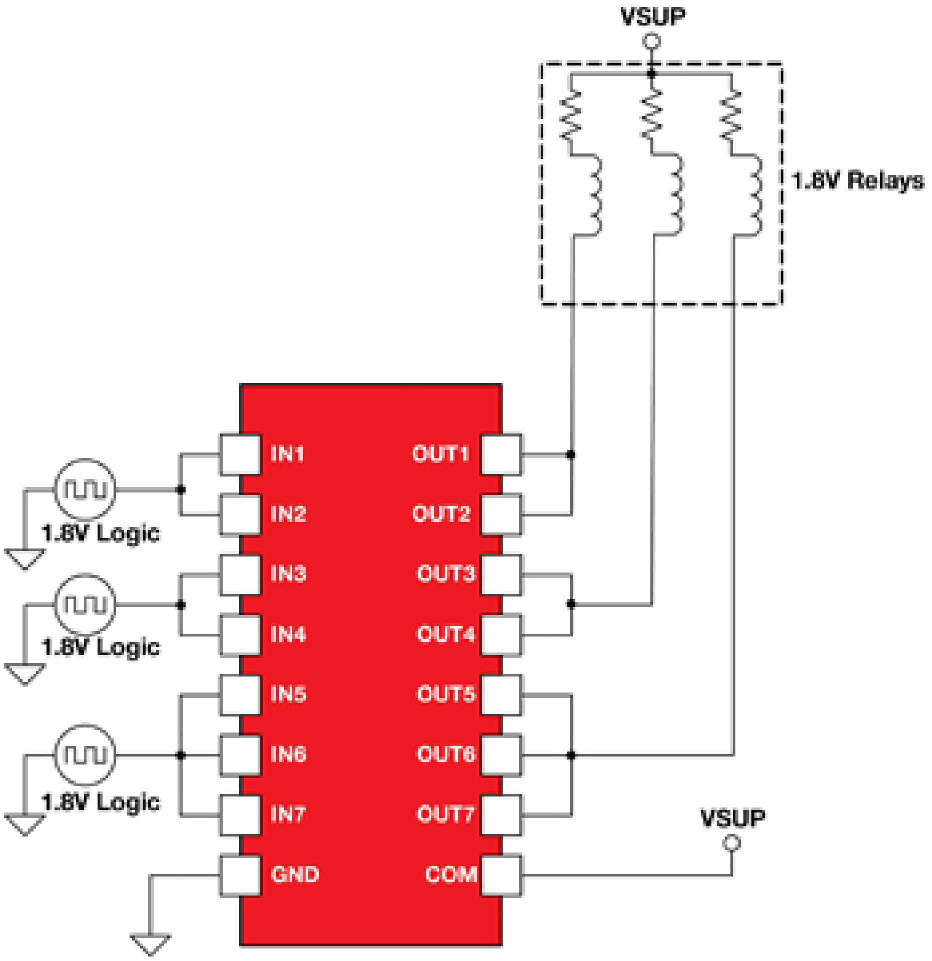

Figure 2. Typical application combines channels to drive different load relays at different voltage levels. Any combination of input and output voltages can be used.

While serving the need for a 3.3-V relay driver, the chosen IC component also has to provide a way for interfacing the 1.8-V relays by providing a lower VOL that is amenable to both 3.3-V and 1.8-V relays. The IC should have a better logic interface making it more compatible to most modern CMOS-based microcontrollers and CPUs. The IC must also provide a higher power efficiency when ON and a lower leakage current when OFF. This helps to reduce vampire power consumption, thus aiding the worldwide green initiatives.

An IC with lower power consumption than a discrete component with built-in RC snubber (Figure 1) for inductive noise reduction, along with simultaneous and parallel use capability of different input/output voltages needed for multiple application designs is a right choice. In addition to the intended relay driver application, the IC also should provide additional applications for overall industry-wide acceptance. Application solutions for stepper motor (Figure 3), logic (Figure 4), and constant current LED drivers help to cost-effectively manufacture optimal performance ICs.

The ULN2003LV from TI is an example of a next-generation relay driver that address the 3.3-V and 1.8-V relay drive requirements for multiple applications.

