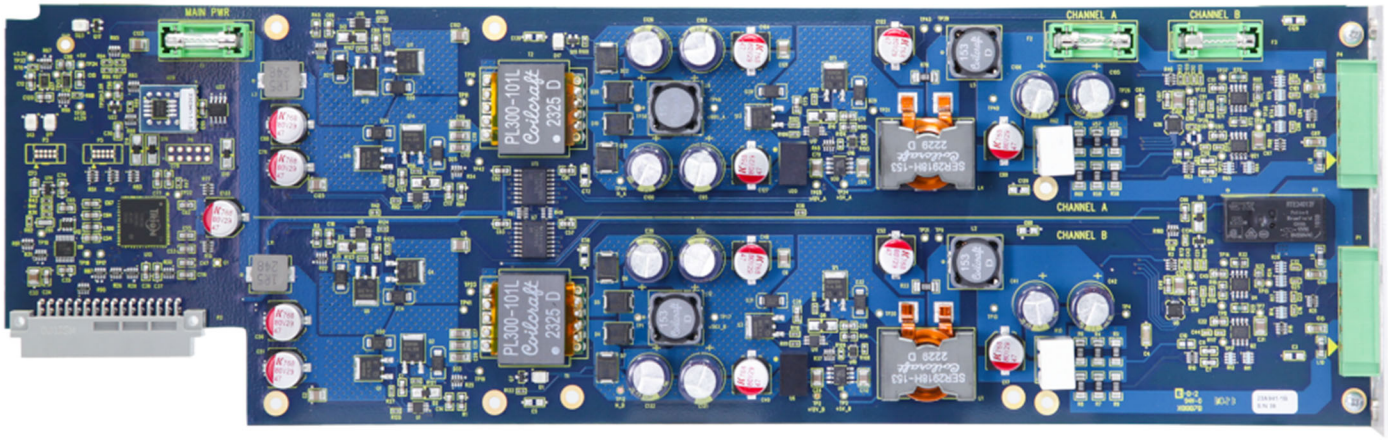
HIGHLAND TECHNOLOGY

Model P941

Dual Isolated DC Power Supply



P940

Modular power system

a Highland Technology innovation

Technical Manual

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Table of Contents

1 *Introduction*

The P941 is a dual channel isolated DC power supply module for the P940 modular power system. Each of the channels is galvanically isolated and can provide up to 48V/6A/160W.

As a part of the P940 system, the P941 is easily synchronized with other P941s to generate tracking power sequences, or with any other P940 module, enabling system architects to build up whatever power and simulation environment they may require.

Features include:

- Two independent, isolated DC power supply channels
- Accurate, low-noise DC power
- Programmable voltage setpoints and limits
- Programmable slew rate control
- Programmable current limits
- Remote voltage sensing for wire voltage drop compensation
- Real-time signal measurement capabilities for voltage, current, and instantaneous power
- Integrated SCPI command set with other P940 modules, available over Ethernet and USB

P941 plug-in modules installed in P940 Modular Power System

2 *Specifications*

FUNCTION	Dual channel DC supply
SIZE	1 P940 slot
VOLTAGE OUTPUT (PER CHANNEL)	0 - 48 V (programmable)
CURRENT OUTPUT (PER CHANNEL)	0 - 6 A (programmable)
POWER OUTPUT (PER CHANNEL)	0 - 160 W
VOLTAGE SLEW RATE	1 V/ms max. (programmable)
VOLTAGE PRECISION	10 mV
CURRENT PRECISION	10 mA
VOLTAGE ACCURACY	±1%
CURRENT ACCURACY	±1%
VOLTAGE SETTLING TIME	100 µs
MAXIMUM REMOTE SENSE WIRING DROP	2V

3 *Hardware*

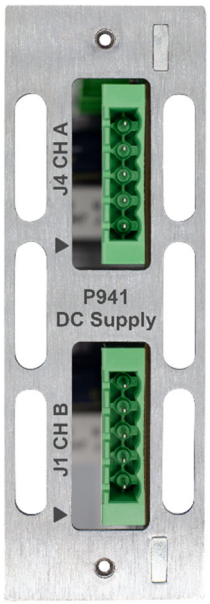
3.1 *Installation*

The P941 can be installed in any slot of a P940 chassis. Please follow the installation instructions in the P940 manual.

