PP41 Revised July 1996

INFORMATION FOR STANDARD USAGE
PD SERIES

The PD150 series DC-to-DC converters convert an unregulated DC voltage with an input voltage in a prescribed range, into a well regulated (steady) DC output voltage. The output voltage is isolated from the input voltage, protected from overloads, over-voltage and over-temperature, and is the correct DC source for most systems *if properly applied*.

In most applications PD150 series DC-to-DC converters are a superior replacement in existing designs due to their higher power, lower profile, and higher efficiency. Except where discussion specifically refers to the circuit or component values of the PD150 series, the information provided herein is applicable to most DC-to-DC converters from any manufacturer. The purpose of this Power Page is to assist the user in optimizing the system performance.

As with all complex electronic components, good fundamental engineering practices must be followed when selecting, installing and applying the PD150 series of DC-to-DC converters. The converter is typically one component in the power system distribution network. Improper application of the converter can result in poor regulation at the load, excessive noise at the load, crosstalk between circuits, system oscillation, and thermal problems. This Power Page suggests connections and components that should help design engineers avoid most of these problems.

Although most of the text in this Power Page addresses applications using PD150 converters, the discussion is equally suitable for Model PD300, a 300 watt DC-to-DC converter. Where applicable, the differences are highlighted in the application.

Basic Connections

To obtain the factory preset output voltage, connect the source DC power supply through a **fuse** to the input pins of the module, and connect the sense leads to the output leads and the output leads to the loads. Connection of the other pins of the module is not required for normal operation.

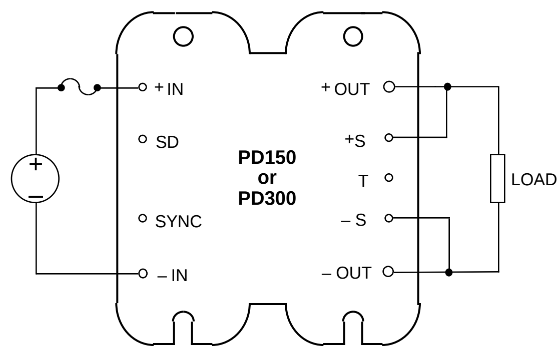

Figure 1. Basic Connection Schematic

Input Connections

In order to improve reliability, safety and performance, several components may be added to the input of the modules. Care should be taken to provide the correct number of components for optimum system performance without unnecessarily adding parts, and needlessly driving up the cost of the power system.

Table 1 lists transient suppressors, fuses and capacitor values for various input voltage options of the PD150 series DC-to-DC converters. These or equivalent components would ensure optimum performance of any DC-to-DC converter.

Transient Surge Suppressor

Transients in electrical circuits result from the sudden release of previously stored energy. Transients may occur either in repeatable fashion or as random impulses. In power supply circuits,

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Input Connections (Continued)

Partial Part Number	Nominal Input Voltage	Rated Transient Input Voltage (1 sec)	Transient Surge Suppressor (or equivalent)	Fuse Part Number (or equivalent)	Cap Value and Part Number (or equivalent)
PD150-300-	300V	450V	1.5KE440	PCC-3 (3 amp)	2.2µF, 450V, ECE-A2WU2R2
PD150-150-	150V	250V	1.5K250	PCE-5 (5 amp)	4.7µF, 250V, ECE-A2EU4R7
PD150-048-	48V	85V	1.5KE82	MCR-10 (10 amp)	22µF, 100V, ECE-A2AU220
PD150-024-	24V	45V	1.5KE39	ABC-12 (12 amp)	33µF, 50V, ECE-A1HU330

TABLE 1. Transient Input Voltage Ratings and Input Circuit Components

transients may be induced during power up, load changes, blown fuses or even lightning. Transient voltage ratings for the PD150 modules are listed in Table 1. Do not exceed the transient input voltage rating of the converter or permanent damage may occur. Table 1 lists the appropriate transient suppressors for each input voltage module. These parts are manufactured by General Instrument, and are able to absorb 1,500 watts of power for short durations. Figure 2 schematically shows the correct placement of the transient voltage suppressor device in the input circuit.

