Lattice Semiconductor Corporation

Interfacing the ispPAC-POWR1208 with Modular DC-to-DC Converters

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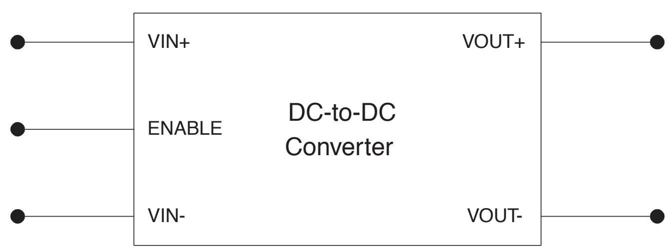
Introduction

The ispPAC®-POWR1208 is a single-chip, fully integrated solution to supervisory and control problems encountered when implementing on-board power conversion and distribution systems. The ispPAC-POWR1208 provides several types of programmable on-chip resources which can be used to meet the requirements of these applications. In addition to providing four high-voltage FET driver outputs, four general purpose open-drain outputs are also provided which can be used to control modular DC-to-DC converters. This application note describes several issues associated with controlling modular DC-to-DC converters, and presents several example circuits for interfacing the ispPAC-POWR1208's digital outputs to these devices.

Characteristics of Modular DC-to-DC Converters

The use of modular DC-to-DC converters is becoming increasingly common as power conversion systems are being implemented in a distributed manner, with final conversions to end-use voltages being performed on circuit cards. Many systems and even individual integrated circuits require power supplies to be sequenced at startup and shutdown, or otherwise switched on and off when changing operating modes. For this reason, an externally controllable ENABLE signal is often provided to switch a DC-to-DC converter on and off (Figure 1). Both positive logic (a HIGH signal turns converter on) and negative logic (a LOW signal turns the converter on) are common types of ENABLE inputs.

Figure 1. DC-to-DC Converter with ENABLE Input



While the ENABLE inputs of some converter modules accept standard (5V or 3.3V) logic levels, many other electrical interfaces are common as well. The purpose of this applications note is to describe how to interface the logic outputs of Lattice Semiconductor's ispPAC-POWR1208 to some of these non-standard interfaces.

Most converters with non-standard-logic interfaces are turned on by shorting their ENABLE pins to either their positive or negative input power supplies, or leaving them floating (open). Table 1 summarizes a few of the possible operating modes.

Table 1. Common Converter ENABLE Modes

Input Type	ENABLE Input Condition		
	Open	Short to Vin-	Short to Vin+
Positive logic with pull-up	ON	OFF	ON[1]
Negative logic with pull-up	OFF	ON	OFF[1]
Positive logic with pull-down	OFF	OFF[1]	ON
Negative logic with pull-down	ON	ON[1]	OFF

1. These conditions may not be tolerated by a given model of DC-to-DC converter

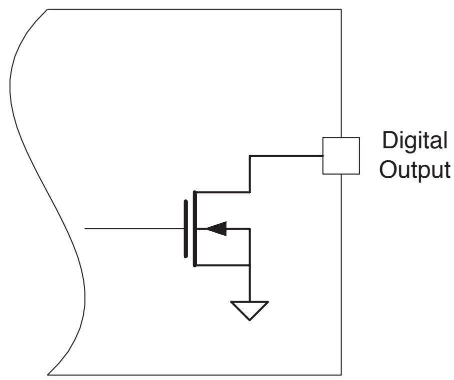
The first major distinction in operating modes is whether the converter turns on with a positive signal (positive logic) or a negative one (negative logic). The second distinction is whether the input is internally pulled-up or pulled-down in the floating case. Note that a converter's internal pull-up or pull-down may terminate to some arbitrary voltage level defined by the converter manufacturer, and not necessarily to a 'standard' voltage such as +3.3V or ground. Often in the case of a pull-up, the termination may be to the converter's positive input voltage, which can create special interfacing problems for those converters running from high voltage 24V and 48V supplies.

Characteristics of ispPAC-POWR1208 Digital Outputs

To effectively interface a given DC-to-DC converter to an ispPAC-POWR1208 output, one must thoroughly understand both the characteristics of both the converter's ENABLE input and the ispPAC-POWR1208's digital outputs.