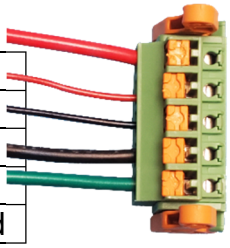
When powered off, a P941 can be moved easily from one P940 system to another. This allows systems to be dynamically configured as desired.

⚠ WARNING: Do not attempt to open the P940 chassis or perform any operations on an open P940 chassis with the power on. Module damage or operator injury may occur.

3.2 *Connector Pinout*



The P941 uses two five-pin 0.200” pitch connectors on the rear panel; the upper is for channel A and the lower for channel B. The pinout is identical for both connectors:



5	Top	V+
4		S+
3		S-
2		V-
1	Bottom	Chassis Ground

The mating connectors are discrete-wire connectors that accept AWG12-AWG24 wire. Two of these connectors are provided with each P941, and additional ones can be purchased directly through Highland Technology as J94-1 or independently as a Phoenix Contact 1808912 or equivalent.

3.3 *Front-Panel Monitors*

Voltages and currents present on the P941 connectors can be brought out to the P940 monitors for real-time observation, selecting their routing via the front-panel interface or ASCII commands. When observing P941 signals, the monitors output 1V per 20V for voltage signals and 1V per 2A for current signals.

If setting this via ASCII commands (see **`SOURce:ROUTe`** in the main P940 manual), the available sources for a P941 in slot *N* are:

Measurement	Indicator	Front Panel Display Text
Channel A Output Voltage	**slotn-a-voltage-output**	N:Volt Out A
Channel A Remote Sense Voltage	**slotn-a-voltage-rsense**	N:Volt RS A
Channel A Output Current	**slotn-a-current**	N:Current B
Channel B Output Voltage	**slotn-b-voltage-output**	N:Volt Out B
Channel B Remote Sense Voltage	**slotn-b-voltage-rsense**	N:Volt RS B
Channel B Output Current	**slotn-b-current**	N:Current B

Therefore, given a P941 in P940 slot 6, to send the channel B output voltage and current to front-panel monitors C and D respectively the commands would be:

```
SOUR:ROUT slot6-b-voltage-output,@C
SOUR:ROUT slot6-b-current,@D
```

Following this, the channel C and D monitor displays on the front panel would read:

		6:Volt Out B	6:Current B

4 *Instrument Behavior*

Throughout this section, ASCII commands used to perform relevant tasks are referenced. Many of these functions can also be performed using the P940 front panel and through the P940 web interface.

For more details about referenced commands, see *5.2 List of ASCII Commands*. Note that applying changes to channel operating parameters requires the use of the **`SYST:STROBE`** command; see *5.1 ASCII Command Interface*.

4.1 *Channels*

The P941 is composed of two independent power supplies, channels A and B, each able to deliver its rated maximum power. These two supplies are electrically isolated from one another and chassis ground and are independently controllable. The core function of a P941 channel is to act as a programmable voltage source, outputting the requested voltage on the V+ and V- pins for the channel; these two connector pins together constitute the 'output' of a channel and are intended to be connected to a load.

The power-on default state of the P941 has both channels disabled. In the disabled state, channels present a high-impedance output. Channels must be enabled using the front-panel or the **`SLOT<n>:OUTPut`** command to produce any voltage, including a low-impedance zero volts. It is worth noting that 'high impedance' does not refer to a completely open circuit presented at the output, but rather a non-driven output voltage. Therefore, setting a channel to high impedance (output disabled) will very slowly discharge the output voltage of a channel.

