Application Note
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Application Guidelines for Non-Isolated Converters

AN04-008: Guidelines for Sequencing of Multiple Modules

Introduction

Today's electronics systems require multiple power supply voltages to power the various ICs. Board designers need to not just provide multiple voltages, but also to ensure proper voltage sequencing for each multi-voltage IC during power-up and power-down. The most common power supply architecture involves dual voltages; usually 1.8V or lower for the core power supply and 3.3V or 2.5V for supporting I/O.

Dual-voltage-supply architectures often need coordinated management of both core and I/O voltages during power-up and power-down, a requirement called sequencing. Generally, there are three types of power sequencing solutions that can be applied to provide a synchronized start-up and shutdown sequence of core and I/O voltages. The first method is called voltage cascading or sequential start-up where one of the voltages, often the core voltage, comes up first and reaches its final regulated value. After a certain specified delay, the other voltage is required to come up and reach its regulation value (see Figure 1 for example waveforms). During power-down, the sequencing order of the supply voltages is reversed.

A second sequencing solution is called the ratiometric approach, where both supply voltages reach the regulation point at the same time. In this scheme, the core and I/O voltages have different slew-rates, (see Figure 2) to enable both voltages to reach their regulation point at approximately the same time instant. During power-down using the ratiometric sequencing method, both output voltages start ramping down at the same time instant but with different slew-rates so that they reach zero at approximately the same time instant. The third sequencing method is simultaneous start-up or voltage tracking where both voltages start ramping up with identical slew rates. After the core or lower voltage reaches its regulationlevel, the I/O voltage continues with the same slew-rate until it reaches its regulation voltage (see Figure 3 for example wavwforms). The pattern is reversed during the power-down sequence. Simultaneous start-up of multiple voltages on an IC is the most common sequencing approach used in applications.

Using EZ-SEQUENCE™

All Austin Lynx™ II series modules (Austin MicroLynx™ II, Austin Lynx™ II, Austin SuperLynx™ II, 12V Austin MicroLynx™ II, 12V Austin Lynx™ II, 12V Austin SuperLynx™ II) include a sequencing feature, EZ-SEQUENCE™ that helps users implement any of the three types of the sequencing just discussed. This is enabled through an additional sequencing (SEQ) pin. When a voltage is applied to the SEQ pin, the output voltage tracks this voltage on a one-to-one basis until the output reaches the set-point voltage. This allows the output voltage to be brought up in a controlled manner as long as the final value of the SEQ voltage is made higher

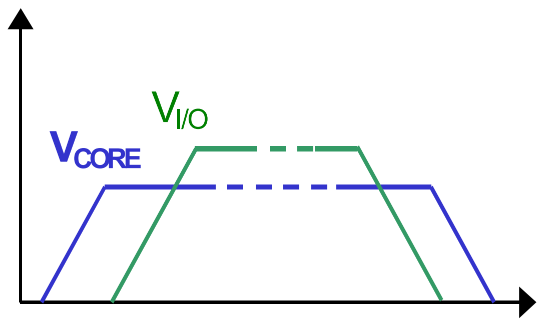

Fig. 1. Voltage waveforms in sequential start-up

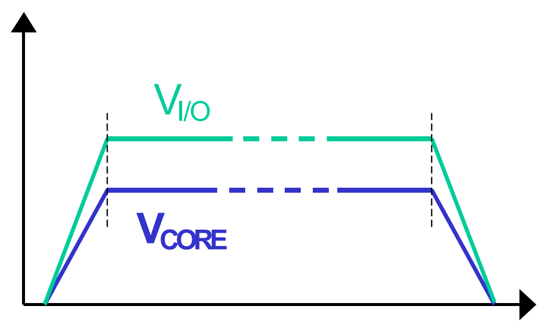

Fig. 2. Voltage waveforms in ratiometric start-up.