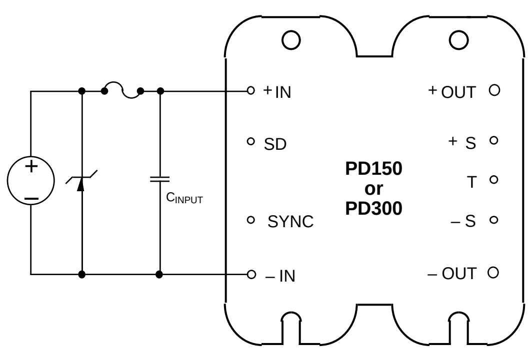

Figure 2. Input Circuit Components Schematic

Safety Considerations

Fuse: In order to meet safety requirements, and as a good general rule, module inputs should be fused. Fusing prevents a fault condition within the module from damaging input power sources, wires, printed circuit boards and connections. Faults on the output of the modules, such as load shorts or overloads will not cause the fuse to blow, since the modules are internally current limited and will automatically recover once the abnormal condition is removed.

Another important consideration in fuse selection is its ability to handle inrush current. When input voltage is first applied to the DC-to-DC converter, it must charge up the input capacitor (C_{INPUT}) as well as the capacitors internal to the converter which are connected to the input. Depending on the amount of capacitance, the input source impedance and the rate of rise of the input voltage, this current can approach 100 amps. If the application requires that the converter be turned ON and OFF frequently, the inrush current can have a significant adverse effect on the fuse's life. In order to make sure that the fuse does not fail prematurely, it is recommended that fuses shown in Table 1 (or equivalent) be used. The listed fuses are from Cooper Industries, Bussmann Division. They have a very high interrupting capacity (300A), which means

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the inrush and transient currents up to 300A will be tolerated without causing the fuse to blow or degrade. Figure 2 schematically shows the correct placement of the fuse in the input circuit.

The fuse should be inserted in the + IN Lead, **not** the – IN Lead. Opening of the – IN Lead (when the fuse blows) would cause the SYNC and SD (P option) or Gate IN and Gate OUT (V Option) pins to rise to the voltage of the + IN Lead, possibly causing damage to connected modules or devices.

For **Model PD300** recommended fuse for **24V input is ABC-20** a 20 ampere fuse. For all other options, fuses used for Model PD150 are suitable for Model PD300 as well.

Shock Hazard Prevention: In addition to fusing, safety agency compliance requires that the baseplate be grounded or made inaccessible, in order to avoid a potential shock hazard.

Capacitor for Stability: The DC-to-DC converters require an input source with low AC impedance. In applications where the input source impedance is greater than 0.5 x (Minimum Input Voltage)^2 / (Maximum Input Power) in order to avoid instability, an input capacitor is recommended. If there is a chance that the impedance is too great, mount a small electrolytic capacitor physically close to the voltage input pins of the module. This will compensate for long, inductive connections from the input source to the converter, or high impedance from the input source. Figure 2 shows the capacitor connection.

The minimum value of the input capacitor should be:

$$C_{INPUT} = \frac{400}{V_{IN(Min.)}} \mu F$$

Example: For a PD150-300-12-PI

$V_{IN(Min.)}$ = 200 Vdc, so C_{INPUT} = 2µF.

Of course, the voltage rating of C_{INPUT} should exceed the maximum input voltage of the converter.

Table 1 lists appropriate capacitors from Panasonic, when the operating temperature range is between –45°C and +85°C.

Input Reverse Voltage Protections: Often it is important to protect the converter in case the input lines are inadvertently connected to the wrong polarity. The module has an internal reverse shunt diode across the + IN and – IN terminals, by virtue of the body diode in the main switching MOSFET (Figure 3). If the module is connected with a fuse in series with the positive input, the module is reverse input voltage protected, since the fuse will blow prior to any module damage.