There are a couple of scenarios in which a channel might not act exactly as expected. These are:

- When a channel is slewing to a lower voltage or excessive power is otherwise fed into the P941 (with a large capacitive load, for example), a channel will limit its absorption of power after an initial absorption buffer. This can make the output look transiently as though it is disobeying a slew downward command. To prevent this, the connected load should not attempt to back feed power into the P941 at the requested voltage slew limit (too much load capacitance combined with too fast a voltage slew rate can cause this phenomenon).
- An over-voltage event on the output pins of the P941 (voltages exceeding 52V) will cause the channel to become high impedance until the load discharges the excessive voltage. Because of this behavior, the P941 will not self-correct extreme over-voltage events; a connected load typically fulfills this function. This is generally not of concern if a P941 is being used as a power supply but is notable behavior.
- A channel may act like a low-impedance short if an external negative voltage is applied to the channel's output pins, even if the channel is disabled. Connecting channel outputs to an externally sourced negative voltage can damage a channel and is not recommended!

4.2 *Voltage Source*

Output voltages must always be positive, with V+ of higher voltage than V- on a channel's connector. A user-set output of low impedance 0V is allowed, however negative voltages are disallowed.

However, because each channel is isolated, it is possible to create a negative voltage output by simply reversing the load's connection polarity: by connecting V+ to the load's negative connection and V- to the load's positive connection, the voltage observed by the load is negative.

Output voltages can be requested using the **SLOT<n>:VOLTage[:LIMit]** command. An output voltage set request may be rejected because the active current limit would cause the new limits to exceed the output power of a P941 channel; see *4.7 Channel Power Limit*.

4.3 *Voltage Slew*

Channels may be programmed to target a voltage slew-rate; whenever the output voltage rises or falls, given that the output is not being current-limited, a channel will linearly slew the output voltage from its current value to the user's voltage setpoint. This may be used to soft start loads or to generate a preferred voltage profile, for instance. The voltage slew rate is programmed on a per-channel basis using the **SLOT<n>:VOLTage:SLEW** command.

The P941 also monitors both voltage and current on the channels. This information is available by querying **SLOT<n>:SENSe:VOLTage?** and **SLOT<n>:SENSe:CURRent?** respectively.

Note that the voltage slew control applies to all conditions where the P941 is not currently operating at its target voltage, even transient conditions. For example, assume that the voltage setpoint is 30V, and the voltage slew rate is set to 1V/ms. If the output is currently 30V and is then shorted, forcing the output voltage to be 0V, when the short is disconnected the output voltage will slew from 0V to 30V over the course of 30ms.

Furthermore, it is important to note that the P941 is not intended to act as a load. Therefore, while the P941 can enforce rising slew rates, it cannot guarantee falling slew rates because the P941 is not designed to absorb power from a connected load. This may occur when loading the P941 with a large capacitance in parallel with a channel's outputs.

4.4 *Remote Sense*

With substantial wiring resistance or high load currents, the voltage seen by a load can be substantially lower than the voltage sourced by the P941 at its connector. To compensate for this, the P941 includes remote sense functionality.

To use remote sense, connections to the S+ and S- pins are required in addition to the V+ and V- pins which transmit load power. For remote sense to work properly, the sense wires must be connected to the load with separate wires from the power output connection (four wires in total), and the sense wires must be connected to the output wires only at the load. The remote sense connections are high-impedance and can therefore be of much thinner gauge than the load's power-supplying wires. Connecting the remote sense wires in the incorrect polarity or exposing them to negative voltages will *not* damage the P941.

Remote sense can be activated on a channel from either the front-panel or by using the **SLOT<n>:RSENse** command.

If the voltage observed by the remote sense pins of a channel's connector falls outside the allowable operating range of remote sense functionality, the channel will simply stop utilizing remote sense and

revert to operating as though remote sense were disabled. The channel's remote sense functionality will re-activate immediately, automatically once remote sense measurements are seen as operable by the P941. For remote sense to be operable, all of the following conditions must be true:

- The remote sense voltage does not exceed the connector output voltage.
- The remote sense voltage is no lower than 2V below the connector output voltage.
- The remote sense voltage is greater than 0V.

