Auto-Track™ voltage sequencing simplifies simultaneous power-up and power-down

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Plug-in Power Solutions

Auto-Track Sequencing is a feature available on select power modules in the Texas Instruments (TI) Plug-in Power Solutions family. The feature is designed to simplify the amount of external circuitry required to configure the modules for simultaneous power-up and power-down supply voltage sequencing.

The ability to sequence the power-up of multiple supply voltages in complex logic and mixed-signal applications has become an important requirement for power-system designers. This is because most VLSI logic devices— including DSPs, ASICs, FPGAs, and microprocessors— now require at least two supply voltages. This usually includes a low voltage to power a high-speed logic core; a standard logic voltage to power the input/output (I/O) interface; and supporting system devices such as memory, data converters, and I/O ports.

The power-up sequencing techniques can be implemented with a number of techniques.[1, 2] The implementation of any one method depends largely on the time and/or voltage restrictions that are allowed between the two supply voltages during both power-up and power-down. The restrictions are imposed on the power-system designer by the respective VLSI device manufacturers. Failure to meet the restrictions can result in undue voltage stress and even "latch up" between the VLSI device's I/O port and a supporting peripheral. This can result in immediate, if not latent, damage to the VLSI device. In the latter case the long-term reliability of the affected device may be compromised.[2]

Simultaneous power-up

One of the most widely used power-up sequencing methods is the simultaneous power-up of the circuit supply voltages. See Figure 1. The core and I/O power-supply voltages must begin rising together at the same rate. The two voltages continue to rise until the core supply reaches its nominal regulation voltage. The higher I/O voltage then continues to rise until it too reaches its regulation voltage.

Of the many alternative techniques, the *simultaneous* method is the more accepted for most dual-supply voltage applications. This is because it significantly reduces the voltage difference that can occur between the two voltage rails throughout the power-up sequence. However, it is not a universal answer for every application. As a rule, VLSI device manufacturers do not specify which sequencing method should be used, only the voltage and time restrictions that must be adhered to during power-up.

Although most widely accepted, the simultaneous power-up method is more difficult to implement. It requires that one or more of the power-supply circuits (generating the supply voltages) be precisely controlled during the power-up period. This level of control not only

Figure 1. Simultaneous power-up of the core and I/O voltages
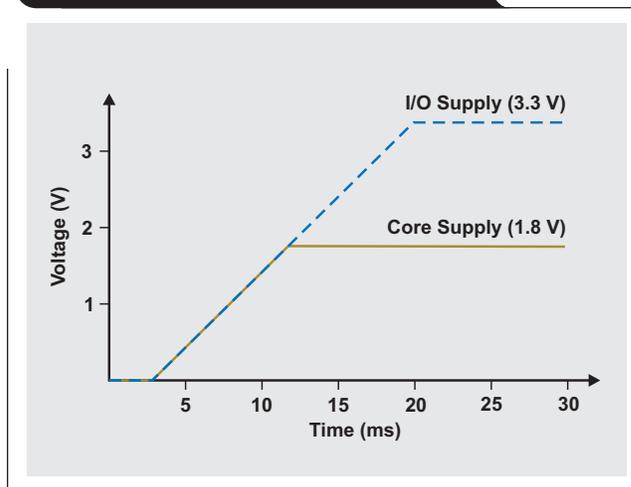
adds components but also requires that the power designer have intimate knowledge of the power-supply regulation circuitry. While this may not be a problem for the designer of a discrete power supply, it adds an unwelcome level of complexity for designers who prefer to use off-the-shelf power-supply modules.

Introducing Auto-Track Sequencing

Auto-Track Sequencing is incorporated into many of the wide-output, adjustable power modules in the PTH series of Plug-in Power Solutions. Products with this feature include circuitry that allows their output voltage to follow a control signal when it is below the module's set-point voltage. The feature specifically enables the output voltage to be directly controlled during power-up and power-down transitions. The control signal can be a system-wide master ramp waveform, the output voltage of another power supply circuit, or the module's own internal RC ramp.

