Application Report
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Sequencing and Tracking With the TPS621-Family and TPS821-Family

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ABSTRACT

The TPS6213x/4x/5x is a family of synchronous buck DC-DC converters with a wide operating input voltage range from 3 V to 17 V and adjustable output voltage of 0.9 V to 6 V. Because of the wide input and output voltage ranges, they are ideal for use in systems which contain multiple output voltage rails. This application note describes how to use the EN, PG, and SS/TR pins in tracking and sequencing applications in such systems which contain any combination of the TPS6213x, TPS6214x, or TPS6215x devices.

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1 Device Description

The TPS6213x/4x/5x devices are easy to use synchronous step down DC-DC converters suited for applications that requires tracking and sequencing. They have a built in power good function to indicate the status of the device, a soft start circuit to control the output voltage slope during start up, and an enable function for controlling the turn on of the device. Each of these functions is useful for tracking and sequencing.

1.1 Soft Start and Tracking (SS/TR)

The rate in which the output voltage rises up to the full operational level during the start up phase is controlled through the SS/TR pin. A capacitance (C_{SS}) is connected between the SS/TR pin and the IC ground; and the size of the capacitor determines the soft start ramp up time (T_{SS}) per Equation 1. Equation 2 shows the relationship between the SS/TR pin voltage and FB pin voltage.

$$T_{SS} = C_{SS} \times (V_{SS/TR\ (MAX)} / I_{SS})\ [sec] \quad (1)$$

$$V_{FB} = 0.64 \times V_{SS/TR} \quad (2)$$

$V_{SS/TR\ (MAX)}$ is the maximum SS/TR pin voltage of 1.25V that relates to the maximum FB pin voltage of 0.8V. Though the SS/TR pin voltage may increase beyond 1.25V, the FB pin voltage stops tracking the increasing SS/TR pin voltage at this point and remains at its final value of 0.8 V. The voltage at the FB pin corresponds to the output voltage. I_{SS} is the SS/TR pin's internal source current which equals I_{SS} = 2.5 µA.

By sourcing a constant current onto the capacitor C_{SS}, the device linearly ramps up the voltage on the SS/TR pin, which corresponds to the voltage on the FB pin and thus the output voltage. Figure 1 shows the typical start up ramp for a device set to 1.8 V output.

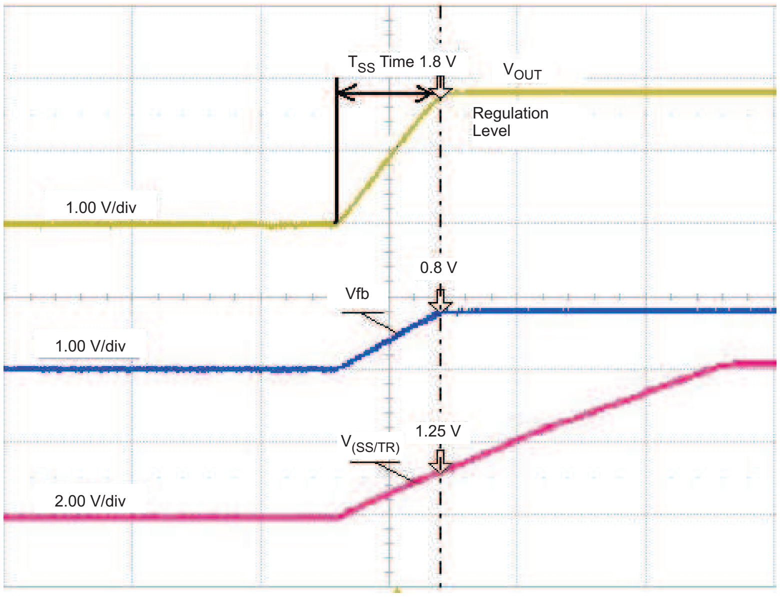


Figure 1. Soft Start Ramp Up Time

1.2 Enable (EN)

The EN pin of the TPS6213x/4x/5x controls the turn on of the device. Setting the enable pin to logic high starts up the device. Conversely, the device is shutdown when the enable pin is logic low. The high threshold voltage of this pin is 0.9 V and the low voltage threshold is 0.3 V. Any voltage between the two levels results in an undefined state of the logic input, EN.