While remote sense is active on a given channel, the default **`SLOT<n>:SENSe:VOLTage?`** query will report the remote sense voltage, rather than the output voltage. Independent queries of the remote sense and output voltages are always available regardless of mode via the **`SLOT<n>:SENSe:VOLTage:OUTPut?`** and **`SLOT<n>:SENSe:VOLTage:RSENse?`** commands.

4.5 *Current Limiting*

P941 channels feature a programmable current limit, which can be used to protect connected equipment from drawing more current than expected. If a connected load attempts to draw current exceeding the programmed current limit, the P941 will stop providing power to the load until the measured load current no longer exceeds the programmed limit. While current limiting, a channel behaves similarly to a constant-current power supply. Note, however, that even brief, instantaneous current limit overshoots will cause a channel to current limit. Combined with the voltage slew rate limiting functionality of the P941, this can cause foldback current limiting behavior with some loads at low voltages.

The current limit is set using the **`SLOT<n>:CURRent[:LIMit]`** command. If a channel's output is less than the requested value due to current limit, the **`SLOT<n>:LIMmode?`** query will report CURR. During typical operation, where the output is constrained by the user-set voltage, it will report VOLT.

4.6 *Dropout*

A channel may be programmed to become high-impedance for a user-specified duration upon the next strobe received by the P941. This can be used to simulate the effects of a misbehaving power supply, faulty or broken cables, or even to sequence channels' output-enables if desired. This can be programmed using the **`SLOT<n>:OUTPut:DROP`** command.

While a channel's drop-out behavior has a time resolution of 20 nanoseconds, the P941 relies on a connected load to discharge a channel's output. Therefore, this feature is most practically used on the milliseconds and beyond timescale.

4.7 *Channel Power Limit*

The power limit of a single P941 channel is 160W, which is less than the product of the maximum voltage and current limits. The P941 supports two modes to enforce this limit: auto-current mode and manual current mode.

In auto-current mode, a P941 sets the current limit to the maximum value (as limited by the power limit) when ia new voltage limit is set with the voltage limit command (**SLOT<n>:VOLTage[:LIMit]**). This mode is enabled when the P941 powers on.

In manual current mode, voltage and current are controlled independently. A P941 enforces the power limit by rejecting any voltage or current limit command if the new voltage-current limit combination would exceed the channel power limit. In this mode, it may be necessary to decrease voltage or current before increasing the other. A general method to set an arbitrary valid voltage-current combination atomically is to set both to 0 before setting the desired values:

```
SLOT0:VOLT:LIM 0, @A
SLOT0:CURR:LIM 0, @A
SLOT0:VOLT:LIM 40, @A
SLOT0:CURR:LIM 4, @A
SYST:STRB 1                # Propagate final values
```

A P941 can be swtiched between auto-current and manual current mode with **SLOT<n>:CURRent:AUTO**. Auto-current mode is also disabled if a current is explicitly set with **SLOT<n>:CURRent[:LIMit]**.

5 *Software Interface*

The primary interface of a P940 system is the ASCII command/reply interface, over either Ethernet or USB. Descriptions of this interface and its configuration can be found in the P940 system manual. The P941 may also be controlled by the P940 front panel and through the P940 web interface.

5.1 *ASCII Command Interface*

5.1.1 *Conventions*

5.1.1.1 *Channel Arguments*

P941 channel arguments begin with the `@` character, followed by the channel letter (A or B) or the channel index (0 or 1, respectively). For example, `@A` and `@0` both indicate channel A.

5.1.1.2 *Integer Arguments*

Integer arguments conform to C-language formatting, which is an optional sign character followed by

- `0x` or `0X`, to be parsed as hexadecimal
- Otherwise, `0` to be parsed as octal
- Otherwise, to be parsed as decimal

5.1.1.3 *Float Arguments*

Floating-point arguments conform to C-language formatting, which is an optional sign character, a sequence of digits with an optional decimal point, and optional exponent.