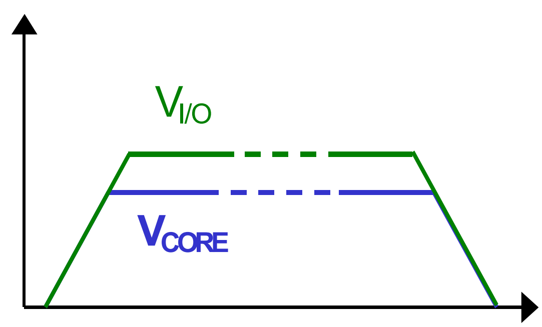

Fig. 3. Voltage waveforms in simultaneous start-up.

than the set-point voltage of the module. By connecting the SEQ pins of multiple modules together, all modules can track their output voltages to the voltage applied on the SEQ pin. When sequencing is not required in the application, the SEQ pin can either be tied to VIN or left unconnected and the module will turn-on with a nominal delay and rise time as indicated in the product data sheets.

For proper voltage sequencing, first, input voltage is applied to the module. The On/Off pin of the module is left unconnected (or tied to GND for negative logic modules or tied to VIN for positive logic modules) so that the module is ON by default. After applying input voltage to the module, a delay of 10msec minimum is required before applying voltage on the SEQ pin. The 10msec delay gives the module enough time to complete the soft-start cycle. During this delay time, the SEQ pin should be kept at a voltage of between 20 and 80mV. After the 10msec delay, the voltage applied to the SEQ pin is allowed to vary and the output voltage of the module will track this voltage on a one-to-one volt basis until the output reaches the set-point voltage. To initiate simultaneous shutdown of the modules, the sequence pin voltage is lowered in a controlled manner. The output voltages of the modules track the sequence pin voltage when it falls below their set-point voltages. A valid input voltage must be maintained until the tracking and output voltages reach zero to ensure a controlled shutdown of the modules. The voltage on the SEQ pin can be obtained from a dedicated controller, the output of another module or from an RC circuit.

Simultaneous Start-up

Simultaneous sequencing of multiple modules can be implemented using the EZ-SEQUENCE™ feature of Austin Lynx II series modules and the circuit configuration shown in Figure 4. The circuit works by providing the same control voltage to the SEQ pins of multiple modules (two in this case). In general, this control voltage can be provided from any source.

First, input voltage is applied to the module. Transistor Q1 is turned-on before VIN reaches the minimum input voltage threshold of the modules. Resistor R2 is selected to maintain 50mV (±10mV) on the SEQ pins until the voltage on the SEQ pin starts to rise (minimum of 10ms delay from when input voltage is applied to the modules). Table 1 provides the required values of R2 to maintain 50mV on the SEQ pin for various input voltages and number of modules used for sequencing. The 5/2.5V Lynx II series SEQ pin is tied to VIN with an internal pull-up resistor of 400kΩ and the 12V Lynx II series uses an internal 1MΩ pull-up resistor. After the 10msec delay, switch Q1 is turned OFF and capacitor C1 starts charging through R1+R2, and voltage on the SEQ pin rises gradually towards VIN. The output voltages track the voltage on the SEQ pins on a one-to-one basis until the module with the lower output voltage (1.2V output module in Fig. 4) reaches its set point first followed by the 3.3V output module.

The equations for calculating R2 to maintain 50mV at the SEQ pin are given below:

Table 1.

Bus Voltage	Resistor R2 (kΩ)	No of Modules
2.5	4.25	2
3.3V	3.4	2
5V	2.2	2
12V	3.03	2
2.5V	2.8	3
3.3V	2.3	3
5V	1.5	3
12V	2.02	3

$$R2 = \frac{20{,}000}{N(Vin,\min - 0.05)} \quad \text{(5/2.5V series)}$$

$$R2 = \frac{50{,}000}{N(Vin,\min - 0.05)} \quad \text{(12V series)}$$

To initiate shutdown, Q1 is turned back ON, and this starts the discharge of capacitor C1 through R2. As the voltage on the SEQ pins falls, the output voltages of the Austin Lynx™ II series modules also fall, with the higher output voltage module starting its output voltage descent first.

The corresponding scope plots describing the power-up and power-down sequences are shown in Figures 5 and 6 respectively. The slope of the voltage on the SEQ pin can be set by selecting values for R1, R2 and C1. Lynx II series modules can track SEQ pin signals with slopes of up to 2V/ms. Table 2 shows values of R1, R2 and C1 for various slopes of power-up and power-down sequencing for the 5V Lynx II series.