1.3 *Power Good (PG)*

The power good output is used to indicate that the output voltage has reached regulation. It floats high when the output voltage reaches its appropriate level and is pulled low by the device when the device is enabled and the output voltage is below the regulated level. The PG pin is an open drain output that requires an external pull up resistor. This pin can be used for enabling other devices in the system when the output voltage reaches the desired level.

2 Sequential Start Up Using EN and PG

The sequential start up method uses the EN and PG functions to turn on a second device after the first device has reached regulation. Figure 2 shows two TPS6213x/4x/5x devices in a sequential system set up. The PG pin of the first device is used to enable the second device. When the first output voltage reaches its appropriate level after getting enabled, the PG pin turns high. As a consequence, the second device is enabled. Note that both SS/TR pins are connected independently, so the soft start times can be different for each device.

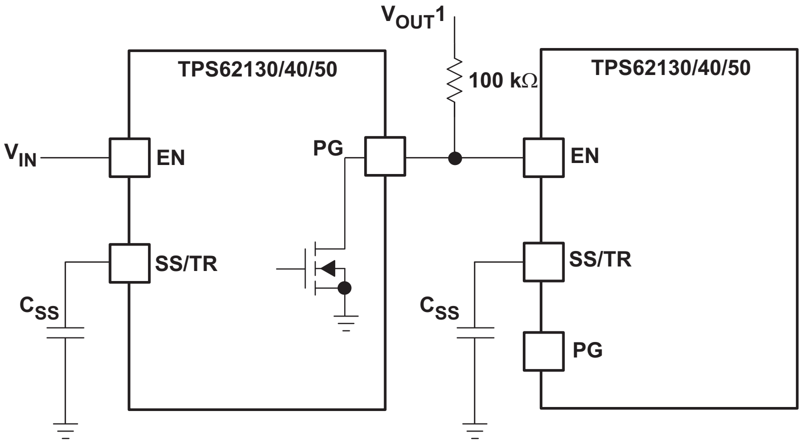


Figure 2. Sequential Start Up Using the EN and PG Pins

Figure 3 shows the result of the sequential start up circuit drawn in Figure 2. The enable pin of the first device turns high to enable the first converter and its output voltage, $V_{OUT}1$, starts rising up. After its soft start time, the output voltage reaches 3.3 V, which is its regulation voltage. The power good goes high and enables the second device. Once the second converter gets enabled, its output voltage rises up to its full operation level of 1.8 V after its programmed soft start time. This illustrates a typical sequential start up using two TPS6213x/4x/5x devices.

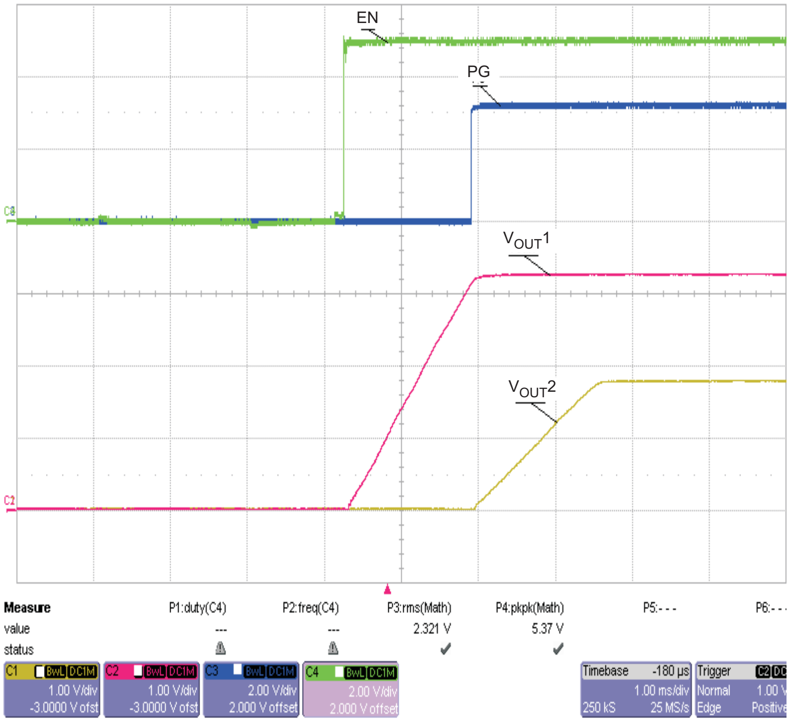


Figure 3. Sequential Start Up Using the EN and PG Pins (Results of the Circuit of Figure 2)