How Auto-Track Sequencing works

Auto-Track Sequencing uses a control pin called "Track" to control the output voltage of the module over a range of 0 V up to the nominal set-point voltage. Within this range the voltage at the module's output will follow the voltage applied to the Track pin on a volt-for-volt basis. However, once the voltage at the Track pin is raised above the module's set-point voltage, the module's output remains at its set-point voltage. As an example, if the Track pin of a 2.5-V regulator is at 1 V, the regulated output will be 1 V; but if

the voltage at the Track pin rises to 3 V, the regulated output will not go higher than 2.5 V.

Since the output from the module simply follows that at the Track pin, it can track virtually any voltage source during the power-up sequence. For the designer's convenience, each Track pin is also provided with its own RC charge circuit that can produce a suitable rising voltage from the input source voltage.

Typical application

The basic implementation of Auto-Track Sequencing allows for simultaneous voltage sequencing of any number of modules that are compliant with this feature. The Track control pins of two or more modules are merely connected together (see Figure 2), which does two things: (1) It forces the Track control of the modules to follow the same collective RC ramp waveform; and (2) it also allows them to be controlled through a single transistor or switch, Q1.

To initiate the power-up sequence, it is recommended that the Track control first be pulled to ground potential. This must be done at or before input power is applied to the modules, and for 20 ms thereafter. This brief period gives the modules time to complete their respective internal power-up sequences so that they are ready to produce an output voltage. A logic-level high signal at the on/off control input turns Q1 on and holds the Track control at ground potential. It should be noted that after the input voltage has stabilized, the output of all modules will remain at 0 V until Q1 is turned off.

After 20 ms, Q1 may be turned off by applying a logic-level, low-drive voltage to the circuit's on/off control. This allows the Track control voltage to rise toward the modules' input voltage automatically. During this period, the output voltage of each respective power module follows the common Track control voltage, rising in unison with other modules to its set-point voltage.