Applications Examples for Simultaneous Start-up

The most common circuit configuration for simultaneous start-up of multiple modules uses the highest voltage output module as the control voltage on the SEQ pin of the other modules. This ensures that all the outputs track the highest voltage till their set-point voltage. Figure 7 shows the circuit configuration for a more elaborate example with simultaneous start up using this approach.

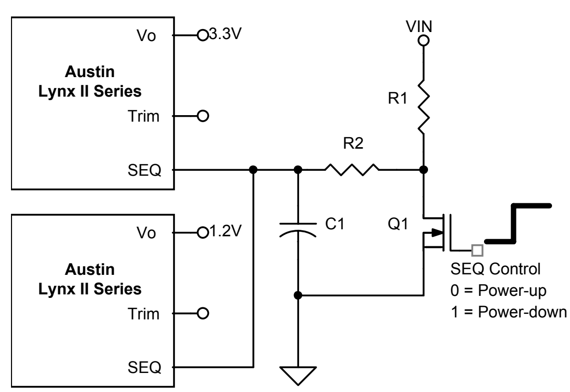

Fig. 4. Circuit configuration for simultaneous start-up using the Austin Lynx II series of modules.

The circuit has three non-isolated dc-dc modules (12V to 3.3V NAOS, 12V to 2.5V Austin MicroLynx II and 12V to 1.8V MicroLynx II). A 48V to 12V isolated dc-dc converter provides the input to the three non-isolated modules.

Table 2.

V_{IN} V	R_1 kΩ	R_2 KΩ	C_2 µF	dV/dt (V/msec) Power-Up	dV/dt (V/msec) Power-Down
5.0	1.0	2.2	10	0.1	0.06
5.0	1.0	2.2	4.7	0.25	0.14
5.0	1.0	2.2	2.2	0.5	0.25
50	1.0	2.2	1.5	0.75	0.4
5.0	1.0	2.2	1.0	1.0	0.5
5.0	1.0	2.2	0.68	2.0	1.0

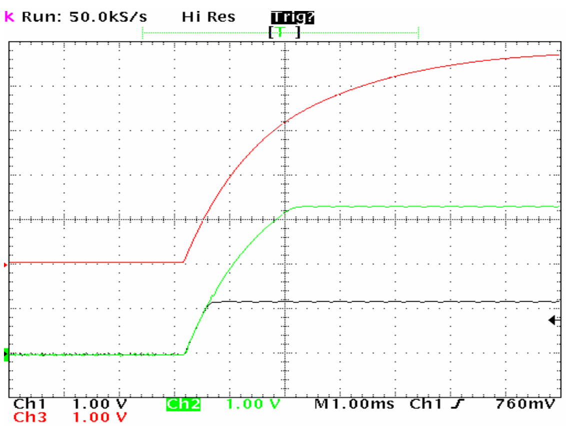

Fig. 5. Scope plots showing simultaneous power-up waveforms of Austin Lynx™ II series modules. The upper waveform is the voltage at the SEQ pin, and the lower waveforms are the two output voltages.

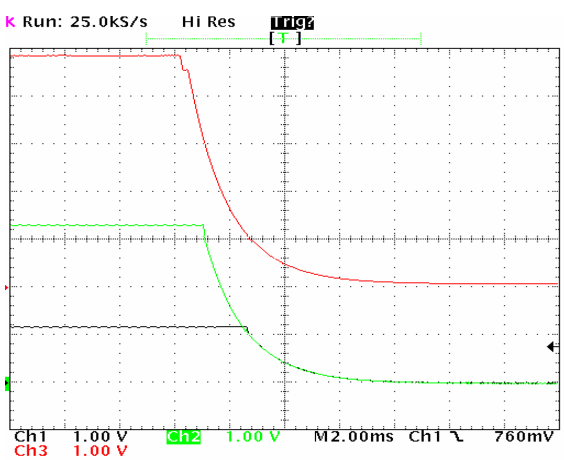

Fig. 6. Scope plots showing simultaneous power-down waveforms of two Austin Lynx™ II series modules. The SEQ pin waveform is the upper one, and the two output voltages are the lower waveforms.