3 Ratiometric Start Up Using Connected SS/TR Pins

In the ratiometric start up sequence, the EN and SS/TR pins of both devices are connected together, as shown in Figure 4. A single soft start capacitor is used. This configuration forces both devices to start up at the same time when their common enable pin turns high. Also, since the SS/TR pins are connected together, the soft start time (T_{SS}) is the same for both devices and both devices reach regulation at the same time. Note that the soft start time, as calculated from Equation 1, will be half of what it should be because both devices' SS/TR pin current sources are feeding onto a single soft start capacitor. To achieve the desired soft start time with Equation 1, double the I_{SS} value to account for the second current source.

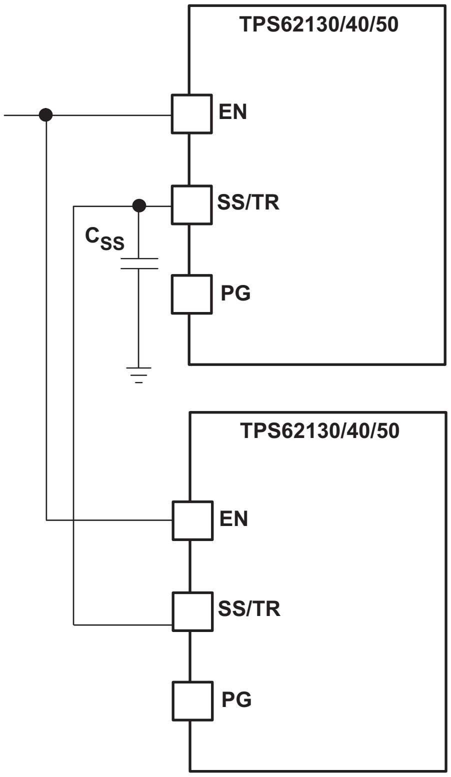
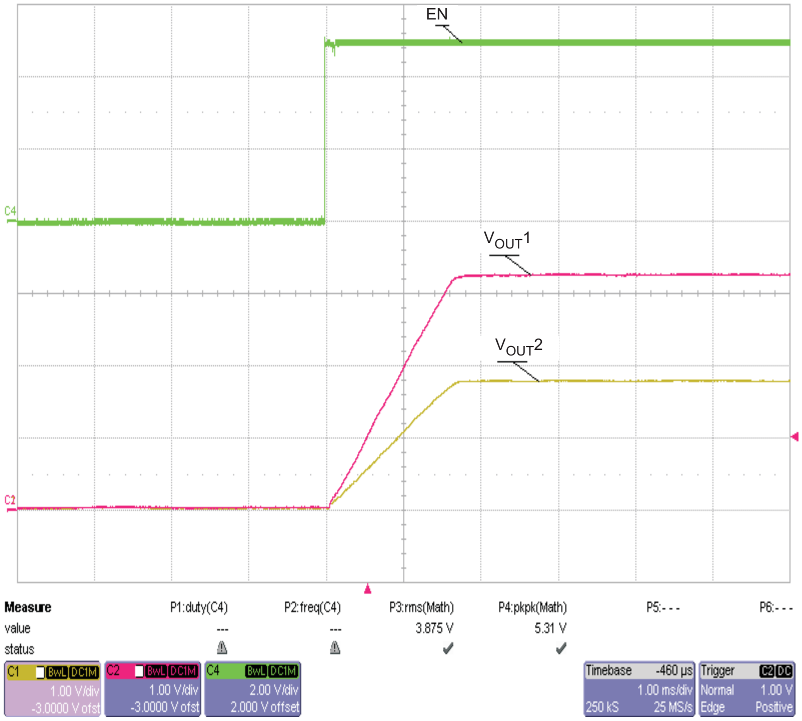


Figure 4. Ratiometric Start Up Using the SS/TR Pins

In Figure 4, both output voltages start once the enable pin goes high and both voltages reach regulation at the same time. Since the output voltages are not the same, but the soft start time is equal, their slopes are different.