5.1.1.4 *Boolean Arguments*

Boolean arguments must be `0` for false or `1` for true.

5.1.1.5 *Strobed Parameters*

Most parameters are strobed parameters; updates to these parameters must be committed by having the P940 send a strobe to the affected module. This allows multiple parameters to become effective simultaneously, whether within a single channel, across all channels of a module, or across multiple modules.

Generally, SCPI commands related to strobed parameters are found in pairs, which are nearly, but not completely, symmetrical. Each pair consists of a command that sets the pre-strobe (pending) parameter value and a query that gets the post-strobe (effective) parameter value. The query will not be guaranteed to return the value from a successful command until a strobe to the targeted module has been performed.

The following example illustrates the two-step process of setting a strobed parameter.

```
SLOT0:OUTPut? @A          # Get initial value
0
SLOT0:OUTPut 1,@A         # First, set pending value
SLOT0:OUTPut? @A          # Effective value has not changed
0
SYST:STRB 0x1             # Second, propagate pending values
SLOT0:OUTPut? @A          # Effective value has changed
1
```

5.1.2 *P941 Strobed Parameters*

The following P941 parameters are strobed parameters.

Parameter	Command (sets pre-strobe value)	Query (gets post-strobe value)
Channel Voltage Limit	**SLOT<n>:VOLTage[:LIMit]**	**SLOT<n>:VOLTage[:LIMit]?**
Channel Current Limit	**SLOT<n>:CURRent[:LIMit]**	**SLOT<n>:CURRent[:LIMit]?**
Channel Output Enable	**SLOT<n>:OUTPut[:STATe]**	**SLOT<n>:OUTPut[:STATe]?**
Channel Remote Sense Enable	**SLOT<n>:RSENse**	**SLOT<n>:RSENse?**
Channel Output Drop	**SLOT<n>:OUTPut:DROP**	**SLOT<n>:OUTPut:DROP?**
Channel Voltage Slew	**SLOT<n>:VOLTage:SLEW**	**SLOT<n>:VOLTage:SLEW?**
Channel Auto Current*	**SLOT<n>:CURRent:AUTO**	**N/A**

* Enabling auto-current mode may pend a change to the current limit, and a strobe is necessary to make that current limit effective. The strobe isn't necessary to make auto-current mode effective for later **SLOT<n>:VOLTage[:LIMit]** commands.

5.1.3 *Example*

For a P941 in P940 slot 0, the following sequence will configure channel A as a 28.5V supply limited to 5A, with a slew no faster than 10 volts per second from the initial output voltage of 0.0V to the final output voltage of 28.5V.

```
SLOT0:OUTP 1,@A
SLOT0:CURR:LIM 5,@A
SLOT0:VOLT:LIM 28.5,@A
SLOT0:VOLT:SLEW 10,@A
SLOT0:SENS:VOLT? @A
0.00
SYST:STROBE 0x1
SLOT0:SENS:VOLT? @A
8.70
SLOT0:SENS:VOLT? @A
19.30
SLOT0:SENS:VOLT? @A
28.50
SLOT0:SENS:CURR? @A
2.14
```

5.2 *List of ASCII Commands*

The P941-specific commands are listed in the following sections. The P941 also supports all commands listed as *General Module Commands* in the P940 system manual.

5.2.1 *OUTPut Commands*

SLOT<n>:OUTPut[:STATe] <boolean>,@<channel>

SLOT<n>:OUTPut[:STATe]? @<channel>

As a command, sets whether the channel is enabled. A strobe on the slot must occur to effect this change.

As a query, returns whether the channel is enabled.

When enabled, a channel drives a low-impedance voltage to the channel's output pins. When disabled, a channel provides a high impedance connection. The P941 powers on with both channels disabled.

