TPS65150-Q1 Automotive LCD Power Supply for Source and Gate Drivers with Gate Voltage Shaping and VCOM Buffer

1 Features

- AEC-Q100 Qualified:
  - Device Temperature Grade 1: –40°C to 125°C Junction Temperature
  - Device HBM ESD Classification According to AEC - Q100-002
  - Device CDM ESD Classification According to AEC - Q100-011
- Input Voltage Range: 1.8 V to 6 V
- $V_{(VS)}$ Boost Converter
  - Up to 15 V Output Voltage
  - < 1% Output Voltage Accuracy
  - 2-A Switch Current Limit
- $V_{(VGH)}$ Positive Regulated Charge Pump Driver
  - Up to 30 V Output Voltage
  - Gate Voltage Shaping
- $V_{(VGL)}$ Negative Regulated Charge Pump Driver
  - Down to –15 V Output Voltage
- Integrated VCOM Buffer
- Adjustable Power On Sequencing
  - Gate Drive Signal for External Isolation MOSFET for $V_{(VS)}$
- Protection Features
  - Out-of-Regulation Protection
  - Over-voltage Protection
  - Adjustable Fault Detection Timing
  - Thermal Shutdown
- 24-Pin TSSOP Package with Exposed Thermal Pad

2 Applications

- LCD Displays ranging approx. from 4" to 17"
  - Automotive Infotainment & Cluster
  - Automotive Navigation Systems
  - Rear Seat Entertainment
  - Smart Mirror

3 Description

The TPS65150-Q1 is an integrated power-supply for automotive LCD applications. The device integrates a boost converter for the source voltage and two regulated adjustable charge pump drivers for the gate voltages. For reduced external cost, improved picture quality and reduced image sticking, the device includes a VCOM buffer and a gate-voltage shaping function.

The device is designed to operate from a supply voltage of 1.8 V to 6 V making it ideal for automotive LCD applications using a fixed 3.3 V or 5 V input-voltage rail.

Adjustable power-on sequencing for VGL and VGH allow the device to be optimized for a variety of displays.

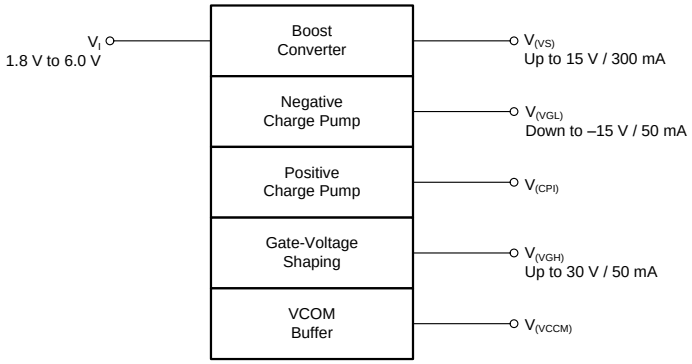
For protection from system malfunction, the TPS65150-Q1 integrates an adjustable shutdown latch feature. The device monitors the outputs ($V_{(VS)}$, $V_{(VGL)}$, $V_{(VGH)}$); and, as soon as one of the outputs falls below its power-good threshold for longer than the adjustable fault delay time, the device enters shutdown.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS65150-Q1	TSSOP (24)	6.40 mm × 7.80 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Block Diagram



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4 Revision History

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

Changes from Revision B (December 2016) to Revision C — **Page**

- Moved "AEC-Q100 Qualified" to the top of *Features* list ... 1
- Changed the *Electrical Characteristics* conditions From: T_A = –40°C to 85°C To: T_A = –40°C to 125°C ... 6

Changes from Revision A (September 2013) to Revision B — **Page**

- Added *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1
- Added specifications to the *Absolute Maximum Ratings* table ... 5
- Added *Switching Characteristics* ... 7
- Changed typical characteristics graphs ... 8
- Changed *Functional Block Diagram* for clarity ... 11

Changes from Original (June 2013) to Revision A — **Page**

- Changed document status from Product Preview to Production Data ... 1

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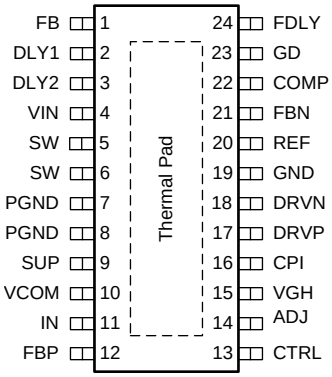
5 Pin Configuration and Functions

PWP Package
24-Pin TSSOP
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	HTSSOP		
ADJ	14	I/O	Gate voltage shaping circuit. Connecting a capacitor to this pin sets the fall time of the positive gate voltage $V_{(VGH)}$.
COMP	22	O	This is the compensation pin for the main boost converter. A small capacitor and if required a series resistor is connected to this pin.
CPI	16	I	Input of the VGH isolation switch and gate voltage shaping circuit.
CTRL	13	I	Control signal for the gate voltage shaping signal. Apply the control signal for the gate voltage control. Usually the timing controller of the LCD panel generates this signal. If this function is not required, this pin must be connected to V_I. By doing this, the internal switch between CPI and VGH provides isolation for the positive charge pump output $V_{(VGH)}$. DLY2 sets the delay time for $V_{(VGH)}$ to come up.
DLY1	2	I/O	Power-on sequencing adjust. Connecting a capacitor from this pin to ground allows to set the delay time between the boost converter output $V_{(VS)}$ and the negative charge pump $V_{(VGL)}$ during start-up.
DLY2	3	I/O	Power-on sequencing adjust. Connecting a capacitor from this pin to ground allows to set the delay time between the negative charge pump $V_{(VGL)}$ and the positive charge pump during start-up. Note that Q5 in the gate voltage shaping block only turns on when the positive charge pump is within regulation. (This provides input-output isolation of $V_{(VGH)}$).
DRVN	18	I/O	Negative charge pump driver.
DRVP	17	I/O	Positive charge pump driver.
FB	1	I	Boost converter feedback sense input.
FBN	21	I	Negative charge pump feedback sense input.
FBP	12	I	Positive charge pump feedback sense input.
FDLY	24	I/O	Fault delay. Connecting a capacitor from this pin to V_I sets the delay time from the point when one or more of the of the outputs $V_{(VS)}$, $V_{(VGH)}$, $V_{(VGL)}$ drops below its power good threshold until the device shuts down. To restart the device, the input voltage must be cycled to ground. This feature can be disabled by connecting the FDLY pin to V_I.
GD	23	I	Active-low, open-drain output. This output is latched low when the boost converter output is in regulation. This signal can be used to drive an external MOSFET to provide isolation for $V_{(VS)}$.
GND	19		Analog ground.
IN	11	I	Input of the VCOM buffer. If this pin is connected to ground, the VCOM buffer is disabled.
PGND	7, 8		Power ground.
REF	20	O	Internal reference output, typically 1.213 V.
SUP	9	I/O	Supply pin of the positive, negative charge pump and boost converter gate drive circuit. This pin must be connected to the output of the main boost converter and cannot be connected to any other voltage rail.

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Pin Functions (continued)

PIN		I/O	DESCRIPTION
NAME	HTSSOP		
SW	5, 6	I	Switch pin of the boost converter.
VCOM	10	O	VCOM buffer output. Typically a 1-µF output capacitor is required on this pin.
VGH	15	O	Positive output voltage to drive the TFT gates with an adjustable fall time. This pin is internally connected with a MOSFET switch to the positive charge pump input CPI.
VIN	4	I	This is the input voltage pin of the device.
Thermal Pad	—		The thermal pad must to be soldered to GND

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)(2)

		MIN	MAX	UNIT
Voltages on pin	VIN, CTRL	–0.3	7	V
	ADJ	–0.3	22	V
	VCOM, IN, DRVP, DRVN	–0.3	15	V
	FBN, COMP, FBP, FB, DLY1, DLY2	–0.3	5.5	V
	REF	–0.3	4	V
	VGH	–0.3	30	V
	FDLY	–0.3	6	V
	GD, SUP	–0.3	15.5	V
	SW	–0.3	20	V
	CPI	–0.3	32	V
Operating junction temperature, T_J		–40	125	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC-Q100-02	±2000	V
		Charged-device model (CDM), per AEC-Q100-011	±500	

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_I	Input voltage range	1.8		6	V
$V_{(VS)}$	Output voltage range of the boost converter $V_{(VS)}$			15	V
L	Inductor(1)		4.7		µH
T_A	Operating ambient temperature	–40		125	°C

(1) See *Typical Application* for further information.