Measure	P1:duty(C4)	P2:freq(C4)	P3:rms(Math)	P4:pkpk(Math)	P5:- - -	P6:- - -
value	---	---	3.875 V	5.31 V		
status	⚠	⚠	✓	✓		

C1 BwL DC1M 1.00 V/div -3.0000 V ofst

C2 BwL DC1M 1.00 V/div -3.0000 V ofst

C4 BwL DC1M 2.00 V/div 2.000 V offset

Timebase -460 µs 1.00 ms/div 250 kS 25 MS/s

Trigger C2 DC Normal 1.00 V Edge Positive

Figure 5. The Ratiometric Start Up (Result of the Circuit in Figure 4)

4 Ratiometric and Simultaneous Start Up

In ratiometric and simultaneous start up, the enable pins of both converters are connected together; thus, both devices start at the same time. The SS/TR pin of the first device is connected to ground through its C_{SS} capacitor. The C_{SS} capacitor value defines the soft start ramp up time as expressed in Equation 1. However, the SS/TR pin in the second device is connected to the output voltage of the first converter through two resistors, R1 and R2, as shown in Figure 6.

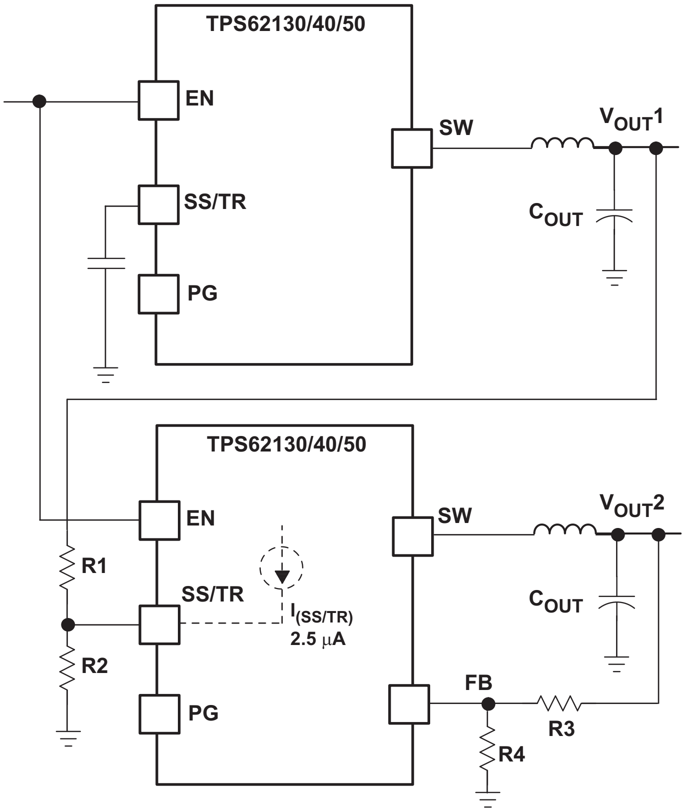


Figure 6. Ratiometric and Simultaneous Start Up Sequence

In this configuration, since the SS/TR pin of the second converter is connected to the output voltage of the first converter, the $V_{OUT}2$ start up slope is related to the start up slope of $V_{OUT}1$. Also, the $V_{OUT}2$ start up slope depends on the values of R1 and R2. Equation 2 and the following equations can be used to control the slope of $V_{OUT}2$.

$$V_{SS/TR}\ 2 = V_{OUT}1 \times R2/(R1 + R2) + I_{SS} \times R2 \quad (3)$$

$$V_{OUT}2 = [\ V_{OUT}1 \times R2/(R1 + R2) + I_{SS} \times R2\ ] \times 0.64 \times [(R3 + R4)/R4 \quad (4)$$