SLOT<n>:OUTPut:DROP <msec>,@<channel>

SLOT<n>:OUTPut:DROP? @<channel>

As a command, requests the channel dropout (high-impedance output) for a fixed amount of time between 0 and 10 seconds (10000 milliseconds). A strobe on the slot must occur for the dropout to take effect. If a dropout is ongoing, a new dropout request overwrites the active one. If a dropout is currently in progress, setting the dropout duration will supersede the existing remaining duration. Thus, setting the duration to 0-milliseconds will clear and deactivate the active dropout.

As a query, returns the number of milliseconds remaining in an on-going dropout, or 0 if the channel is not currently in dropout.

5.2.2 *VOLTage Commands*

SLOT<n>:VOLTage[:LIMit] <volts>,@<channel>

SLOT<n>:VOLTage[:LIMit]? @<channel>

As a command, sets the voltage limit, in Volts. If auto-current mode is enabled, then the current limit will be automatically adjusted. A strobe on the slot must occur to effect these changes.

As a query, returns the voltage limit, in Volts.

When a channel is operating voltage-limited, the voltage limit may also be thought of as a voltage target.

SLOT<n>:VOLTage:SLEW <volts_per_second>,@<channel>

SLOT<n>:VOLTage:SLEW? @<channel>

As a command, sets the voltage slew rate limit, in Volts/second. A strobe on the slot must occur to effect this change.

As a query, returns the voltage slew rate limit, in Volts/second.

SLOT<n>:VOLTage:MAXimum <volts>,@<channel>

SLOT<n>:VOLTage:MAXimum? @<channel>

As a command, sets the software-enforced maximum voltage limit, in Volts. Requests for voltage limits above this value will cause a **-221,"Settings conflict"** error.

As a query, returns the software-enforced maximum voltage limit, in Volts.

5.2.3 *CURRent Commands*

SLOT<n>:CURRent[:LIMit] <amps>,@<channel>

SLOT<n>:CURRent[:LIMit]? @<channel>

As a command, sets the current limit, in Amps. A strobe on the slot must occur to effect this change.

As a query, returns the current limit, in Amps.

SLOT<n>:CURRent:AUTO <boolean>,@<channel>

SLOT<n>:CURRent:AUTO? @<channel>

As a command, sets whether auto-current mode is enabled. Enabling auto-current mode will change the current limit to the maximum value, as determined by the power limit and pre-strobe voltage limit. A strobe on the slot must occur to effect this change.

As a query, returns whether auto-current mode is enabled.

5.2.4 *SENSe Commands*

SLOT<n>:SENSe:VOLTage[:AUTO]? @<channel>

Returns the output voltage if remote sense is disabled or the remote sense voltage if remote sense is enabled. Returned value is in Volts.

SLOT<n>:SENSe:VOLTage:OUTPut? @<channel>

Returns the output voltage. Returned value is in Volts.

SLOT<n>:SENSe:VOLTage:RSENse? @<channel>

Returns the remote sense voltage. Returned value is in Volts.

SLOT<n>:SENSe:CURRent? @<channel>

Returns the output current. Returned value is in Amps.

5.2.5 *Uncategorized Commands*

SLOT<n>:LIMmode? @<channel>

Returns **VOLT** if the output is currently limited by the voltage limit, **CURR** if the output is limited by the current limit, or **NONE** if the output is disabled.

SLOT<n>:RSENse <boolean>,@<channel>

SLOT<n>:RSENse? @<channel>

As a command, sets whether voltage remote sense is enabled. A strobe on the slot must occur to effect this change.

As a query, returns whether voltage remote sense is enabled.

6 *Versions*

P941-1: Dual Isolated DC Power Supply Plug-In Module for P940 Modular Power System

7 *Customization*

Consult factory for information about additional custom versions.

8 *Revision History*

8.1 *Hardware Revision History*

23A941-1B	July 2023
	Initial release

8.2 *Firmware Revision History*

23C941-1-1.0	July 2023
	Initial release

9 *Accessories*

J94-1: Phoenix Contact mating connector (2 furnished with purchase)