6.4 Thermal Information

THERMAL METRIC(1)		TPS65150-Q1 PWP (TSSOP) 24 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	40.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	20.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	18.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	18.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	1.9	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

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6.5 Electrical Characteristics

V_I = 3.3 V, $V_{(VS)}$ = 10 V, T_A = –40°C to 125°C, typical values are at T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
SUPPLY CURRENT							
V_I	Input voltage (VIN)			1.8		6	V
	Supply current (VIN)	Device not switching			14	25	µA
	Supply current (SUP)	Device not switching			1.9	3	mA
	Supply current (VCOM buffer)				750	1500	µA
$V_{IT–}$	Undervoltage lockout threshold (VIN)	V_I falling	–40 °C < T_A < 85 °C		1.6	1.8	V
			–40 °C < T_A < 125 °C		1.6	1.85	
V_{IT+}	Undervoltage lockout threshold (VIN)	V_I rising	–40 °C < T_A < 85 °C		1.7	1.9	V
			–40 °C < T_A < 125 °C		1.7	1.95	
	Thermal shutdown temperature threshold	T_J rising			155		°C
	Thermal shutdown temperature hysteresis				10		°C
LOGIC SIGNALS							
V_{IH}	High-level input voltage (CTRL)			1.6			V
V_{IL}	Low-level input voltage (CTRL)					0.4	V
I_{IH}, I_{IL}	Input current (CTRL)	CTRL = V_I or GND			0.01	0.2	µA
BOOST CONVERTER							
V_O	Output voltage					15	V
V_{ref}	Boost converter reference voltage (FB)	–40 °C < T_A < 85 °C		1.136	1.146	1.154	V
		–40 °C < T_A < 125 °C		1.132	1.146	1.160	
I_{IB}	Input bias current (FB)				10	100	nA
$r_{DS(on)}$	Drain-source on-state resistance (Q1)	I_{DS} = 500 mA	V_O = 10 V		200	300	mΩ
			V_O = 5 V		305	450	
$r_{DS(on)}$	Drain-source on-state resistance (Q2)	I_{DS} = 500 mA	V_O = 10 V		8	15	Ω
			V_O = 5 V		12	22	
I_{DS}	Drain-source current rating (Q2)			1			A
	Current limit (Q1)			2	2.5	3.4	A
$I_{(SW)(off)}$	Off-state current (SW)	$V_{(SW)}$ = 15 V			1	10	µA
V_{IT+}	Overvoltage protection threshold (SUP)	$V_{(SUP)}$ rising		16		20	V
$\Delta V_{O(\Delta VI)}$	Line regulation	V_I = 1.8 V to 5 V	I_O = 1 mA		0.007		%/V
$\Delta V_{O(\Delta IO)}$	Load regulation	V_I = 5 V	I_O = 0 A to 400 mA		0.16		%/A
V_{IT+}	Gate drive threshold (FB)(1)			–12% of V_{ref}		–4% of V_{ref}	V
NEGATIVE CHARGE PUMP							
V_O	Output voltage					–2	V
$V_{(REF)}$	Reference output voltage (REF)	–40 °C < T_A < 85 °C		1.205	1.213	1.219	V
		–40 °C < T_A < 125 °C		1.203	1.213	1.223	
V_{ref}	Feedback regulation voltage (FBN)			–36	0	36	mV
I_{IB}	Input bias current (FBN)				10	100	nA
$r_{DS(on)}$	Drain-source on-state resistance (Q4)	I_{DS} = 20 mA			4.4		Ω
$V_{(DRVN)}$	Current sink voltage drop(2)	$V_{(FBN)}$ = 5% above nominal voltage	$I_{(DRVN)}$ = 50 mA		130	300	mV
			$I_{(DRVN)}$ = 100 mA		280	450	
$\Delta V_{O(\Delta IO)}$	Load regulation	V_O = –5 V	I_O = 0 mA to 20 mA		0.016		%/mA

(1) The GD signal is latched low when the main boost converter output is within regulation. The GD signal is reset when the voltage on the VIN pin goes below the UVLO threshold voltage.
(2) The maximum charge pump output current is half the drive current of the internal current source or sink.

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Electrical Characteristics (continued)

V_I = 3.3 V, $V_{(VS)}$ = 10 V, T_A = –40°C to 125°C, typical values are at T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
POSITIVE CHARGE PUMP							
V_O	Output voltage	CTRL = GND	VGH = open			30	V
V_{ref}	Feedback regulation voltage (FBP)	CTRL = GND	VGH = open	1.187	1.214	1.238	V
I_{IB}	Input bias current (FBP)	CTRL = GND	VGH = open		10	100	nA
$r_{DS(on)}$	Drain-source on-state resistance (Q3)	I_{DS} = 20 mA			1.1		Ω
$V_{(SUP)} - V_{(DRVP)}$	Current sink voltage drop (2)	$V_{(FBP)}$ = 5% below nominal voltage	$I_{(DRVP)}$ = 50 mA		420	650	mV
			$I_{(DRVP)}$= 100 mA		900	1400	
$\Delta V_{O(\Delta IO)}$	Load regulation	V_O = 24 V	I_O = 0 mA to 20 mA		0.07		%/mA
GATE-VOLTAGE SHAPING							
$r_{DS(on)}$	Drain-source on-state resistance (Q5)	I_O = –20 mA			12	30	Ω
$I_{(ADJ)}$	Capacitor charge current	$V_{(ADJ)}$ = 20 V	$V_{(CPI)}$ = 30 V	160	200	240	µA
$V_O$min	Minimum output voltage	$V_{(ADJ)}$ = 0 V	I_O = –10 mA		2		V
I_{OM}	Maximum output current			20			mA
TIMING CIRCUITS DLY1, DLY2, FDLY							
$I_{(DLY1)}$	Drive current into delay capacitor (DLY1)	$V_{(DLY1)}$ = 1.213 V		3	5	7	µA
$I_{(DLY2)}$	Drive current into delay capacitor (DLY2)	$V_{(DLY2)}$ = 1.213 V		3	5	7	µA
$R_{(FDLY)}$	Fault time delay resistor			250	450	650	kΩ
GATE DRIVE (GD)							
$V_{(GD\_VS)}$	Gate Drive Threshold	$V_{(VS)}$ rising		–12% of $V_{(SUP)}$		–4% of $V_{(SUP)}$	
V_{OL}	Low-level output voltage (GD)	I_{OL} = 500 µA				0.5	V
I_{OH}	Off-state current (GD)	V_{OH} = 15 V			0.001	1	µA
VCOM BUFFER							
V_{ISR}	Single-ended input voltage (IN)			2.25		$V_{(SUP)}$ – 2 V	V
V_{IO}	Input offset voltage (IN)	I_O = 0 mA		–25		25	mV
$\Delta V_{O(\Delta IO)}$	Load regulation	I_O = ±25 mA		–37		37	mV
		I_O = ±50 mA		–77		55	
		I_O = ±100 mA		–85		85	
		I_O = ±150 mA		–110		110	
I_{IB}	Input bias current (IN)			–300	–30	300	nA
I_{OM}	Maximum output current (VCOM)	$V_{(SUP)}$ = 15 V		1.2			A
		$V_{(SUP)}$ = 10 V		0.65			
		$V_{(SUP)}$ = 5 V		0.15			

6.6 Switching Characteristics

over operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Oscillator frequency		1.02	1.2	1.38	MHz
Duty cycle (DRVN)			50%		
Duty cycle (DRVP)			50%		

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6.7 Typical Characteristics

The typical characteristics are measured at 3.3 V

Table 1. Table Of Graphs

		FIGURE
Boost converter switch (Q1) current limit	vs temperature	Figure 1
Boost converter switch (Q1) $r_{DS(on)}$	vs temperature	Figure 2
Boost converter rectifier (Q2) $r_{DS(on)}$	vs temperature	Figure 3
Boost converter reference Voltage	vs temperature	Figure 4
Positive charge pump reference voltage	vs temperature	Figure 5
REF pin voltage	vs temperature	Figure 6
Oscillator frequency	vs temperature	Figure 7