Equation 2 provides the relationship between the voltages of the FB pin and the SS/TR pin. V_{FB} varies from 0 V to 0.8 V; thus $V_{(SS/TR)}$ varies from 0V to 1.25V. The relationship between the SS/TR pin voltage and the output voltage of the first converter is expressed in Equation 3. This equation is obtained by the voltage divider from $V_{OUT}1$ summed with the internal SS/TR pin current source. The current source is small (2.5µA), so it can be neglected if the value of R2 is smaller than 10KΩ. Note that an error of 2% in Equation 3 is produced if R2 × I_{SS} is neglected with R2 = 10KΩ. Equation 4 gives the relationship between $V_{OUT}2$ in terms of $V_{OUT}1$. R3 and R4 are the feed back resistors of the second converter as shown in Figure 6. They are used to set the output voltage of $V_{OUT}2$ when it is in regulation. $V_{OUT}1$ and $V_{OUT}2$ are the output voltages of each converter at some point in time during start up. They will be used in the following sections to achieve different ratiometric sequencing configurations.

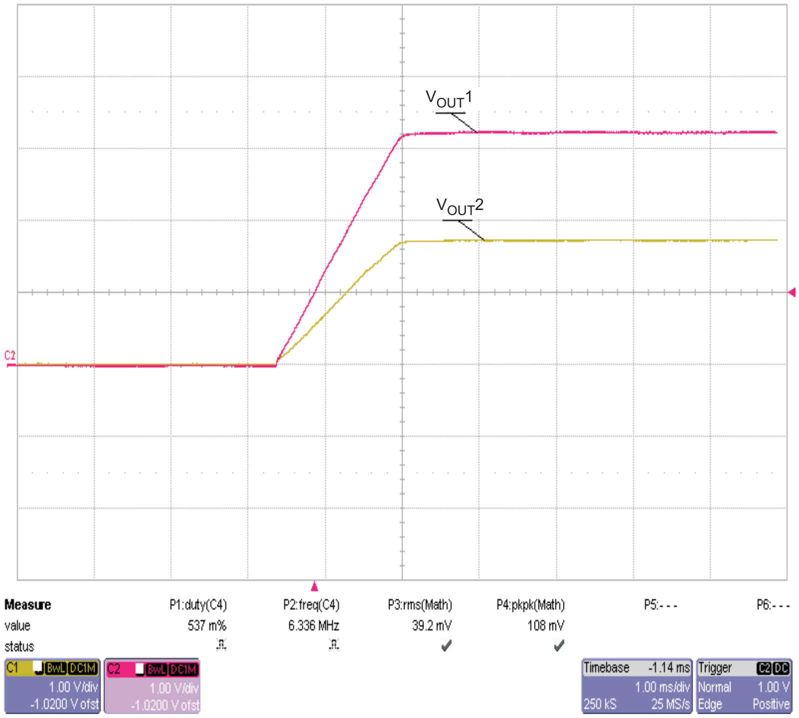
With the configuration of Figure 6, three situations are possible: $V_{OUT}1$ ramps up faster than $V_{OUT}2$, $V_{OUT}2$ ramps up faster than $V_{OUT}1$, and V_{OUT} 1 ramps up at the same rate as $V_{OUT}2$. The next sections explain how to calculate the values of R1 and R2 for the desired ramp up relationship. R3 and R4 are sized in the same way as described by the data sheet to set the output voltage.

4.1 $V_{OUT}1$ Leading $V_{OUT}2$

In this configuration, the output voltage of the first converter leads the output voltage of the second converter. In Figure 7, $V_{OUT}1$ and $V_{OUT}2$ are regulated to 3.3 V and 1.8 V respectively. Also both voltages reach their regulated levels at the same time. The V_{FB} voltage should reach 0.8V for full regulation, and from Equation 2, $V_{SS/TR}$ should equal 1.25 V. This should happen when $V_{OUT}1$ reaches 3.3V. Choosing R2 as 1KΩ and with I_{SS} = 2.5 µA, R1 is found from Equation 3:

$$1.25\ \text{V} = 3.3\ \text{V} \times 1\ \text{K}\Omega\ /\ (\text{R1} + 1\ \text{K}\Omega) + 2.5\ \mu\text{A} \times 1\ \text{K}\Omega. \tag{5}$$

R1 is found to be equal to 1.65 KΩ.