The ispPAC-POWR1208 provides four high-voltage outputs (HVOUT1-4) designed to drive power MOSFETs and four open-drain general-purpose digital outputs (OUT5-8). The high voltage outputs can also be configured to serve as open-drain logic outputs. An open drain output is shown schematically in Figure 2.

Figure 2. ispPAC-POWR1208 Open-drain Output



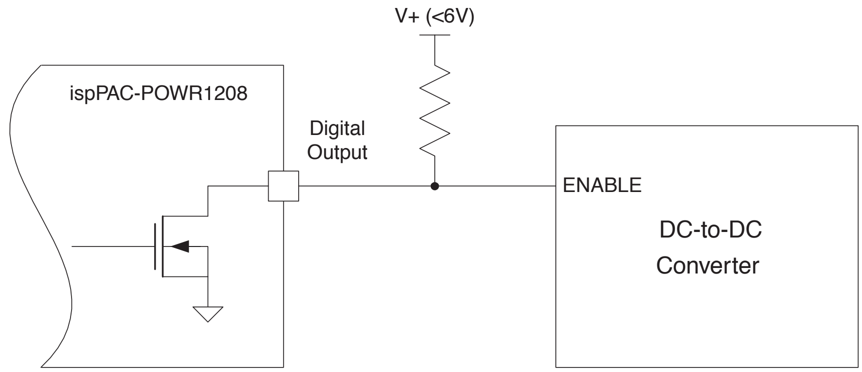
Although this output circuit can be characterized in a great deal of detail, there are three parameters which are of paramount importance in this application:

1. Output current when transistor switched on
2. On-state saturation voltage for a given current
3. Maximum allowable voltage at the pin

The first two of these three parameters can be obtained from digital V_{OL} specification on the ispPAC-POWR1208 data sheet. When conducting 4mA of sink current, the maximum saturation voltage is specified as 0.4V. The maximum allowable voltage the output can be subjected to is given in the absolute maximum ratings section under V_{TRI}, and is specified as 6V.

Knowing these three parameters allows us to determine interface requirements. The simplest interfacing case is that of driving a converter which has a logic-level compatible input. In this case the output of the ispPAC-POWR1208 can be run directly into the converter's ENABLE input (Figure 3). Because the ispPAC-POWR1208 provides open-drain outputs however, an external pull-up resistor needs to be added to provide a HIGH logic voltage level. Because the pull-up resistor can be terminated to any voltage up to 6V, it is straightforward to interface to inputs with different HIGH logic level requirements (e.g. 1.8V, 2.5V, 3.3V, 5.0V). In the case of the HVOUT1-HVOUT4 outputs, when they are configured in open-drain mode, their associated pull-up resistors may be terminated to voltages as high as 7.5V above the ispPAC-POWR1208's V_{DD} supply.

Figure 3. Logic Interface Between ispPAC-POWR1208 and Converter

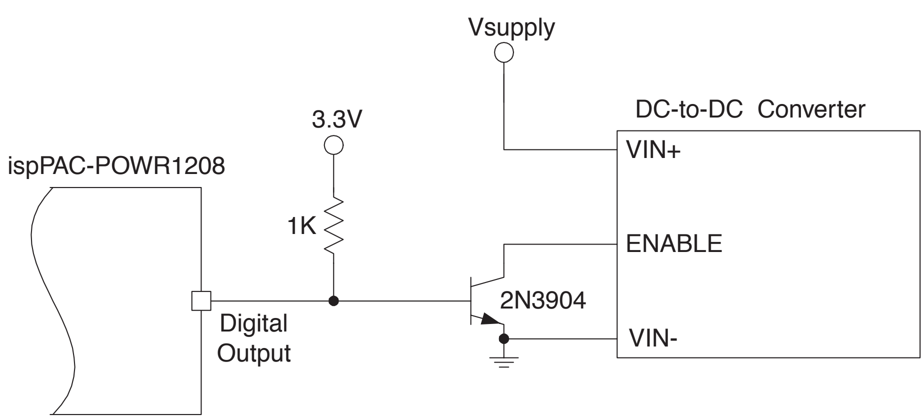


For converters with non-standard inputs requiring either an open state or short-to-ground, the circuit of Figure 3 can also be used if one removes the pull-up resistor. In this case, the converter must have the following characteristics:

1. The ENABLE pin's two control states are OPEN or SHORT-TO-GROUND
2. The ENABLE pin can be shorted to ground by pulling 4mA or less of current from it.
3. The ENABLE pin has an open circuit voltage less than 6V.