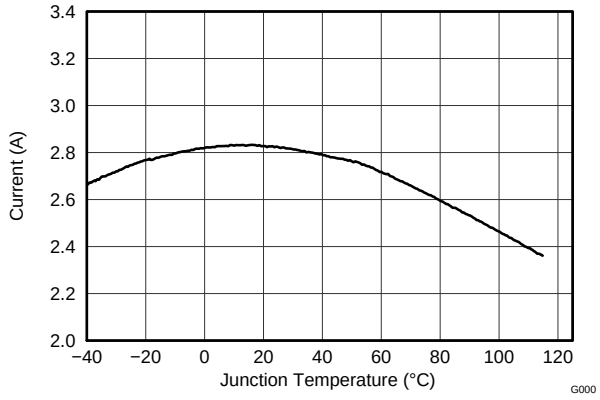

Figure 1. Boost Converter Switch (Q1) Current Limit vs Temperature

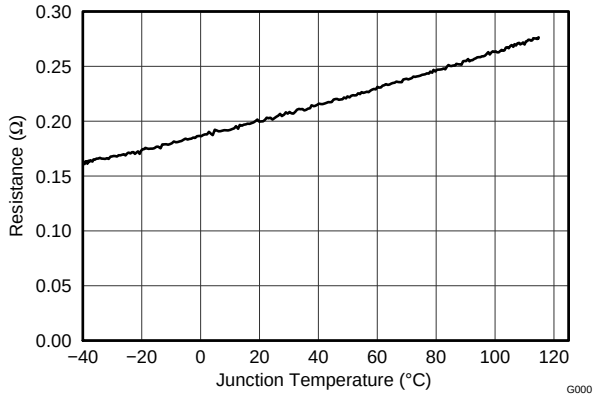

Figure 2. Boost Converter Switch (Q1) $r_{DS(on)}$ vs Temperature

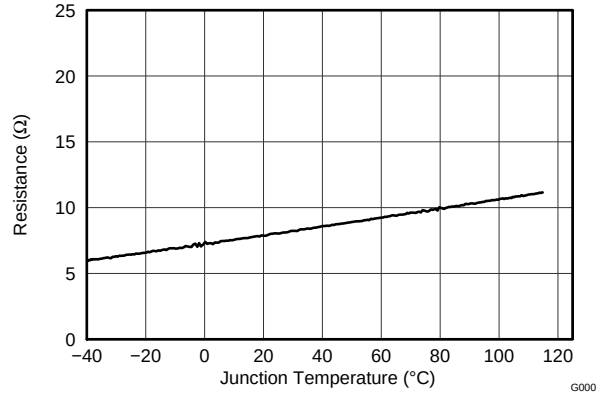

Figure 3. Boost Converter Rectifier (Q2) $r_{DS(on)}$ vs Temperature

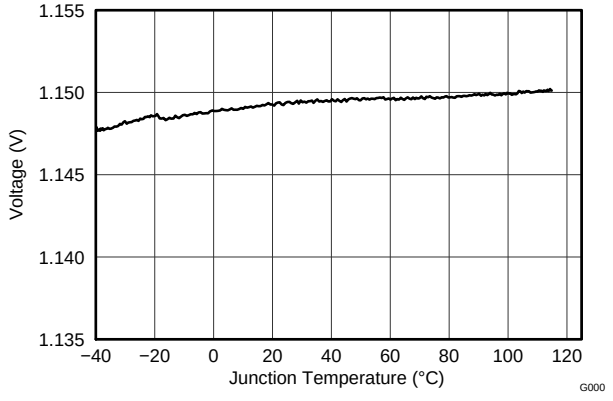

Figure 4. Boost Converter Reference Voltage vs Temperature

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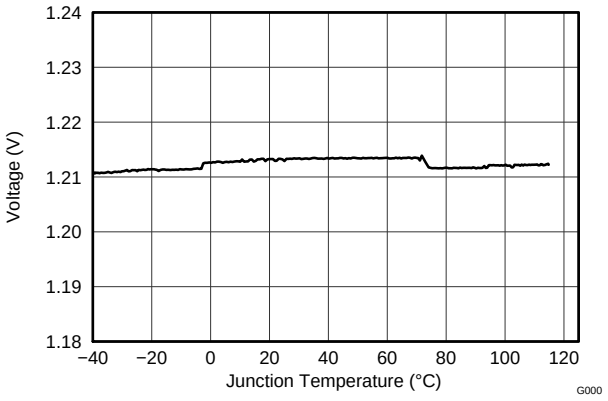

Figure 5. Positive Charge Pump Reference Voltage vs Temperature

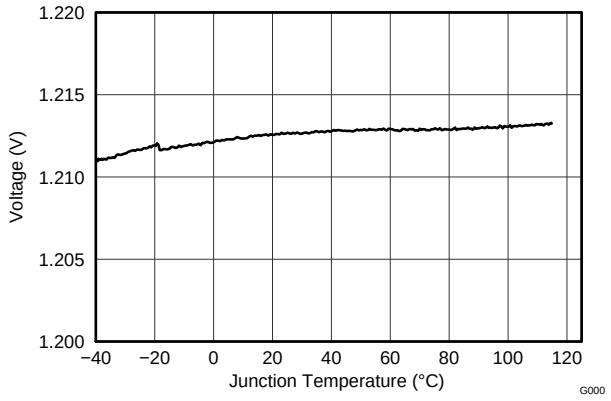

Figure 6. REF Pin Voltage vs Temperature

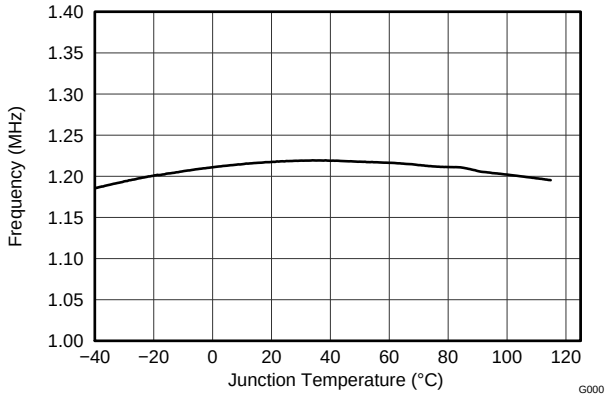

Figure 7. Oscillator Frequency vs Temperature

7 Detailed Description

7.1 Overview

The TPS65150-Q1 device is a complete bias supply for LCD displays. The device generates supply voltages for the source driver and gate driver ICs in the display as well as generating the common plane voltage of the display (V_{COM}). The device also features a gate-voltage shaping function that can be used to reduce image sticking and improve picture quality. The use of external components to control power-up sequencing, fault detection time, and boost converter compensation allows the device to be optimized for a variety of displays.

The device has been designed to work from input supply voltages as low as 1.8 V and is therefore ideal for use in applications where it is supplied from fixed 2.5-V, 3.3-V, or 5-V supplies.

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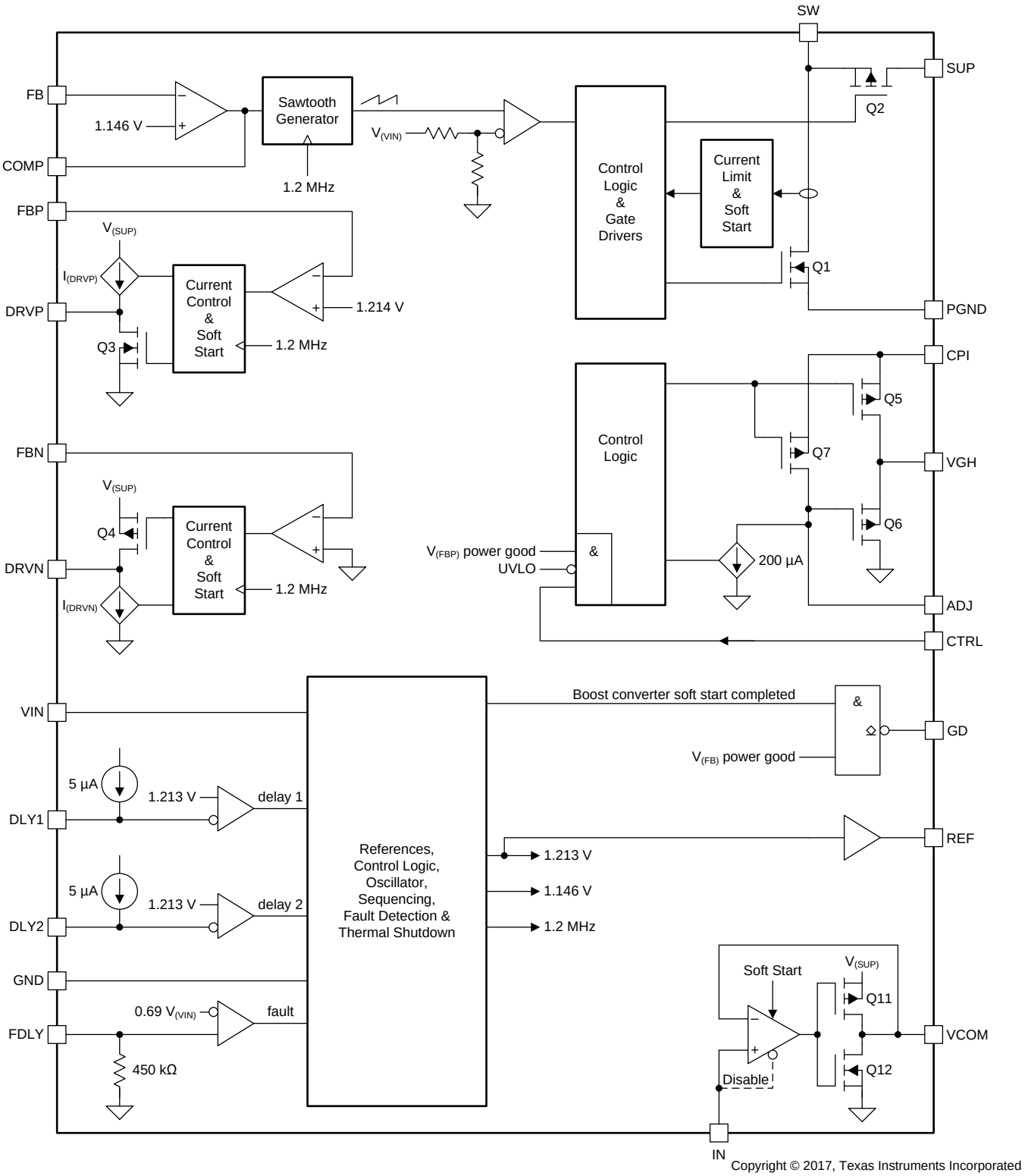
7.2 Functional Block Diagram