To achieve simultaneous start up of these modules, the output of the 3.3V NAOS module is tied to the SEQ pins of the two Austin MicroLynx II modules. The on/Off pins of the two Austin MicroLynx II modules are tied to either the input or ground (depending on the on/off logic) as the output of these modules is now controlled through the SEQ pin. First, the input to the non-isolated modules is applied by turning on the isolated 48 to 12V converter. The 3.3V NAOS module is kept off by maintaining Q1 off. Since the NAOS module output is tied to the SEQ pin of two MicroLynx II modules, their outputs will be zero as well. After a pre-set delay (10ms minimum), Q1 is turned-on which turns-on the 3.3V NAOS module. The two Microlynx II module outputs will now track the 3.3V rail as shown in Fig. 8. The required 50mV offset at the SEQ pins of the two MicroLynx II modules is provided by a voltage divider network across the 12V input. During turn-off, all three modules will turn-off simultaneously as the 1.8V and 2.5V modules track the 3.3V module.

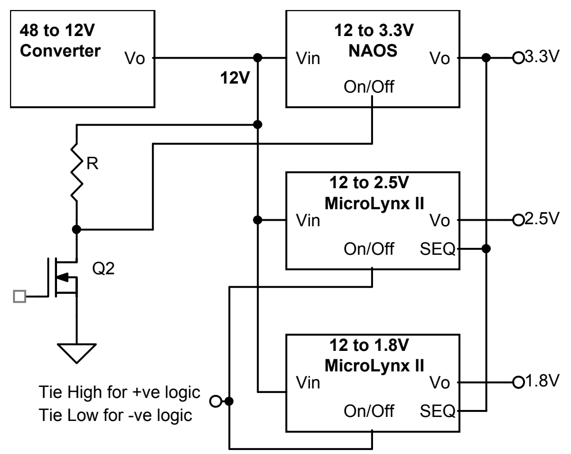

Fig. 7. Circuit configuration for an example for simultaneous startup of three modules.

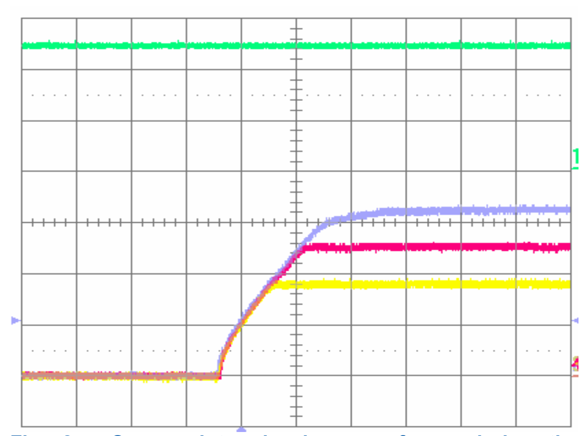

Fig. 8. Scope plots showing waveforms during the simultaneous power-up of multiple modules. The upper waveform is the input voltage, and the module output voltages are the lower waveforms.

Ratiometric Start-up

Ratiometric start-up is achieved by applying control voltages proportional to the respective nominal output voltages to the SEQ pins of the two modules. These proportional voltages on the SEQ pins will result in two different output slew-rates, with each module reaching its set-point voltage at approximately the same time instant. Figure 9 shows the circuit configuration with proportional control voltages applied to each of the two modules. Figure 10 shows the ratiometric power-up sequence with control voltages on the SEQ pins and the resulting output voltages with identical rise times. Figure 11 shows the power down sequence with this configuration.