If any of the above conditions are violated, some additional circuitry may be required to reliably interface the ispPAC-POWR1208 to the DC-to-DC converter. In the case where more current needs to be sinked to pull the ENABLE line low, or its open-circuit voltage exceeds the maximum supported by the open-drain output (6V), adding an external transistor (Figure 4) will satisfy these requirements.

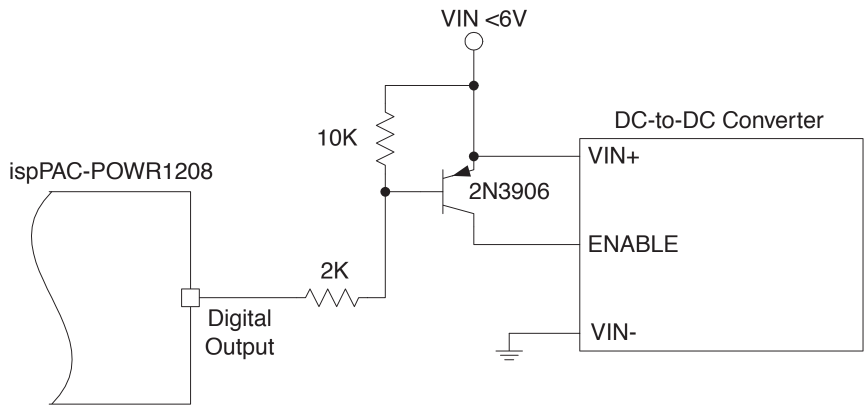
Figure 4. Using External Transistor to Increase Output Sink Capability



In this circuit, the maximum sink current is determined by transistor's base drive current (~2.5mA) multiplied by its gain, and can easily be in the tens or even hundreds of mA. The maximum allowable off-state voltage also increases to the external transistor's collector breakdown voltage, in this case approximately 40V. Note that the external transistor is turned ON (shorting the converter ENABLE line to ground) when the ispPAC-POWR1208's output is HIGH.

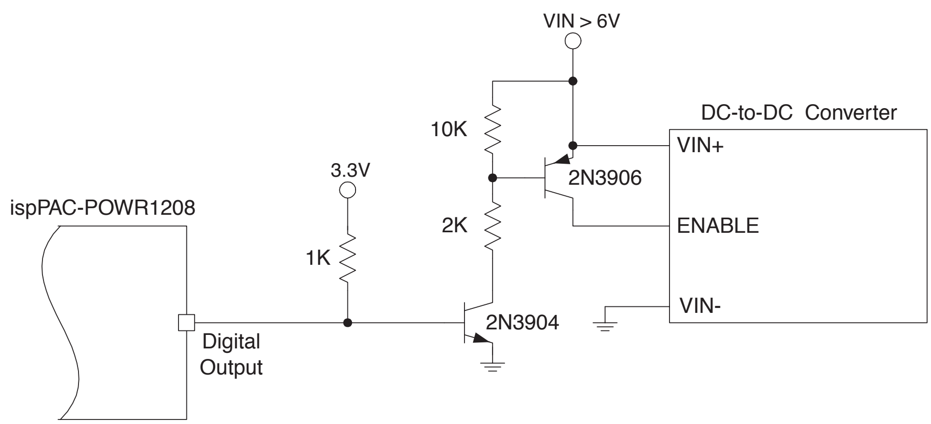
To handle the case where the converter's enable line must be shorted to its positive input supply to control it, a different circuit is required, as shown in Figure 5.