If it is not acceptable to allow the fuse to blow following application of a reverse polarity input, the converter can be protected against reverse input voltages by placing a diode in series with the positive input (Figure 4). Note that this will decrease the efficiency of the power system, since there will be additional voltage drop across the series diode.

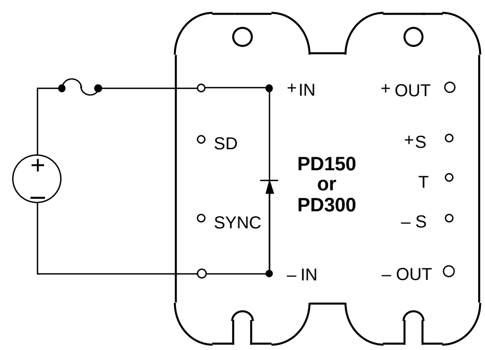

Figure 3. Internal Reverse Input Protection

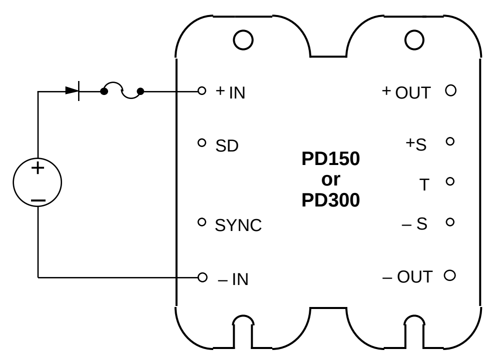

Figure 4. External Reverse Input Protection

Output Connections

Maintaining Regulation at the Load: If the resistance of the wire, printed circuit board runs or connectors used to connect a converter to the system components is too high, excessive voltage drops will result, which in turn will degrade converter performance. For example, a simple power supply application is that of a single +5V output power converter module connected to a single 15A load, which is one foot wire distance from the converter. In this example, #14 gauge wire is used for the 24-inch round trip distance between the load and the converter module. Ignoring contact resistance, there is 5.05mΩ of resistance in the conductor. With 15A running through the wire, the voltage drop is 75mV, or 1.5% of the total output value. For higher output current (up to 50A with Model PD300) the problem is still worse.

If possible, shorten the distance between the converter and the load. If not possible, use larger wire size for the load lines. Table 2 gives approximate resistance per foot for the copper wire of various AWG sizes. Also, printed circuit board traces should have short lengths and large width or cross-sectional area. Whenever possible, parallel lines, paths and/or connections should be used to keep the voltage drops to minimum.

AWG NO.	mΩ/Foot	AWG NO.	mΩ/Foot
10	1.00	21	12.8
11	1.26	22	16.2
12	1.59	23	20.3
13	2.01	24	25.7
14	2.52	25	32.4
15	3.18	26	41.0
16	4.02	27	51.4
17	5.05	28	65.2
18	6.39	29	81.2
19	8.05	30	103.7
20	10.13	31	140.0

Table 2 AWG Sizes and Resistance

Obviously, any connections made to the power distribution bus present a similar problem. Poor connections (such as micro-cracking around solder joints) can cause serious problems like arcing and excessive heat. Contact resistance must be minimized. Proper workmanship standards must be followed to ensure reliable solder joints when soldering to the module and loads. If sockets are used to connect to the pins, they should be carefully cleaned to remove corrosion.