Measure	P1:duty(C4)	P2:freq(C4)	P3:rms(Math)	P4:pkpk(Math)	P5:---	P6:---
value	537 m%	6.336 MHz	39.2 mV	108 mV		
status	⎍	⎍	✓	✓		

Figure 7. Ratiometric Start Up with $V_{OUT}1$ Leading $V_{OUT}2$

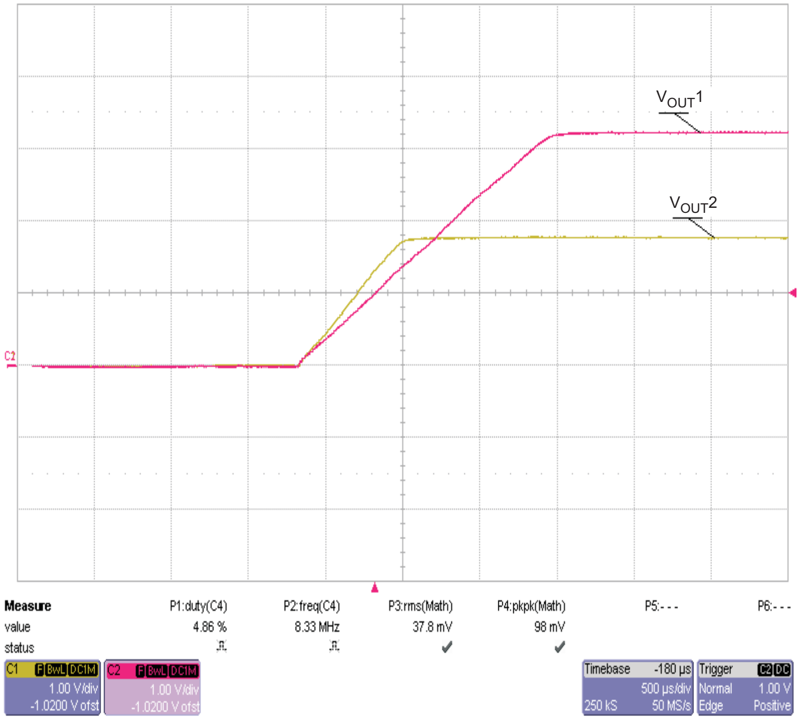
Also, Equation 4 can be used instead to calculate the values of R1 and R2 for a design where $V_{OUT}1$ and $V_{OUT}2$ do not need to reach regulation at the same time. The next section shows an example.

4.2 $V_{OUT}2$ Leading $V_{OUT}1$

With this configuration, the output voltage of the second converter leads the output voltage of the first converter. In Figure 8, $V_{OUT}1$ and $V_{OUT}2$ are regulated to 3.3 V and 1.8 V respectively. However, the second output voltage reaches its regulation voltage first. R1 and R2 are designed in such a way the first output voltage reaches only 1.4 V as $V_{OUT}2$ gets to 1.8V as shown in Figure 8. As described in the previous section, R2 is first fixed and Equation 4 is used to calculate R1. The values of R3 and R4 are fixed to 150 KΩ and 187 KΩ respectively and R2 is chosen as 2KΩ.

$$1.8\ \text{V} = [1.4\ \text{V x } 2\ \text{K}\Omega/\ (\text{R1} + 2\ \text{K}\Omega) + 2.5\ \mu\text{A x } 2\ \text{K}\Omega] \text{ x } 0.64 \text{ x } [(150\ \text{K}\Omega + 187\ \text{K}\Omega)/150\ \text{K}\Omega] \tag{6}$$

R1 is found to be equal to 240Ω.