Figure 5. Circuit for Shorting the ENABLE Line to the Positive Supply



In this circuit, when the ispPAC-POWR1208's output goes LOW, it sinks current from the base of the PNP transistor, turning it on. Because of the transistor's gain, this circuit can source a significant amount of current (tens of mA), into the converter's ENABLE pin. One limitation, however, is that the VIN+ voltage is still applied to the output of the ispPAC-POWR1208 when the open drain is in the HIGH state. This limits its usefulness to cases in which this supply voltage is less than 6V. In these situations, Figure 6 shows one way of modifying the circuit for higher-voltage operation. The voltage that was applied to the open-drain output is now applied to the collector of the NPN transistor.

Figure 6. Circuit for Shorting ENABLE Line to a High-voltage Positive Supply

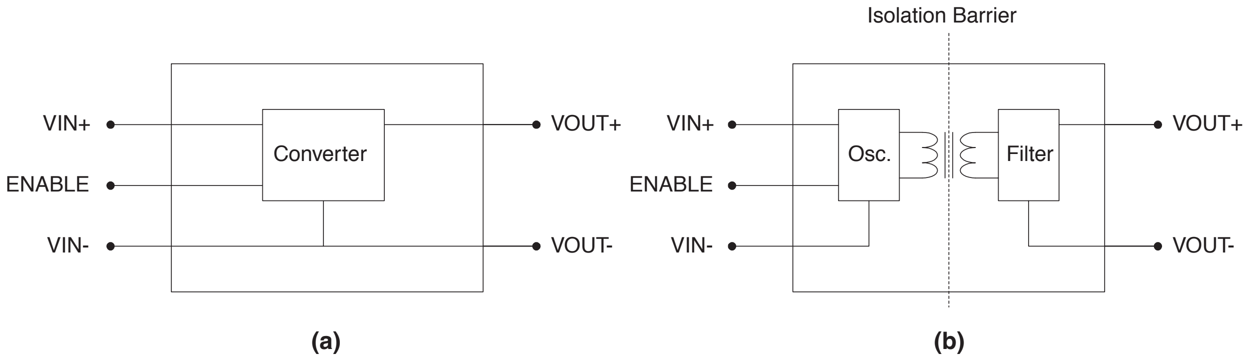


In this circuit, the collector of the NPN transistor now stands-off the VIN+ voltage instead of the ispPAC-POWR1208's output, offering compatibility with higher VIN+ voltages, depending on the choice of transistors. The addition of the extra transistor also has the effect of inverting the ispPAC-POWR1208's digital output, so that the PNP transistor is now turned ON when the digital output is HIGH. Note that a similar solution using opto-couplers will be discussed later in this application note.

Isolated Control Circuits

Many DC-to-DC converters offer galvanic isolation between their input supply and output supply terminals. Galvanic isolation means that there is no electrical connection between these two sets of terminals. Figure 7 shows the difference between a non-isolated (a) and isolated (b) converter.

Figure 7. Non-isolated (a) and Isolated (b) DC-to-DC Converters



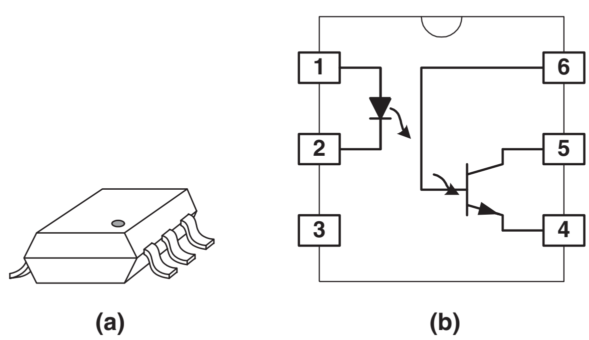
In the case of non-isolated converters, the ENABLE line is electrically referenced to both VIN- and VOUT-, so as long as the control circuitry is 'ground' referenced to either of these pins, no special measures need to be taken beyond assuring compatible voltage and current levels.

In the case of an isolated converter, however, there is NO electrical connection between the VIN- and VOUT- pins. In some systems there could potentially be hundreds of volts of potential difference between these two points. Accommodating large or unpredictable potential differences between inputs and outputs is one of the primary applications of isolation circuits.

If the ground of the ispPAC-POWR1208 controlling the converter is referenced to the VOUT- pin, the interface circuitry needs to be able to accommodate the possibility that the ENABLE pin might be at a wildly different voltage potential. The need to transmit a control signal across an isolation barrier is a common problem faced when designing power supply systems, and properly handling it can be difficult with conventional circuit design techniques.