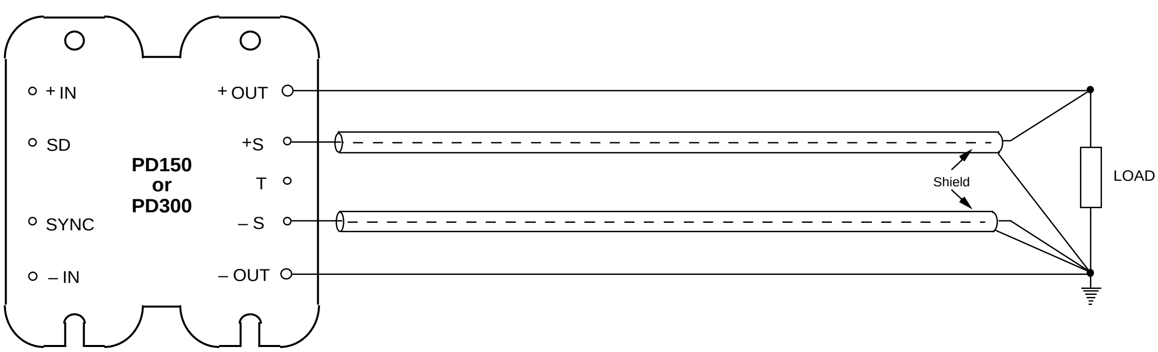

Figure 5. Remote Sensing Connections (using separate shields)

Remote Sensing: To solve the problem of preserving the load regulation specification right at the load, the PD150 has a feature known as REMOTE SENSING, where the connection to the internal regulator is made by special sense leads run directly to the load. By sensing the voltage directly across the load, the voltage drop in the load lines is compensated.

Connection of the sense leads is shown in Figures 5 and 6. There is one lead for each output terminal, designated as +S and –S. Compared to the load leads, the sense leads carry very low current and are usually shielded as shown to prevent noise pickup by the regulation circuit of the power supply. The current fed back from the load will adjust the output of the converter to keep the voltage constant at the load. The shielding on the sense leads is used to prevent the noise pick-up and is needed only if the load is more than three (3) feet from the DC-to-DC converter or in a highly noisy environment. Two separate shields for each sense lead (Figure 5) or a single shield for both sense leads (Figure 6) may be used. The PD150 can compensate for load conductor drops of up to 0.5V by producing a higher output voltage at the supply terminals, so that the voltage at the load is precisely the correct value. If the voltage drop across the output lines is greater than 0.5V, the remote sense network will not be able to compensate for it.

Remember that the output voltage between +OUT and -OUT must not exceed 110% of nominal or the over-voltage protect circuit may shut down the module. Also, do not exceed 0.25V drop between –OUT and –S. Although exceeding 0.25V will not damage the module, it may reduce the output voltage (the PD150 Sense Lead Protection Circuit may become active).

Sense Lead Protection Circuit: In order to maintain regulation in the event that the sense leads are not connected to their respective power output terminals, a resistor internal to the PD150 connects the sense leads to their respective output terminals. Without the internal resistors, the output voltage would increase to the point of over-voltage protection and the PD150 would shut down, in case a user forgot to connect the sense leads externally or the connection was broken.

These two internal resistors are 20Ω, 1/4W resistors, which means that only 2.24V can be put across them before their power rating is exceeded. If the user accidentally allows greater than 2.24V differential between the sense lead and its respective output terminal, the resistor may be damaged. Unfortunately, this can happen very easily.

An example: The sense leads are connected directly across the load (to utilize the PD150 remote sense feature) and the power leads are also connected across the loads, using separate, more robust wires. If the – OUT power connection becomes damaged, but the

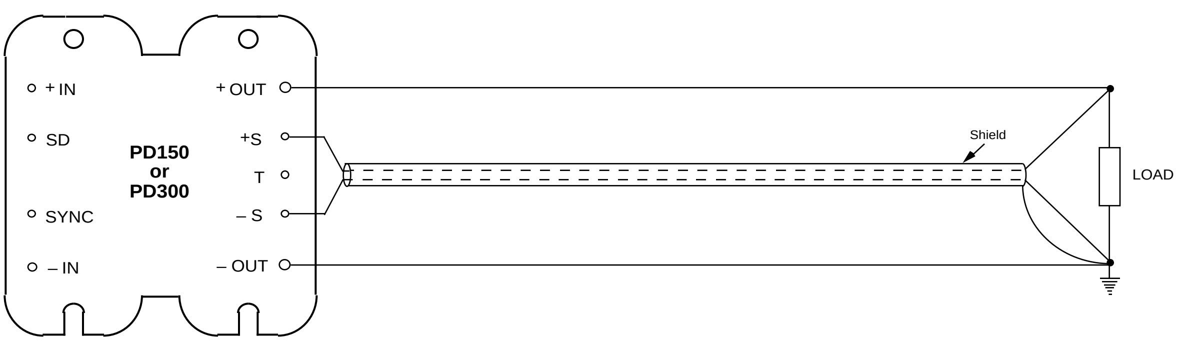

Figure 6. Remote Sensing Connections
(using single shield)