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7.3 Feature Description

7.3.1 Boost Converter

Figure 8 shows a simplified block diagram of the boost converter.

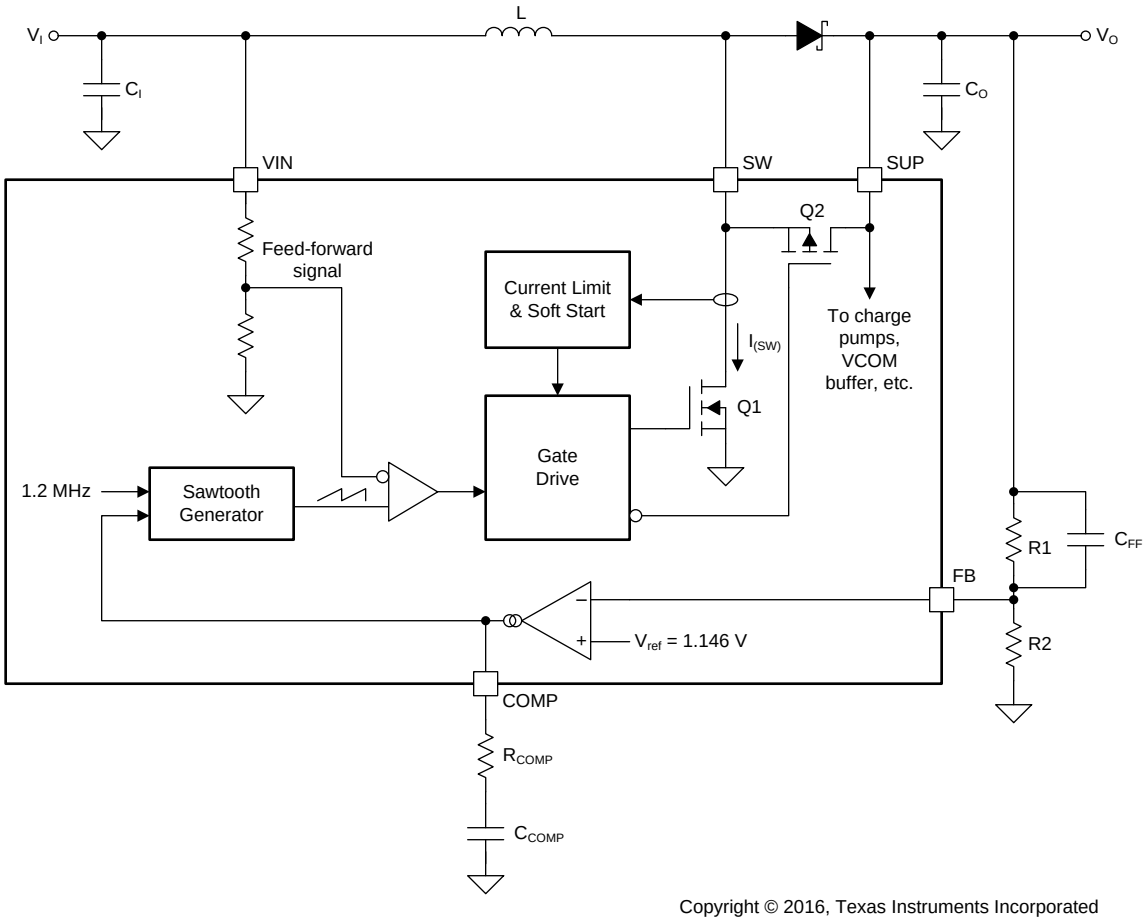

Figure 8. Boost Converter Block Diagram

The boost converter uses a unique fast-response voltage-mode controller scheme with input feedforward to achieve excellent line and load regulation, while still allowing the use of small external components. The use of external compensation adds flexibility and allows the response of the boost converter to be optimized for a wide range of external components.

The TPS65150-Q1 device uses a virtual-synchronous topology that allows the boost converter to operate in continuous conduction mode (CCM) even at light loads. This is achieved by including a small MOSFET (Q2) in parallel with the external rectifier diode. Under light-load conditions, Q2 allows the inductor current to become negative, maintaining operation in CCM. By operating always in CCM, boost converter compensation is simplified, ringing on the SW pin at low loads is avoided, and additional charge pump stages can be driven by the SW pin. The boost converter duty cycle is given by Equation 1.

$$D = 1 - \frac{\eta V_I}{V_O} \quad (1)$$

where

- η is the boost converter efficiency (either taken from data in *Application Curves* or a worst-case assumption of 75%),
- V_I is the boost converter input supply voltage, and
- V_O is the boost converter output voltage.

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Feature Description (continued)

Use Equation 2 to calculate the boost converter peak switch current.

$$I_{(SW)M} = \frac{DV_I}{2fL} + \frac{I_O}{1 - D} \quad (2)$$

where

- f = 1.2 MHz (the boost converter switching frequency),
- I_O is the boost converter output current, and
- L is the boost converter inductance.

7.3.1.1 Setting the Boost Converter Output Voltage

The boost converter output voltage is set by the R1/R2 resistor divider, and is calculated using Equation 3.

$$V_O = \left(1 + \frac{R1}{R2}\right) V_{ref} \quad (3)$$

where

- V_{ref} = 1.146 V (the boost converter internal reference voltage).

To minimize quiescent current consumption, the value of R1 should be in the range of 100 kΩ to 1 MΩ.

7.3.1.2 Boost Converter Rectifier Diode

The reverse voltage rating of the diode must be higher than the maximum output voltage of the converter, and its average forward current rating must be higher than the output current of the boost converter. Use Equation 4 to calculate the rectifier diode repetitive peak forward current.

$$I_{FRM} = I_{(SW)M} \quad (4)$$

Use Equation 5 to calculate the power dissipated in the rectifier diode.

$$P_D = V_F I_O \quad (5)$$

where

- V_F is the rectifier diode forward voltage.

The main diode parameters affecting converter efficiency are its forward voltage and reverse leakage current, and both should be as low as possible.

7.3.1.3 Choosing the Boost Converter Output Capacitance

The output capacitance of the boost converter smooths the output voltage and supplies transient output current demands that are outside the loop bandwidth of the converter. Generally speaking, larger output currents or smaller input supply voltages require larger output capacitances. Use Equation 6 to calculate the output voltage ripple of the boost converter.

$$V_{O(PP)} = \frac{DI_O}{fC_O} \quad (6)$$

where

- C_O is the boost converter output capacitance.

7.3.1.4 Compensation

The boost converter requires a series R-C network connected between the COMP pin and ground to compensate its feedback loop. The COMP pin is the output of the boost converter's error amplifier, and the compensation capacitor determines the amplifier's low-frequency gain and the resistor its high-frequency gain. Because the converter gain changes with the input voltage, different compensation capacitors may be required: lower input voltages require a higher gain, and therefore a smaller compensation capacitor value. If an input supply voltage of the application changes (for example, if the TPS65150-Q1 device is supplied from a battery), choose compensation components suitable for a supply voltage midway between the minimum and maximum values. In all cases, verify that the values selected are suitable by performing transient tests over the full range of operating conditions.