Fortunately, one solution is the use of optocouplers. An optocoupler is an opto-electronic device designed specifically to transmit information across a galvanic isolation barrier in the form of light. A typical optocoupler consists of an LED (emitter) and a phototransistor (detector) molded into a single package (Figure 8a) in such a way that the light from the LED is sensed by the phototransistor (Figure 8b). Because there is no electrical connection between the LED and phototransistor, data can be transmitted across potential differences of hundreds or even thousands of volts between the emitter and detector sides of the circuit.

Figure 8. Optocoupler Package (a) and Schematic with Typical Pinout (b)



To effectively use an optocoupler, one must understand its characteristics. Some of the more important of these include:

- LED Forward Voltage (V_F)
- Phototransistor Collector-Emitter Breakdown Voltage (BV_{CEO})
- Current Transfer Ratio (CTR)

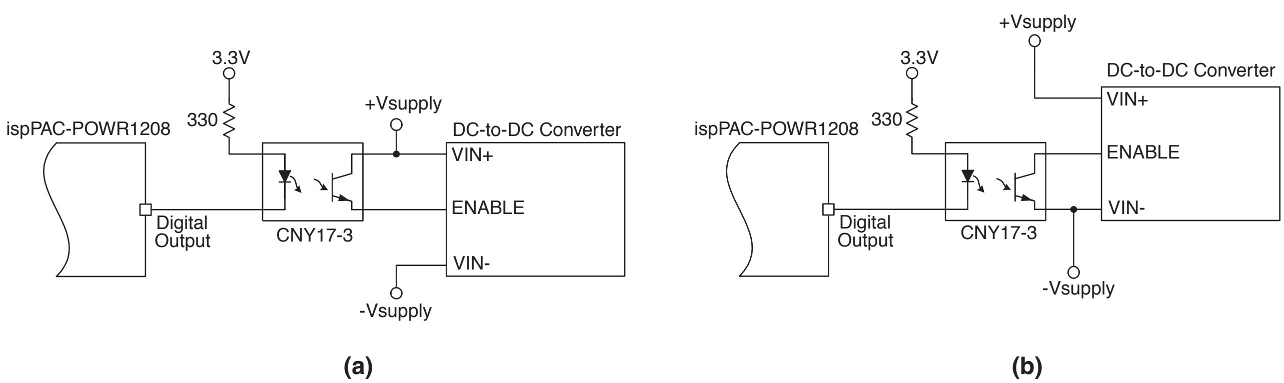
LED forward voltage is important because it defines the voltage drop one can expect to see across the LED when it is switched on at a given operating current. Unlike a silicon signal diode, an LED typically has a forward voltage drop ranging from 1.0 to 1.8V. Accounting for this drop is important when selecting a current-limiting resistor for the LED, especially in systems running at low supply voltages such as 3.3V.

The phototransistor's breakdown voltage is also a very important parameter, because the device may have to withstand moderately high voltages (e.g. 24, 48V) when interfaced to a DC-to-DC converter ENABLE pin.

Finally, current transfer ratio describes the amount of current conducted through the phototransistor's collector vs. the amount of current used to drive the LED. The higher the current transfer ratio, the higher the optocoupler's drive capability for a given amount of LED current. Because the sink current from ispPAC-POWR1208's open collector outputs is limited (4mA at 0.4V saturation), a high current transfer ratio in the optocoupler is desirable because it maximizes the amount of current available to drive controlled circuitry. Nominal current transfer ratios for typical optocouplers range from 10% to 300%. For any given device, however, current transfer ratio is highly dependent on the amount of LED current and ambient temperature, and is usually specified in detail in the manufacturer's data sheet as functions of these variables.

For DC-to-DC converters with low (< 1-2 mA) ENABLE pin drive current requirements, the circuits in Figure 9 can be used to provide isolated control between the ispPAC-POWR1208 and the converter.