Measure	P1:duty(C4)	P2:freq(C4)	P3:rms(Math)	P4:pkpk(Math)	P5:- - -	P6:- - -
value	4.86 %	8.33 MHz	37.8 mV	98 mV		
status	⎍	⎍	✓	✓		

C1 F BwL DC1M 1.00 V/div -1.0200 V ofst
C2 F BwL DC1M 1.00 V/div -1.0200 V ofst
Timebase -180 µs 500 µs/div 250 kS 50 MS/s
Trigger C2 DC Normal 1.00 V Edge Positive

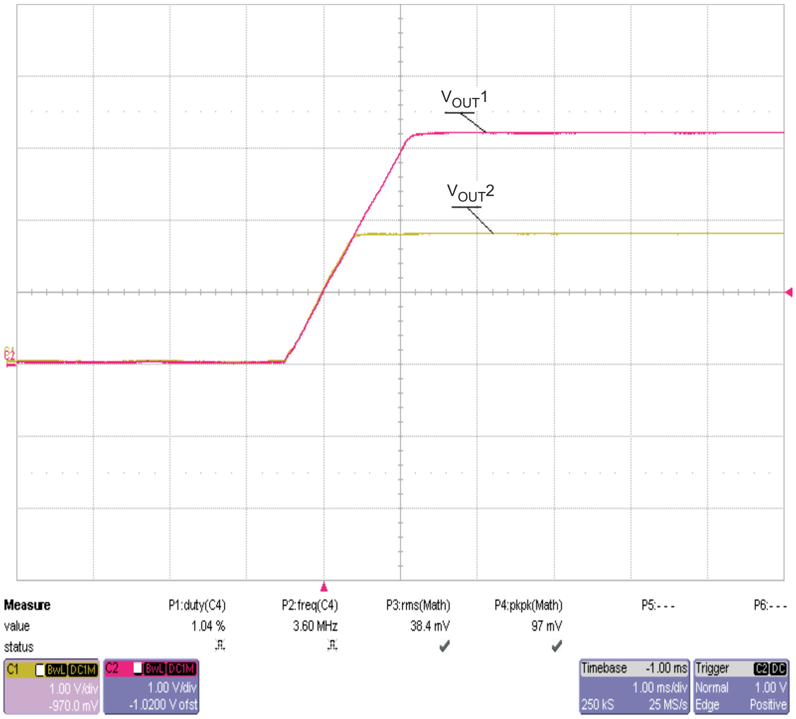
Figure 8. Ratiometric Start Up with $V_{OUT}2$ Leading $V_{OUT}1$

4.3 *Simultaneous Start Up*

In the simultaneous start up, the slopes of both output voltages are the same. Thus, both voltages reach regulation in two different times. Equation 3 calculates the required R1 and R2 values. Note that in this method, when VSS/TR equals 1.25 V the first converter is at an output voltage equal to $V_{OUT}2$'s regulation voltage. For this example, $V_{OUT}2$ = 1.8 V when $V_{OUT}1$ = 1.8 V. If R2 is equal to 1 KΩ, Equation 3 is used as follows:

$$1.25\text{ V} = 1.8\text{ V} \times 1\text{ K}\Omega / (R1 + 1\text{ K}\Omega) + 2.5\ \mu\text{A} \times 1\text{ K}\Omega. \quad (7)$$

The R1 value is found to be 432Ω. Figure 9 shows the result of simultaneous start up.



Measure	P1:duty(C4)	P2:freq(C4)	P3:rms(Math)	P4:pkpk(Math)	P5:- - -	P6:- - -
value	1.04 %	3.60 MHz	38.4 mV	97 mV		
status	⎍	⎍	✓	✓		

Figure 9. Simultaneous Start Up

5 Conclusion and References

5.1 Conclusion

This application note described three different tracking and sequencing methods: sequential, ratiometric, and simultaneous. Sequential start up using the EN and PG pins starts two or more devices in some order, one device after another. The ramp up slope of each device is independent. In ratiometric start up with connected SS/TR pins, all devices turn on at the same time and have the same ramp up time. With simultaneous start up, two devices start up at the same rate. With small adjustments to resistor values, one device can ramp up at a faster or slower rate compared to the other device. All of these options are available with the TPS6213x/4x/5x family of devices.

5.2 References

1. TPS62130 Datasheet (SLVSAG7)
2. TPS62140 Datasheet (SLVSAJ0)
3. TPS62150 Datasheet (SLVSAL5)
4. TPS54320 Datasheet (SLVS982)

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (November 2011) to A Revision	Page
• Updated title to the application report.	1

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