Figure 2. Simplest implementation of Auto-Track voltage sequencing for power-up and power-down
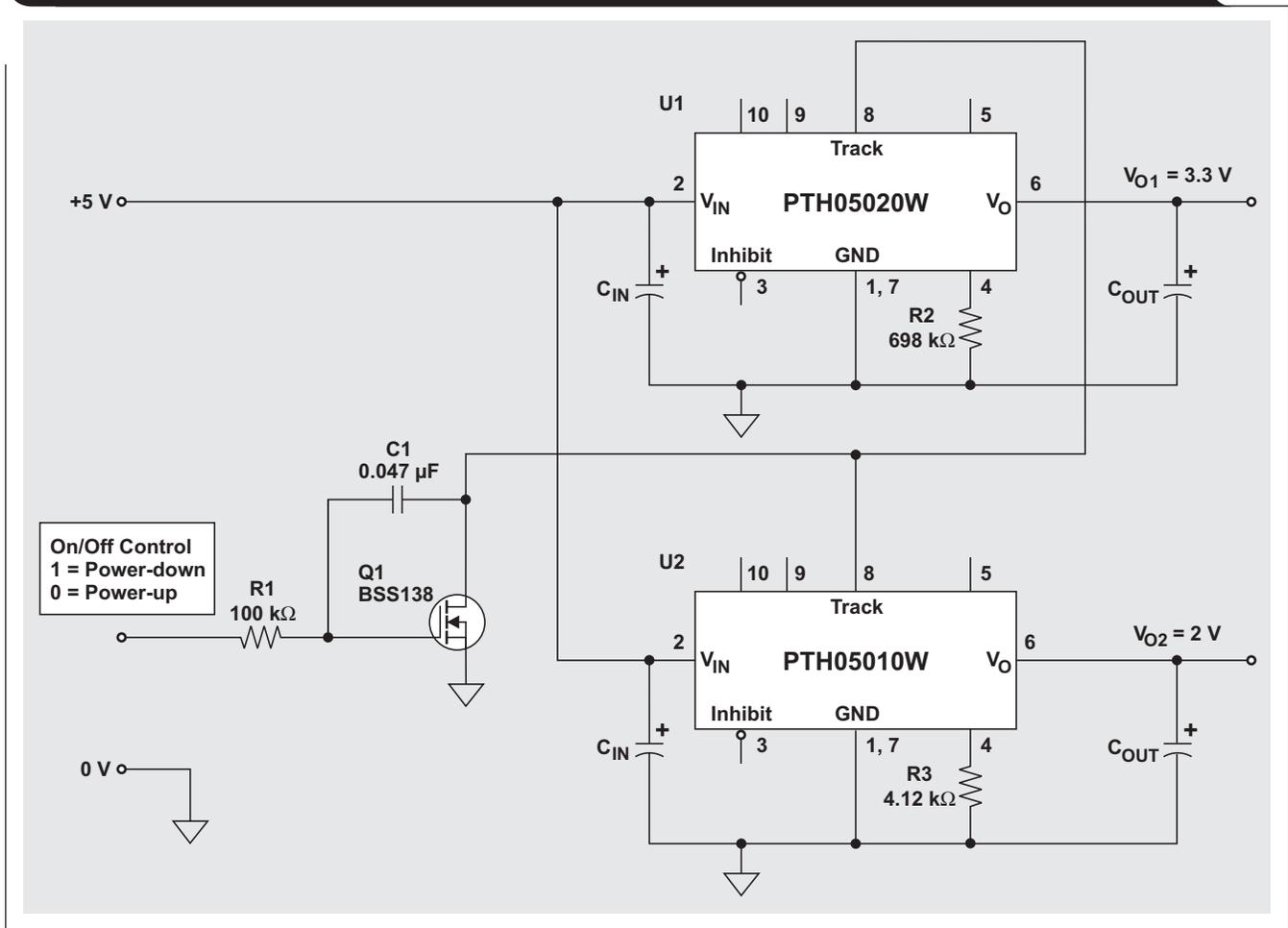
Figure 3 shows the output voltage waveforms from the circuit in Figure 2 after the on/off control voltage to the circuit is set from a high to a low level. The waveforms, V_{O1} and V_{O2}, represent the output voltages from the two power modules, U1 (3.3 V) and U2 (2.0 V), respectively. Figure 3 shows the output voltages, V_{O1} and V_{O2}, rising together to produce the desired simultaneous power-up characteristic.

The same circuit also provides a power-down sequence, although this is not always a strict requirement. Power-down is the reverse of power-up and is accomplished by lowering the Track control voltage back to 0 V. An important constraint is that the input voltage must be present until the sequence is complete. Q1 must be turned off relatively slowly so that the Track control voltage does not fall faster than Auto-Track Sequencing's slew-rate capability, which is 5 V/ms. The components R1 and C1 in Figure 2 limit the rate at which Q1 can pull down the Track control voltage. The values of 100 kΩ and 0.047 µF correlate to a decay rate of about 0.6 V/ms.

The power-down sequence is initiated with a low-to-high transition at the on/off control input to the circuit. Figure 4 shows the waveforms of V_{O1} and V_{O2} after the on/off control voltage goes high. Although the Track control voltage begins its downward slope immediately, there is a short time delay before it reaches the voltage of the highest output. As the Track control voltage falls below the nominal set-point voltage of each power module, the respective output decays with all the other modules under Auto-Track Sequencing control.

Simultaneous power-up and power-down from another power module

One of the most powerful attributes of the Auto-Track Sequencing feature is its flexibility. The Track pin of any power module compliant with Auto-Track Sequencing will follow almost any voltage up to a slew rate of 5 V/ms. This includes the output voltage of another power module, even a module that is not compliant with this feature.