Figure 9. Positive (a) and Negative (b) Isolated Enable Circuits

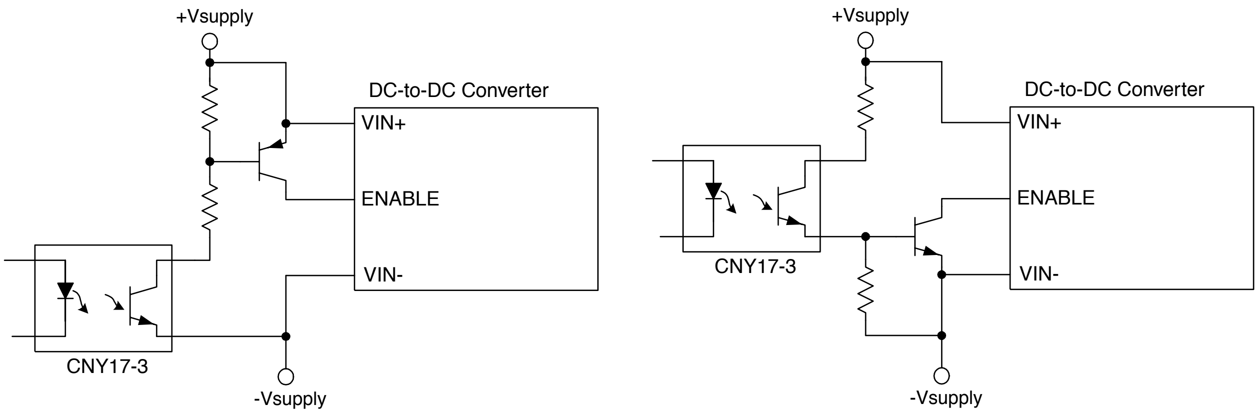


For both of these circuits, the optocoupler's LED will be turned on with approximately 4mA of forward current when the ispPAC-POWR1208's open drain output goes low. This will in turn on the optocoupler's phototransistor. The particular optocoupler shown here, the CNY17-3, typically provides greater than 100% current transfer ratio, therefore making it able to switch at least 4mA to the ENABLE pin. When the ispPAC-POWR1208's output goes low, the ENABLE line in Figure 9a is pulled to VIN+, and in Figure 9b, the ENABLE line is pulled to VIN-. The CNY17-3's high collector breakdown voltage (70V) makes it straightforward to interface to converters with high open-circuit voltages present at the ENABLE pin.

In cases where more current drive capability is needed than can be obtained from just an optocoupler, there are several alternatives that can be explored. The first is to use a Darlington-output optocoupler. These devices can offer current transfer ratios of more than 500%, because instead of using a simple phototransistor, they use a phototransistor wired into a second transistor in the Darlington configuration. The drawback to using this type of device, however, is that they have minimum on-state saturation voltages of 1.2V or more, which can limit their ability to pull an ENABLE line to either VIN+ or VIN-. Another option is to use a MOSFET-output optocoupler. While the behavior of a MOSFET-output optocoupler approximates that of an ideal switch to a better degree than a traditional phototransistor-based optocoupler, they tend to be considerably more expensive.

Another way to get increased output drive capability is to combine an optocoupler with an external transistor. Figure 10 shows how this can be done for both the cases where one needs to pull the converter's ENABLE line to VIN+ (Figure 10a) and VIN- (Figure 10b).

Figure 10. Isolated High-drive Pull-to-VIN+ (a) and Pull-to-VIN- (b) Interface Circuits



(a) **(b)**

In both of these circuits, when the optocoupler's LED is forward biased, it turns on the external transistor. The transistor's gain enables it to switch much more current than the optocoupler alone could. Additionally, in these circuit configurations, the external transistor can saturate to a very low (<0.2V) voltage, providing a more definitive ON state than a Darlington-output optocoupler would. Note however, that in these circuits, the optocoupler must have an output breakdown voltage greater than the converter's input power supply, and that the external transistor must have a breakdown voltage rating exceeding the voltage impressed across it by the converter's ENABLE pin.

Conclusion

The ispPAC-POWR1208 can be used to control modular DC-to-DC converters using its digital output pins. Because of the wide variety of input characteristics found in commercially available converters, a small amount of discrete interface circuitry often needs to be used to effectively connect the ispPAC-POWR1208 to the converter. This application note has shown several common cases of converter interfacing requirements, and the circuitry necessary to drive them.

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