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Feature Description (continued)

Table 2. Recommended Compensation Components for Different Input Supply Voltages

V_I	C_{COMP}	R_{COMP}	FEED-FORWARD ZERO CUT-OFF FREQUENCY
2.5 V	470 pF	68 kΩ	8.8 kHz
3.3 V	470 pF	33 kΩ	7.8 kHz
5 V	2.2 nF	0 kΩ	11.2 kHz

A feed-forward capacitor C_{FF} in parallel with the upper feedback resistor R1 adds an additional zero to the loop response, which improves transient performance. Table 2 suggests suitable values for the cut-off frequency of the feedforward zero; however, these are only guidelines. In any application, variations in input supply voltage, inductance, and output capacitance all affect circuit operation, and the optimum value must be verified with transient tests before being finalized.

The cut-off frequency of the feed-forward zero is determined using Equation 7.

$$f_{co} = \frac{1}{2\pi(R1)C_{FF}} \quad (7)$$

where

- f_{co} is the cutoff frequency of the feedforward zero formed by R1 and C_{FF}.

7.3.1.5 Soft Start

The boost converter features a soft-start function that limits the current drawn from the input supply during start-up. During the first 2048 switching cycles, the switch current of the boost converter is limited to 40% of its maximum value; during the next 2048 cycles, it is limited to 60% of its maximum value; and after that it is as high as it must be to regulate the output voltage (up to 100% of the maximum). In typical applications, this results in a start-up time of about 5 ms (see Figure 9).

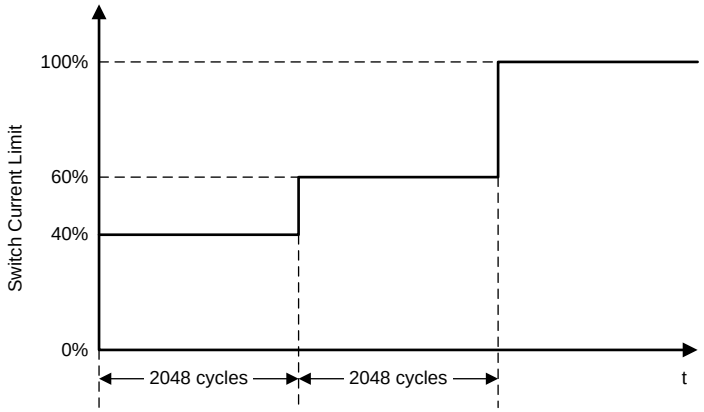

Figure 9. Boost Converter Switch Current Limit During Soft-Start

7.3.1.6 Gate Drive Signal

The GD pin provides a signal to control an external P-channel enhancement MOSFET, allowing the output of the boost converter to be isolated from its input when disabled (see Figure 36). The GD pin is an open-drain type whose output is latched low as soon as the output voltage of the boost converter reaches its power-good threshold. The GD pin goes high impedance whenever the input voltage falls below the undervoltage lockout threshold or the device shuts down as the result of a fault condition (see *Adjustable Fault Delay*).

7.3.2 Negative Charge Pump

Figure 10 shows a simplified block diagram of the negative charge pump.

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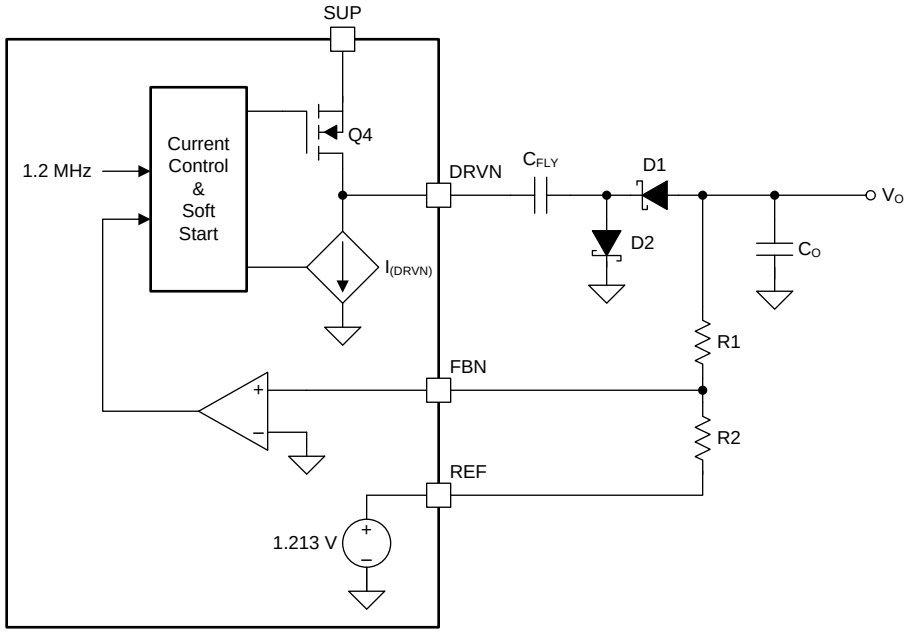

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Figure 10. Negative Charge Pump Block Diagram

The negative charge pump operates with a fixed frequency of 1.2 MHz and a 50% duty cycle in two distinct phases. During the charge phase, transistor Q4 is turned on, controlled current source $I_{(DRVN)}$ is turned off, and flying capacitance C_{FLY} charges up to approximately $V_{(SUP)}$. During the discharge phase, Q4 is turned off, $I_{(DRVN)}$ is turned on, and a negative current of $I_{(DRVN)}$ flows through D1 to the output. The output voltage is fed back through R1 and R2 to an error amplifier that controls $I_{(DRVN)}$ so that the output voltage is regulated at the correct value.

7.3.2.1 Negative Charge Pump Output Voltage

The negative charge pump output voltage is set by resistors R1 and R2 and is given by Equation 8.

$$V_O = -\left(\frac{R1}{R2}\right) V_{(REF)} \quad (8)$$

where

- $V_{(REF)}$ = 1.213 V (the voltage on the REF pin).

Resistor R2 should be in the range 39 kΩ to 150 kΩ. Smaller values load the REF pin too heavily and larger values may cause stability problems.

7.3.2.2 Negative Charge Pump Flying Capacitance

The flying capacitance transfers charge from the SUP pin to the negative charge pump output. TI recommends a flying capacitor of at least 100 nF for output currents up to 20 mA. Smaller values can be used with smaller output currents.

7.3.2.3 Negative Charge Pump Output Capacitance

The output capacitor smooths the discontinuous current delivered by the flying capacitor to generate a DC output voltage. In general, higher output currents require larger output capacitances. Use Equation 9 to calculate the negative charge pump output voltage ripple.

$$V_{O(PP)} = \frac{I_O}{2fC_O}$$

where

- I_O is the negative charge pump output current,
- C_O is the negative charge pump output capacitance, and
- f = 1.2 MHz (the negative charge pump switching frequency). (9)

7.3.2.4 Negative Charge Pump Diodes

The average forward current of both diodes is equal to the negative charge pump output current. If the recommended flying capacitor (or larger) is used, the repetitive peak forward current in D1 and D2 is equal to twice the output current.

7.3.3 Positive Charge Pump

Figure 11 shows a simplified block diagram of the positive charge pump, which works in a similar way to the negative charge pump except that the positions of the current source I_{DRVP} and the MOSFET Q3 are reversed.

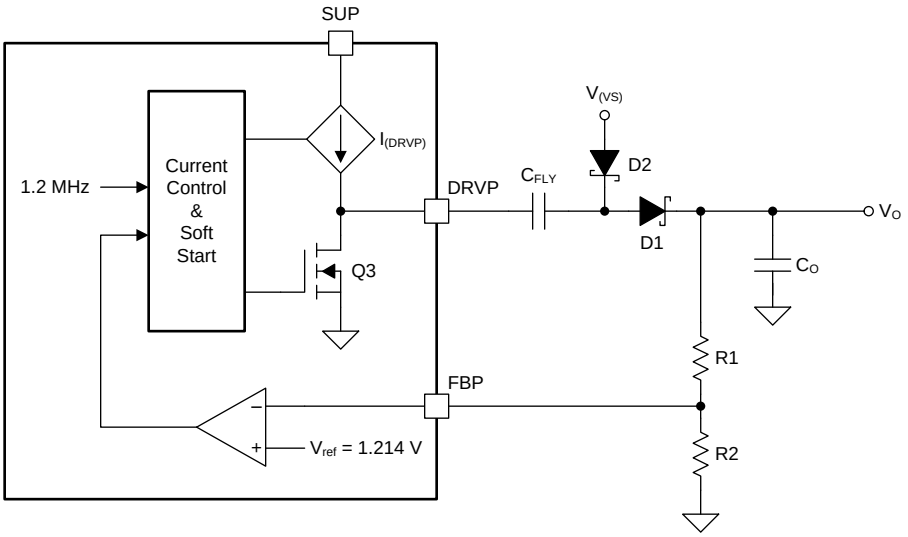

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Figure 11. Positive Charge Pump Block Diagram

If higher output voltages are required another charge pump stage can be added to the output, as shown in Figure 34 at the end of the data sheet.