Figure 3. Simultaneous power-up of two modules under Auto-Track Sequencing control
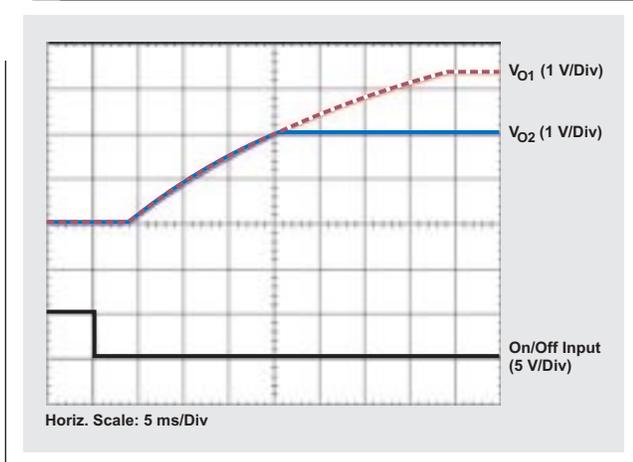

V_{O1} (1 V/Div)

V_{O2} (1 V/Div)

On/Off Input (5 V/Div)

Horiz. Scale: 5 ms/Div

Figure 4. Simultaneous power-down of two modules under Auto-Track Sequencing control

V_{O1} (1 V/Div)

V_{O2} (1 V/Div)

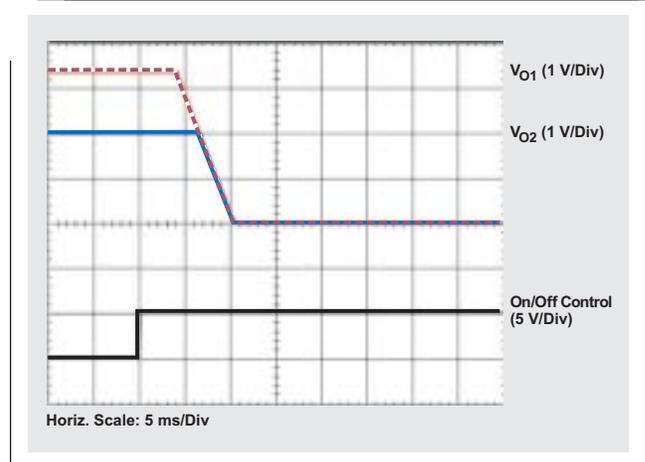On/Off Control (5 V/Div)