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+ OUT power and sense connections remain intact, the – S lead is pulled up toward the + OUT voltage because the load is still connected to the + OUT, and usually has a resistance much lower than the internal 20Ω resistor. Thus the internal 20Ω resistor is destroyed.

The PD150 series DC-to-DC converters employ an innovative circuit to protect itself from such an occurance. Both negative Sense (– S) and positive Sense (+ S) use independent circuits to monitor these voltages across two (2) sense resistors. When either of these voltages exceed a predetermined value, the PD150 converter is shut down.

Also note that in the PD150 series there is no change in its current limit set point, regardless of voltage drops on the output.

During operation, if the output leads are disconnected before the sense leads, the full load current will try to flow through the sense leads. This will force the converter to increase the output voltage and the over-voltage protection (OVP), and/or sense lead protection circuit will shut down the converter.

If the remote sense is not used, then the sense leads should be shorted to their respective output leads, and the supply will operate in its normal manner with local sensing.

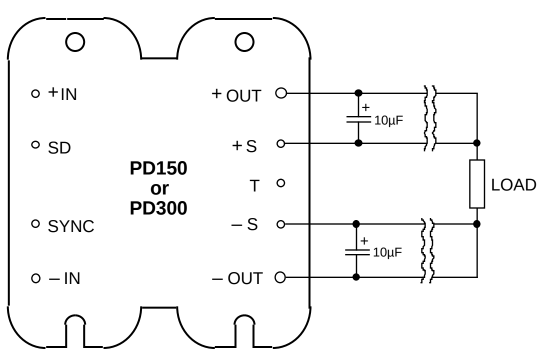

Figure 7. Long-Load Connection

For applications where the load is too far away (12 feet or more) from the power supply, the inductance from long lines together with capacitance at the load could cause instability. This can be compensated for by using two by-pass tantalum capacitors (approximately 10µF) one between + OUT and + S pins and second between – OUT and – S pins (Figure 7). Also, the sense leads should be shielded as shown in Figure 5 or Figure 6.

Output Voltage Trimming: The DC output voltage of the PD150 series converters can be adjusted by using the trim pin "T." This is accomplished by simply adjusting the internal reference voltage, which then changes the output voltage proportionally. The output voltage can be changed by any of several methods.

For more details ask for

POWER PAGE

PP42, Output Voltage Trimming

This pin "T" may be safely left floating (no connection) if factory preset voltage is acceptable for your application.

Remote ON / OFF Function: For applications where conserving power is important, e.g., battery-powered equipment or applications where inrush currents are high (applications involving high-powered pulsed loads), the remote ON / OFF function is extremely useful. PD150 series DC-to-DC converters have an SD pin (option P) or GATE-IN pin (Option V), which may be used to turn the module ON or OFF remotely. When this pin is left floating (open collector), the module is turned ON. When it is held low (2V @ 4mA), the module is turned OFF.

Figure 8 shows a simple module ON/OFF schematic. Note that SD (Gate IN) pin is referenced to – IN. If the turn off signal is referenced to a different return, an opto-isolator may be required. Another possible method for controlling the ON/OFF pin is a relay connected between SD (Gate IN) pin and – IN, which could be operated remotely.