7.3.3.1 Positive Charge Pump Output Voltage

The positive charge pump output voltage is set by resistors R1 and R2 and is calculated using Equation 10.

$$V_O = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

where

- V_{ref} = 1.214 V (the positive charge pump reference voltage). (10)

TI recommends choosing a value for R2 not greater than 1 MΩ.

7.3.3.2 Positive Charge Pump Flying Capacitance

The flying capacitance transfers charge from the SUP pin to the charge pump output. TI recommends a flying capacitor of at least 330 nF (1) for output currents up to 20 mA. Smaller values can be used with smaller output currents.

(1) The minimum recommended flying capacitance for the positive charge pump is larger than for the negative charge pump because the $r_{DS(on)}$ of Q3 is smaller than the $r_{DS(on)}$ of Q4.

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7.3.3.3 Positive Charge Pump Output Capacitance

The output voltage ripple of the positive charge pump is given by Equation 11.

$$V_{O(PP)} = \frac{I_O}{2fC_O}$$

where

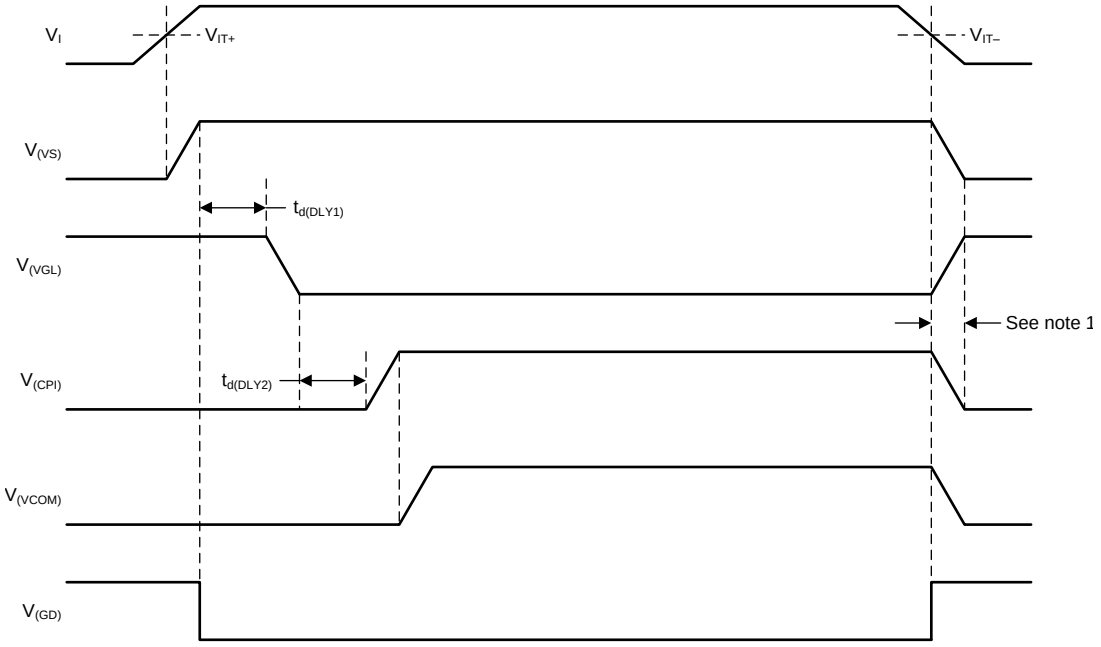
- I_O is the output current of the positive charge pump,
- C_O is the output capacitance of the positive charge pump, and
- f = 1.2 MHz (the switching frequency of the positive charge pump). (11)

7.3.3.4 Positive Charge Pump Diodes

The average forward current of both diodes is equal to the positive charge pump output current. If the recommended flying capacitance (or larger) is used, the repetitive peak forward current in D1 and D2 equal to twice the output current.

7.3.4 Power-On Sequencing, DLY1, DLY2

The boost converter starts as soon as the input supply voltage exceeds the rising UVLO threshold. The negative charge pump starts $t_{d(DLY1)}$ seconds after the boost converter output voltage has reached its final value, and the positive charge pump starts $t_{d(DLY2)}$ seconds after the output of the negative charge pump has reached its final value. The VCOM buffer starts up as soon as the output voltage of the positive charge pump ($V_{(CPI)}$) has reached its final value.



Notes
1. The fall times of $V_{(VS)}$, $V_{(VGL)}$, $V_{(CPI)}$ depend on their respective load currents and feedback resistances.

Figure 12. Start-Up Sequencing With CTRL = High

The delay times $t_{d(DLY1)}$ and $t_{d(DLY2)}$ are set by the capacitors connected to the DLY1 and DLY2 pins respectively. Each of these pins is connected to its own 5-µA current source ($I_{(DLY1)}$ and $I_{(DLY2)}$) that causes the voltage on the external capacitor to ramp up linearly. The delay time is defined by how long it takes the voltage on the external capacitor to reach the reference voltage, and is given by Equation 12.

$$t_{d(DLY1)} = \frac{C_{DLY1}V_{ref}}{I_{(DLY1)}} \text{ and } t_{d(DLY2)} = \frac{C_{DLY2}V_{ref}}{I_{(DLY2)}}$$

where

- V_{ref} = 1.213 V (the internal reference voltage),
- $I_{(DLY1)}$ = 5 µA (the DLY1 pin output current), and
- $I_{(DLY2)}$ = 5 µA (the DLY2 pin output current). (12)

7.3.5 Gate Voltage Shaping

The gate voltage shaping function can be used to reduce crosstalk between LCD pixels by reducing the gate drivers' input supply voltage between lines. Figure 13 shows a simplified block diagram of the gate voltage shaping function. Gate voltage shaping is controlled by a logic-level signal applied to the CTRL pin. When CTRL is high, Q5 and Q7 are on and Q6 is off, and the output of the positive charge pump is connected to the VGH pin. When CTRL is low, Q5 and Q7 are off and Q6 is on. Q6 operates as a source follower and tracks the voltage on the ADJ pin, which ramps down linearly as the current sink $I_{(ADJ)}$ discharges the external capacitor C_{ADJ} (see Figure 14). The peak-to-peak voltage on the VGH pin is determined by the value of C_{ADJ} and the duration of the low level applied to the CTRL pin, and is calculated using Equation 13.

$$V_{(VGH)(PP)} = \frac{I_{(ADJ)} t_{w(CTRL)}}{C_{ADJ}}$$

where

- $I_{(ADJ)}$ = 200 µA (ADJ pin output current),
- $t_{w(CTRL)}$ is the duration of the low-level signal connected to the CTRL pin, and
- C_{ADJ} is the capacitance connected to the ADJ pin. (13)

When the input supply voltage is below the UVLO threshold or the device enters a shutdown condition because of a fault on one or more of its outputs, Q5 and Q6 turn off and the VGH pin is high impedance.

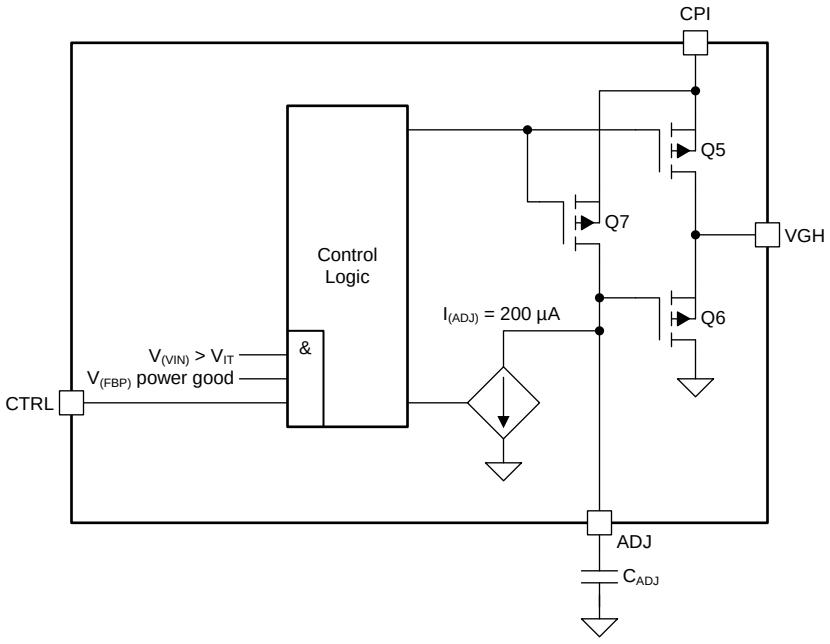


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Figure 13. Gate Voltage Shaping Block Diagram

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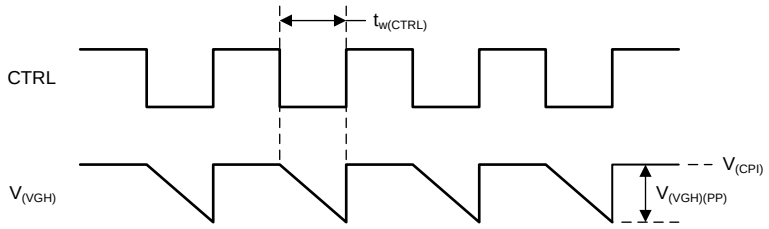

Figure 14. Gate Voltage Shaping Timing

7.3.6 VCOM Buffer

The VCOM Buffer is a transconductance amplifier designed to drive capacitive loads. The IN pin is the input of the VCOM buffer. The VCOM buffer features a soft-start function that reduces the current drawn from the SUP pin when the amplifier starts up.