Values of R3 and R4 for desired output voltages can be determined by the following equation:

$$\frac{V2}{V1} = \frac{R4}{R3 + R4}$$

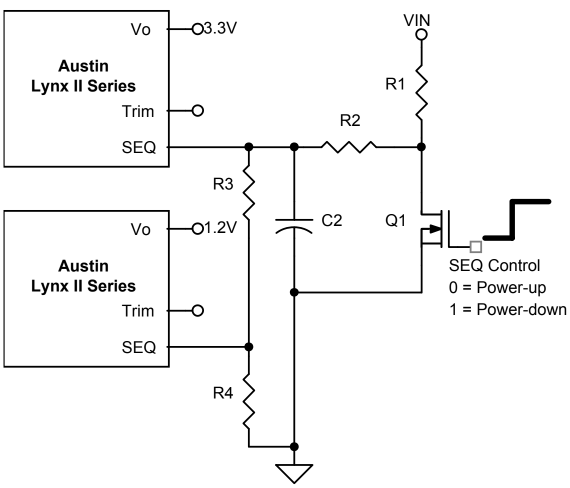

Figure 9. Circuit configuration for ratiometric start-up using Austin Lynx II series

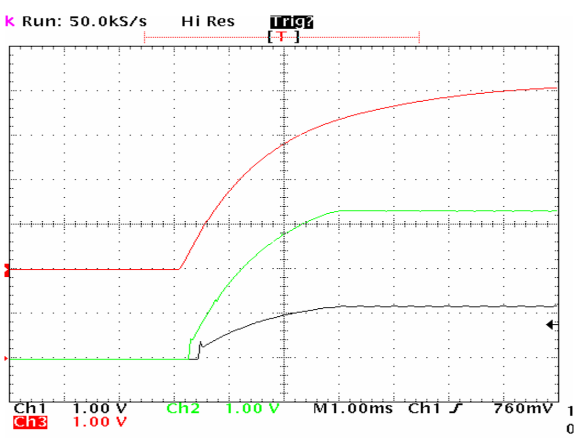

Fig. 10. Scope plot showing the ratiometric power-up sequence of two modules. Upper waveform shows the tracking voltage while the two lower waveforms are the output voltages.

Sequential Start-up

Sequential startup can be implemented easily using the on/off pin alone and does not require using the SEQ pin. The **Application Note AN004-03** ***titled "Application Guidelines for Non-Isolated Converters – On/off Considerations"*** provides guidelines and an example for how sequential startup can be implemented.

Summary

The EZ-SEQUENCE in the Lynx II series of modules provides the extra level of flexibility needed to power loads that require a precise sequence of voltages during the power up and down phases. By use of the sequencing pin and the example circuits shown in this application note, all three types of sequencing – tracking, simultaneous startup and ratiometric startup can be supported.

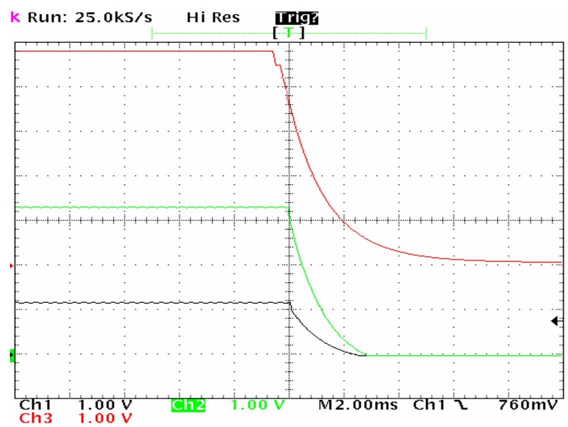

Fig. 11. Scope plot showing the ratiometric power-down sequence of two Austin Lynx™ II series modules. Upper waveform shows the tracking voltage while the two lower waveforms are the output voltages.

World Wide Headquarters
Tyco Electronics Power Systems, Inc.
3000 Skyline Drive, Mesquite, TX 75149, USA
+1-800-526-7819
(Outside U.S.A.: **+1-972-284-2626**)
www.power.tycoelectronics.com
e-mail: techsupport1@tycoelectronics.com

Europe, Middle-East and Africa Headquarters
Tyco Electronics Power Systems
Tel: +49 89 6089 286

Latin America, Brazil, Caribbean Headquarters
Tyco Electronics Power Systems
Tel: +56 2 209 8211

India Headquarters
Tyco Electronics Systems India Pte. Ltd.
Tel: +91 80 841 1633 x3001

Asia-Pacific Headquarters
Tyco Electronics Singapore Pte. Ltd.
Tel: +65 6416 4283

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