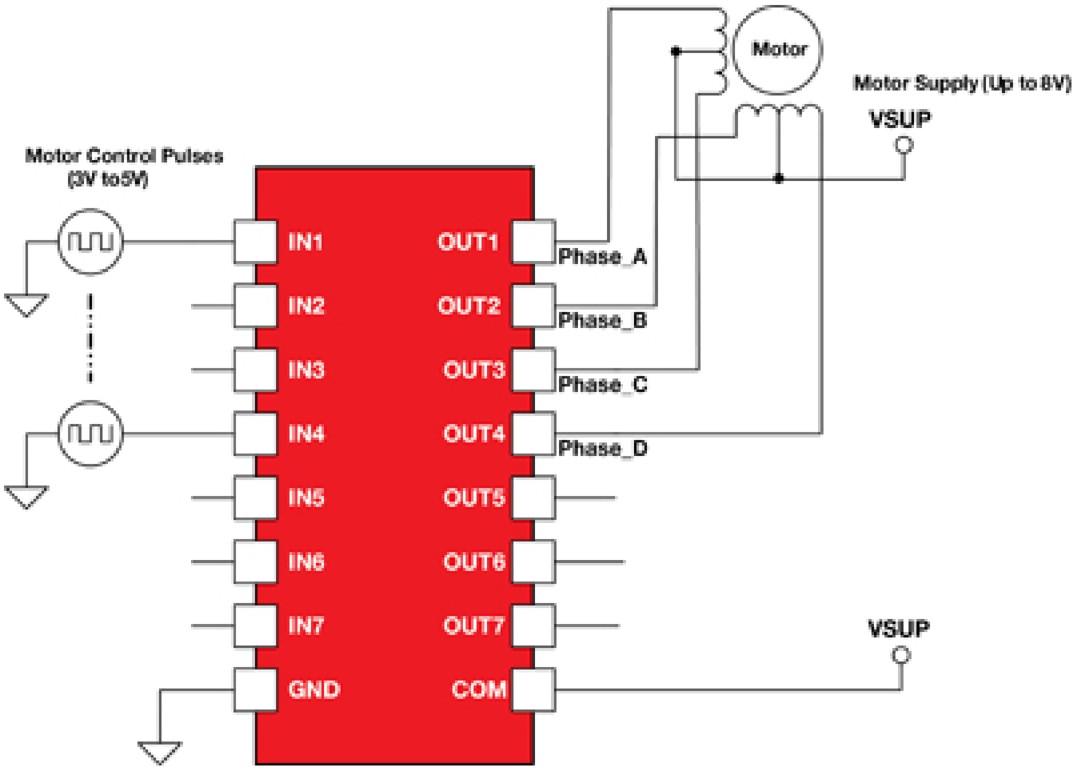

Figure 3. A stepper motor driver application layout. Input and output voltages can be mixed and matched for specific application needs.

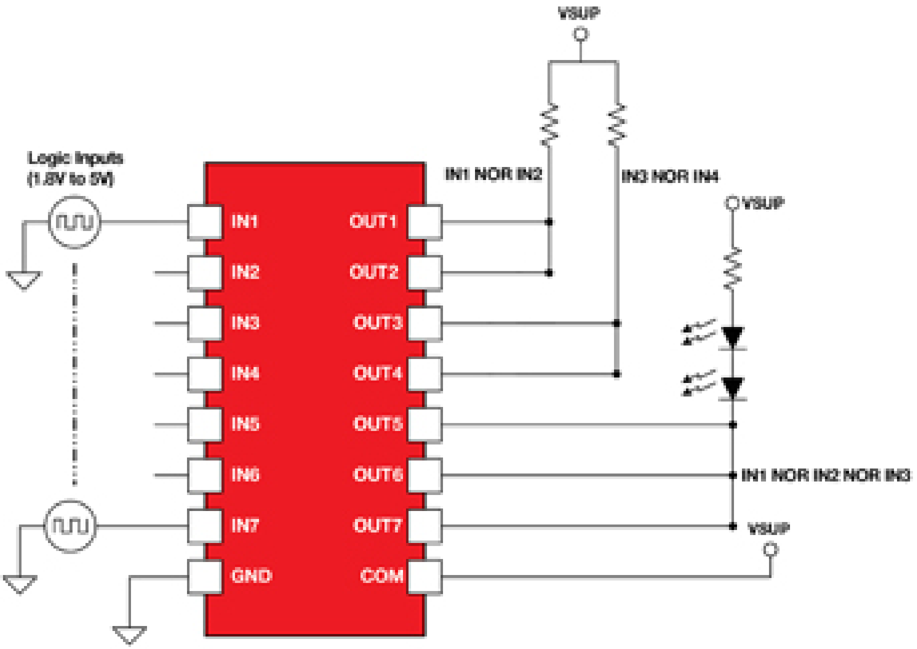

Figure 4. Logic and LED driver applications achieved my multi-staging the same IC with different voltage levels.

Summary

Lowering the supply voltage rails to achieve higher speed and higher power efficiency is a common theme across various analog and digital IC components and their end applications. The old generation relay drivers are not amenable to driving the low-voltage 3.3-V/1.8-V relays. Without a low-voltage relay driver, end applications resorted to discrete components which incurred higher cost, demanded more board space, and inherited quality issues. The proposed solution uses a versatile integrated chip that reliably drives and switches low-voltage relays in various combinations of supply and input conditions – saving costs and valuable board space and a greener thumbprint

References

To learn more about relay drivers, visit: www.ti.com/uln2003lv-ca [1].

About the Author

Kalyan Cherukuri is a systems and applications manager with TI's Standard Linear and Logic (SLL) group, as well as a Distinguished Member of Technical Staff. Kalyan is responsible for new product technology development, product definitions, and application improvements for SLL. Kalyan received his MSEE from Clemson University, Clemson, South Carolina, and was issued two patents and two trade secrets, with three patents pending.

Links:
[1] http://www.ti.com/uln2003lv-ca