If the VCOM buffer is not required for certain applications, it is possible to shut down the VCOM buffer by connecting IN to ground, reducing the overall quiescent current. The IN pin cannot be pulled dynamically to ground during operation.

7.3.7 Protection

7.3.7.1 Boost Converter Overvoltage Protection

The boost converter features an overvoltage protection function that monitors the voltage on the SUP pin and forces the TPS65150-Q1 device to enter fault mode if the boost converter output voltage exceeds the overvoltage threshold.

7.3.7.2 Adjustable Fault Delay

The TPS65150-Q1 device detects a fault condition and shuts down if the boost converter output or either of the charge pump outputs falls out of regulation for longer than the fault delay time $t_{d(FDLY)}$. Fault conditions are detected by comparing the voltage on the feedback pins with the internal power-good thresholds. Outputs that fall below their power-good threshold but recover within less than $t_{d(FDLY)}$ seconds are not detected as faults and the device does not shut down in such cases. The output fault detection function is active during start-up, so the device shuts down if any of its outputs fails to reach its power-good threshold during start-up. Shut-down following an output voltage fault is a latched condition, and the input supply voltage must be cycled to recover normal operation after it occurs.

The fault detection delay time is set by the capacitor connected between the FDLY and VIN pins and is given by Equation 14.

$$t_{d(FDLY)} = R_{(FDLY)} C_{FDLY} \quad (14)$$

where

- $R_{(FDLY)}$ = 450 kΩ (the internal resistance connected to the FDLY pin) and
- C_{FDLY} is the external capacitance connected to the FDLY pin.

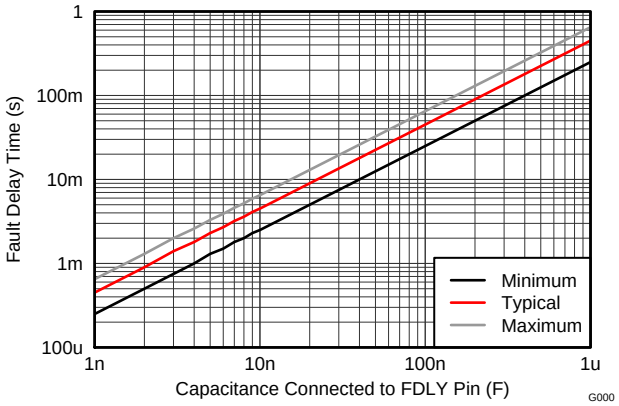

Figure 15. Adjustable Fault Delay Time

7.3.7.3 Thermal Shutdown

A thermal shutdown is implemented to prevent damage because of excessive heat and power dissipation. Typically, the thermal shutdown threshold is 155°C. When this threshold is reached, the device enters shutdown. The device can be enabled again by cycling the input supply voltage.

7.3.7.4 Undervoltage Lockout

The TPS65150-Q1 device has an undervoltage lockout (UVLO) function. The UVLO function stops device operation if the voltage on the VIN pin is less than the UVLO threshold voltage. This makes sure that the device only operates when the supply voltage is high enough for correct operation.

7.4 Device Functional Modes

Figure 16 shows the functional modes of the TPS65150-Q1.

7.4.1 $V_I > V_{IT+}$

When the input supply voltage is above the undervoltage lockout threshold, the device is on and all its functions are enabled. Note that full performance may not be available until the input supply voltage exceeds the minimum value specified in *Recommended Operating Conditions*.

7.4.2 $V_I < V_{IT-}$

When the input supply voltage is below the undervoltage lockout threshold, the TPS65150-Q1 device is off and all its functions are disabled.

7.4.3 Fault Mode

The TPS65150-Q1 device immediately enters fault mode when any of the following is detected:

- boost converter overvoltage
- overtemperature

The TPS65150-Q1 device also enters fault mode if any of the following conditions is detected and persists for longer than $t_{d(FDLY)}$:

- boost converter output out of regulation
- negative charge pump output out of regulation
- positive charge pump output out of regulation

The TPS65150-Q1 device does not function during fault mode. Cycle the input supply voltage to exit fault mode and recover normal operation.

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Device Functional Modes (continued)

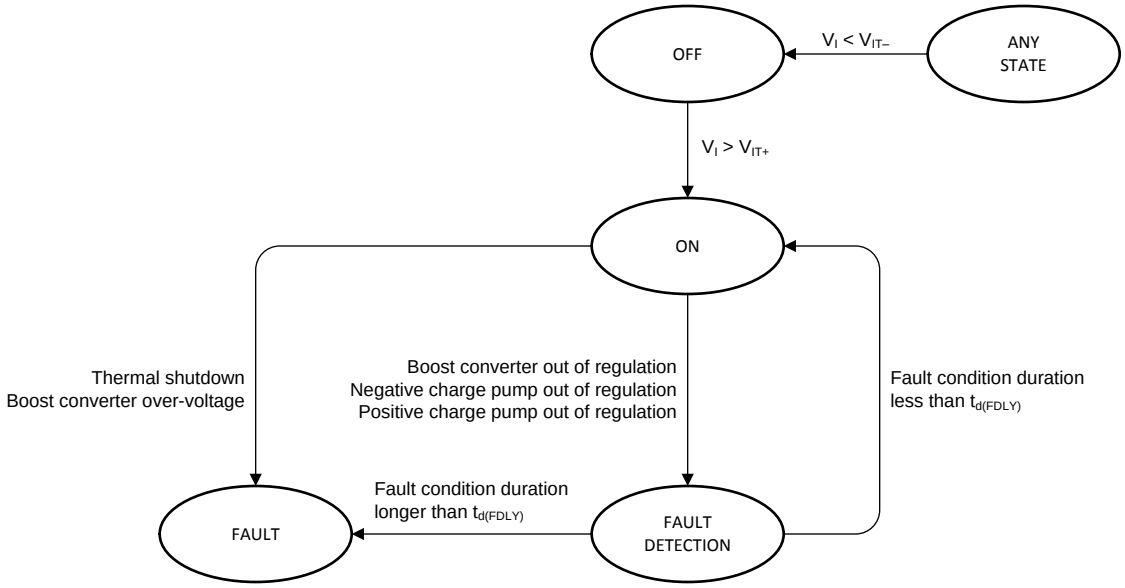

Figure 16. Functional Modes

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TPS65150-Q1 device has been designed to provide the input supply voltages for the source drivers and gate drivers plus the voltage for the common plane in LCD display applications. In addition, the device provides a gate voltage shaping function that can be used to modulate the gate drivers' positive supply to reduce image sticking.

8.2 Typical Application

Figure 17 shows a typical application circuit for a monitor display powered from a 5-V supply. It generates up to 450 mA at 13.5 V to power the source drivers, and 20 mA at 23 V and –5 V to power the gate drivers.