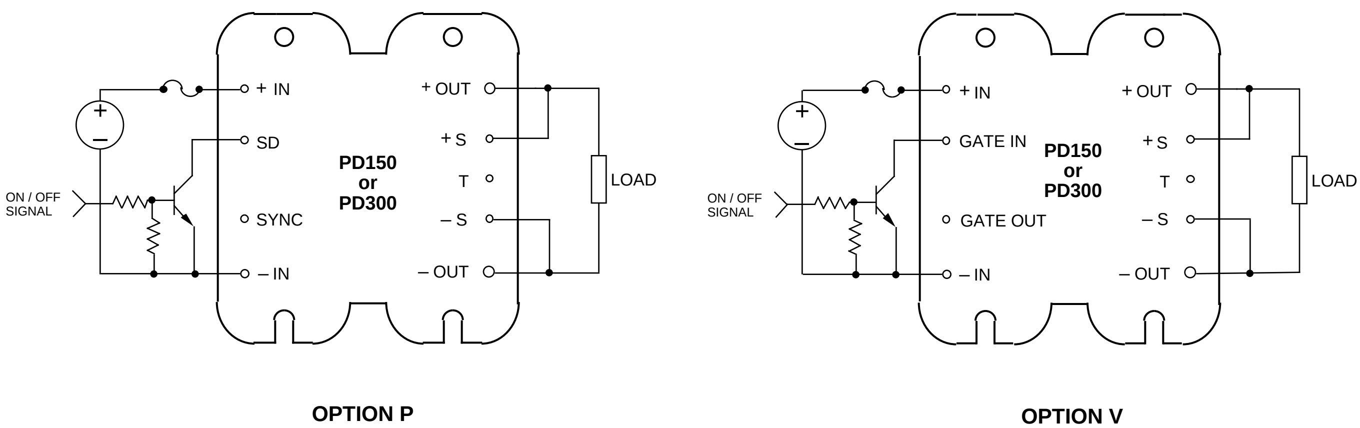

Figure 8. Module On / Off Schematic

As this pin is also used for parallel operation, no external pull-up resistors should be used to program the converter to the ON state. Use only open-collector, open-drain or open switch contacts which transition from a high impedance to a low impedance when the converter is programmed to the OFF state.

Thermal Considerations: Keep the temperature of the baseplate at 100°C or less, as measured on the middle slot of the module (positive pin side). Temperature should be measured under worst case load and highest ambient temperature conditions. Heat is generated within the module due to losses caused by the power processing. The power dissipated in each module is the Input power minus the Output power. Heat is removed through the flat metal baseplate of the module. The baseplate is electrically isolated from, but thermally closely coupled to, all internal heat dissipating components. Heat is removed from the baseplate by means of conduction and/or convection.

With no heatsinking and no fan blowing on the unit, the modules will output up to 50 watts at 25°C ambient temperature. To allow for increased output power, air may be forced over the module or the module should be mounted to a heatsink or other heat conducting member such as the chassis. When mounting the baseplate of the module to a heatsink or chassis, thermal compound or a heat conducting pad such as Grafoil® should be used. Precut, predrilled heatsinks and Grafoil® pads are available from Thermalloy at (214)243-4321.

Mechanical Considerations: If attachment of the baseplate to a heatsink is required, use four #6 machine screws along with Belville washers. Lightly finger-tighten all screws, and then torque the screws to 5-7 inch lbs. The mounting surface should be flat (0.01" per inch maximum) and smooth, so that unnecessary tension is not placed on the module while it is tightened to the heatsink.

When more than one module is being mounted to the same heatsink, they should be mounted to the heatsink prior to securing the PC board to the module pins, to allow for mechanical misalignment. If sockets are needed to attach the pins to the PC board, they are available from Concord at (212)777-6571.