Horiz. Scale: 5 ms/Div

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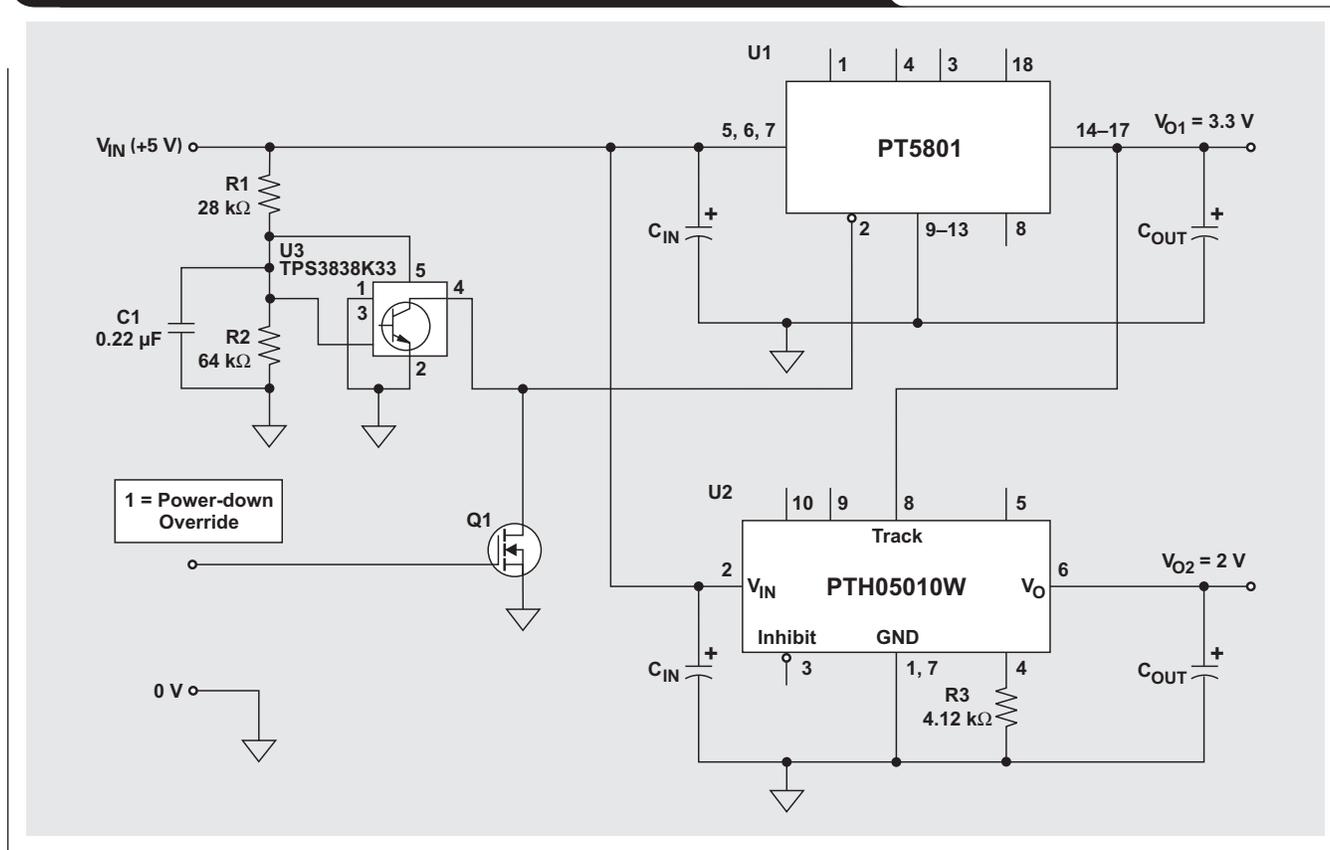**Figure 5. Sequenced power-up and power-down with other modules**

Figure 5 illustrates this arrangement. The Track pins of the lower-voltage modules must be connected directly to the output of the module with the *highest* output voltage, which in this case is PT5801 (U1). In this configuration, U1 must be controlled from its on/off Inhibit control pin.

Figure 6. Simultaneous power-up waveforms from the circuit in Figure 5

Horiz. Scale: 5 ms/Div

To initiate the power-up sequence, the U1 Inhibit control must be held to ground as input power is applied, then held there for another 20 ms. This allows time for the auto-tracking module, U2 (PTH05010W), to complete its internal power-up. In this circuit the TPS3838K33, a nanopower supervisor IC (U3), is used both to detect the input voltage and to provide the required 20-ms time delay.

Figure 6 shows the power-up waveforms for the circuit in Figure 5. The combination of the capacitor C1 and the nanopower supply supervisor U3 delays the release of the ground signal to U1 until about 20 ms after the input source, V_{IN}, has been applied. Soon after its Inhibit control input rises, U1's output voltage rises to its set-point voltage. The rate at which the outputs rise is limited only by U1's internal soft-start circuit. This is about 0.65 V/ms, slow enough for the Auto-Track Sequencing units to follow.