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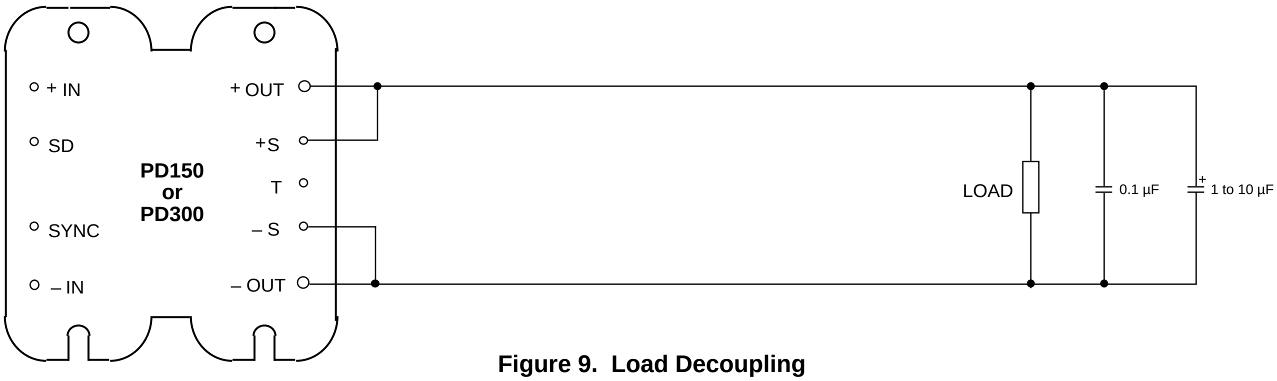

Figure 9. Load Decoupling

Bypassing and Decoupling: Bypassing and decoupling means adding filter components to reduce noise. Just as all power supplies have some output resistance and inductance, the power distribution leads do as well. Digital and high speed analog circuits may generate noise spikes across the inductance of the load lines.

Figure 9 depicts this type of load decoupling circuit, which serves to minimize the resonant effects of the series line impedance with stray capacitance and the effects of rapidly changing load currents with series inductance. For most applications, a 0.1µF ceramic capacitor in parallel with a 1 to 10µF tantalum capacitor connected across the load terminals is sufficient to provide effective decoupling. In effect, this decoupling creates a medium and high frequency bypass, which help in preventing cross-talk between different loads.

When bypassing analog and digital circuits individually, it is important to use the bypass capacitors close to each signal current loop by the shortest possible path rather than just placing a capacitor close to the load. Figure 10 shows the correct way of connecting the bypass capacitor in an analog circuit. Note that the bypass capacitor is using the shortest and most direct signal path with the capacitor going directly from the power terminal at the circuit to the load connection point common.

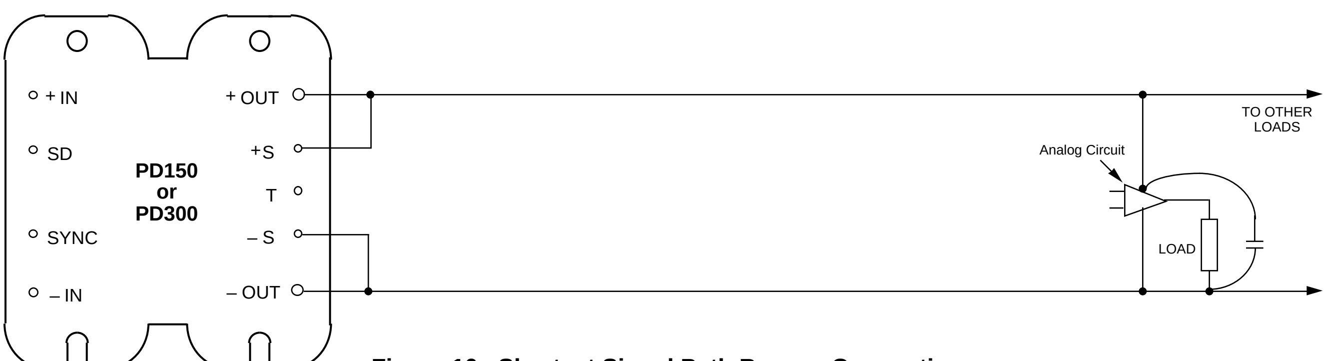

Figure 10. Shortest Signal Path Bypass Connection

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