As mentioned, power-down sequencing with Auto-Track Sequencing is subject to the same constraint as power-up. That is, a valid input voltage must be available to all modules controlled by the Track pin throughout the power-down sequence. This constraint makes it necessary for the power system to conduct a coordinated power shutdown for all circumstances, irrespective of whether the shutdown is initiated by a human operator or is the result of a line-voltage failure. In the latter case, there must be sufficient hold-up charge in the power system to allow time for a power-down sequence to be completed before any drop in the input voltage to the circuit occurs. The nanopower

supervisor (U3) will turn off U1 (via the Inhibit pin) only after the input voltage has already begun to decay. Therefore, it cannot be used to initiate power-down; a separate transistor must be used. Q1 in Figure 5 is in parallel with U3 and can turn off U1 prior to any drop in the input voltage. When U1 (PT5801) is turned off, its output is tri-stated, which means it will neither source nor sink current from the load. This allows the output voltage to fall only as fast as the load discharges the output capacitors. Once the output voltage from U1 decays below U2's set-point voltage, it pulls down U2's output via its Track pin.

Figure 7 shows the output waveforms from the circuit in Figure 5 during power-down. To ensure that Auto-Track Sequencing can follow the output of another module, the voltage being followed must not change faster than Auto-Track Sequencing's slew-rate capability of 5 V/ms. During power-down, a decay rate faster than this will result in a delay before the lower-voltage outputs begin to follow the higher voltage, possibly producing an excessive voltage differential. The decay-rate limitation correlates to a minimum of 100 μF of capacitance per ampere of load current at the output of U1. In addition to having the highest output voltage, the module for U1 should be carefully selected to ensure that it does not sink current when turned off via its on/off Inhibit control.

Conclusion

Auto-Track Sequencing is a feature incorporated into select power modules in TI's Plug-in Power Solutions family. The feature makes it possible for the output voltage of these modules to be directly controlled (volt-for-volt) below their respective set-point voltages. This added flexibility allows a number of modules with different output voltages (for example, 3.3 V, 2.5 V, and 1.5 V) to be easily configured for simultaneous power-up and power-down voltage sequencing. Two examples of how Auto-Track Sequencing can be configured were discussed. The first showed how the Track control of a number of modules can be connected so that their output voltages rise in unison to their own internally generated RC ramp voltage. The second showed how the Track control of lower-voltage modules can be connected to directly follow the output of another higher-voltage module during both power-up and power-down transitions.

Figure 7. Simultaneous power-down waveforms from the circuit in Figure 5

V_{O1} (1 V/Div)

V_{O2} (1 V/Div)

V_{O1} Inhibit (5 V/Div)

Horiz. Scale: 0.5 ms/Div
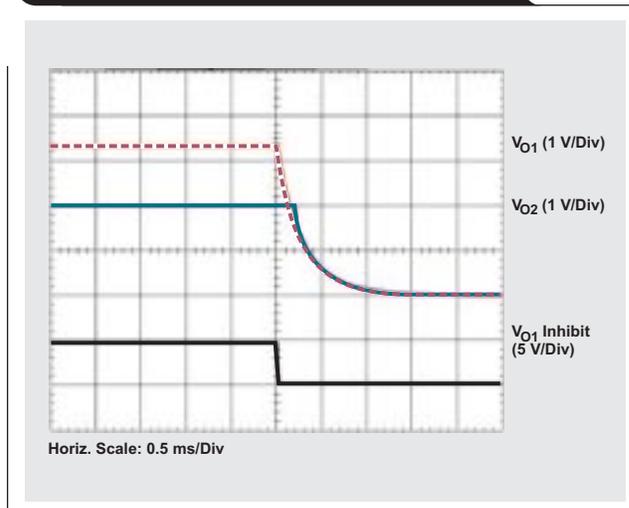
References

For more information related to this article, you can download an Acrobat Reader file at www-s.ti.com/sc/techlit/ *litnumber* and replace *"litnumber"* with the **TI Lit. #** for the materials listed below.

Document Title	TI Lit. #
1. Brian Rush, "Power-Supply Sequencing for Low-Voltage Processors," *EDN*, September 1, 2000.	—
2. David Daniels and Tom Fowler, "Dual Output Power Supply Sequencing for High Performance Processors"	slva117

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