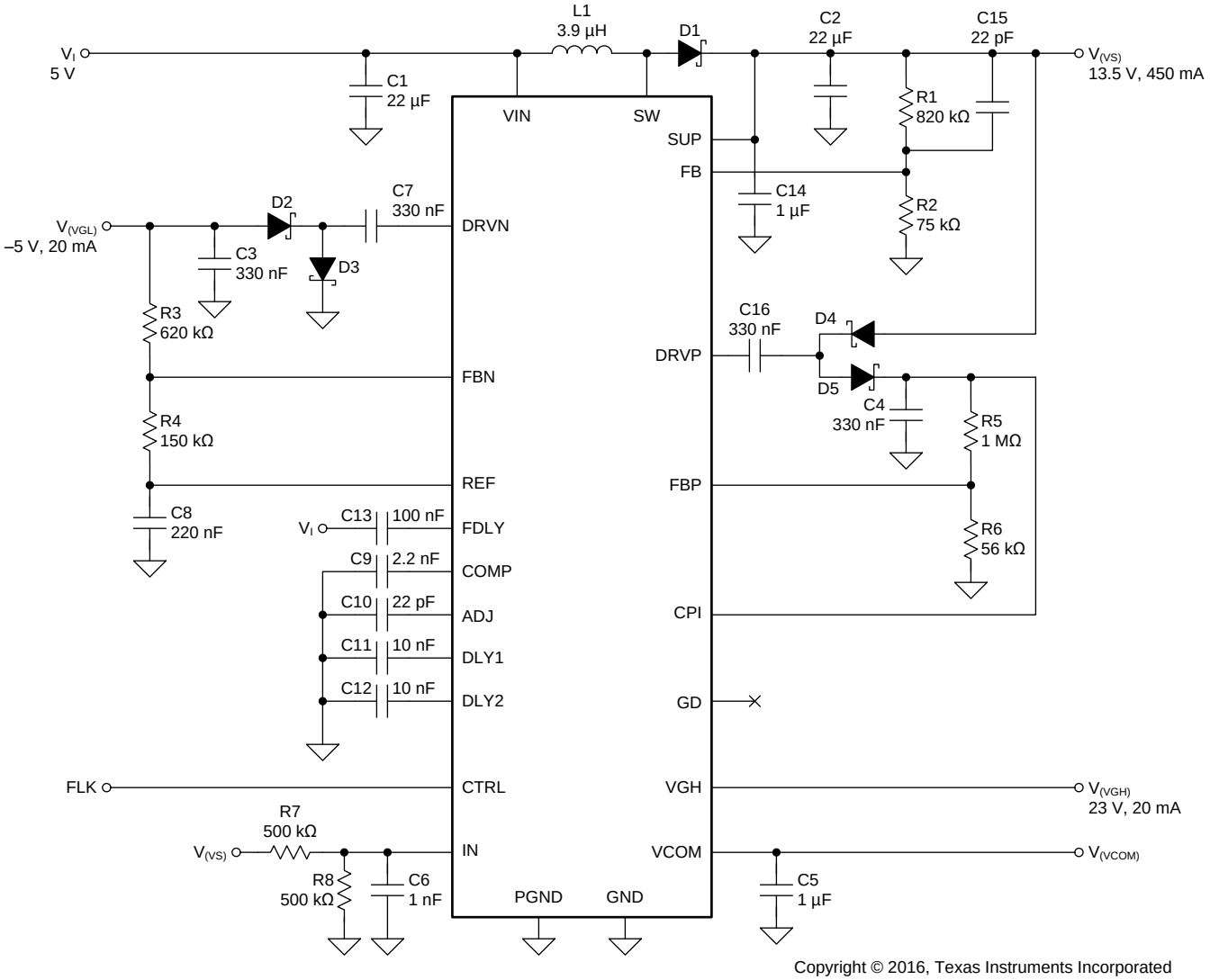

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Figure 17. Monitor LCD Supply Powered from a 5-V Rail

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Typical Application (continued)

8.2.1 Design Requirements

Table 3 shows the parameters for this example.

Table 3. Design Parameters

PARAMETER		VALUE
V_I	Input supply voltage	5 V
$V_{(VS)}$	Boost converter output voltage and current	13.5 V at 450 mA
$V_{(VS)(PP)}$	Boost converter peak-to-peak output voltage ripple	10 mV
$V_{(CPI)}$	Positive charge pump output voltage and current	23 V at 20 mA
$V_{(VGH)(PP)}$	Positive charge pump peak-to-peak output voltage ripple	100 mV
$V_{(VGL)}$	Negative charge pump output voltage and current	–5 V at 20 mA
$V_{(VGL)(PP)}$	Negative charge pump peak-to-peak output voltage ripple	100 mV
t_{d1}	Negative charge pump start-up delay time	1 ms
t_{d2}	Positive charge pump start-up delay time	1 ms
$t_{d(fault)}$	Fault delay time	45 ms
	Gate voltage shaping slope	10 V/µs

8.2.2 Detailed Design Procedure

8.2.2.1 Boost Converter Design Procedure

8.2.2.1.1 Inductor Selection

Several inductors work with the TPS65150-Q1, and with external compensation the performance can be adjusted to the specific application requirements.

The main parameter for the inductor selection is the inductor saturation current, which must be higher than the peak switch current as calculated in Equation 2 with additional margin to cover for heavy load transients. The alternative, more conservative approach, is to choose the inductor with a saturation current at least as high as the maximum switch current limit of 3.4 A.

The second important parameter is the inductor DC resistance. Usually, the lower the DC resistance the higher the efficiency. It is important to note that the inductor DC resistance is not the only parameter determining the efficiency. For a boost converter, where the inductor is the energy storage element, the type and material of the inductor influences the efficiency as well. Especially at a switching frequency of 1.2 MHz, inductor core losses, proximity effects, and skin effects become more important. Usually, an inductor with a larger form factor gives higher efficiency. The efficiency difference between different inductors can vary from 2% to 10%. For the TPS65150-Q1, inductor values from 3.3 µH and 6.8 µH are a good choice, but other values can be used as well. Possible inductors are shown in Table 4. Equivalent parts can also be used.

Table 4. Inductor Selection(1)

INDUCTANCE	I_{SAT}	DCR	MANUFACTURER	PART NUMBER	DIMENSIONS
4.7 µH	2.6 A	54 mΩ	Coilcraft	DO1813P-472HC	8.89 mm × 6.1 mm × 5 mm
4.2 µH	2.2 A	23 mΩ	Sumida	CDRH5D28-4R2	5.7 mm × 5.7 mm × 3 mm
4.7 µH	1.6 A	48 mΩ	Sumida	CDC5D23-4R7	6 mm × 6 mm × 2.5 mm
4.2 µH	1.8 A	60 mΩ	Sumida	CDRH6D12-4R2	6.5 mm × 6.5 mm × 1.5 mm
3.9 µH	2.6 A	20 mΩ	Sumida	CDRH6D28-3R9	7 mm × 7 mm × 3 mm
3.3 µH	1.9 A	50 mΩ	Sumida	CDRH6D12-3R3	6.5 mm × 6.5 mm × 1.5 mm

(1) See *Third-party Products* disclaimer

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The first step in the design procedure is to verify whether the maximum possible output current of the boost converter supports the specific application requirements. A simple approach is to estimate the converter efficiency, by taking the efficiency numbers from the provided efficiency curves, or use a worst case assumption for the expected efficiency, for example, 75%.

From Figure 19, it can be seen that the boost converter efficiency is about 85% when operating under the target application conditions. Inserting these values into Equation 1 yields Equation 15.

$$D = 1 - \frac{(0.85)(5\ V)}{13.5\ V} = 0.69 \quad (15)$$

and from Equation 2, the peak switch current can be calculated as Equation 16.

$$I_{(SW)M} = \frac{(0.69)(5\ V)}{2(1.2\ MHz)(3.9\ \mu H)} + \frac{(0.45\ A)}{1 - 0.69} = 1.8\ A \quad (16)$$

The peak switch current is the peak current that the integrated switch, inductor, and rectifier diode must be able to handle. The calculation must be done for the minimum input voltage where the peak switch current is highest. For the calculation of the maximum current delivered by the boost converter, it must be considered that the positive and negative charge pumps as well as the VCOM buffer run from the output of the boost converter as well.

8.2.2.2 Rectifier Diode Selection

The rectifier diode reverse voltage rating must be higher than the maximum output voltage of the converter (13.5 V in this application); its average forward current rating must be higher than the maximum boost converter output current of 450 mA, and its repetitive peak forward current must be greater than or equal to the peak switch current of 1.8 A. Not all diode manufacturers specify repetitive peak forward current; however, a diode with an average forward current rating of 1 A or higher is suitable for most practical applications.

From Equation 5, the power dissipated in the rectifier diode is calculated with Equation 17.

$$P_D = I_O V_F = (0.45\ A)(0.5\ V) = 0.225\ W \quad (17)$$

Table 5 lists a number of suitable rectifier diodes, any of which would be suitable for this application. Equivalent parts can also be used.

Table 5. Rectifier Diode Selection(1)

$I_{F(AV)}$	V_R	V_F	MANUFACTURER	PART NUMBER
2 A	20 V	0.44 V at 2 A	Vishay Semiconductor	SL22
2 A	20 V	0.5 V at 2 A	Fairchild Semiconductor	SS22
1 A	30 V	0.44 V at 2 A	Fairchild Semiconductor	MBRS130L
1 A	20 V	0.45 V at 1 A	Microsemi	UPS120
1 A	20 V	0.45 V at 1 A	ON Semiconductor	MBRM120

(1) See *Third-party Products* disclaimer.

8.2.2.3 Setting the Output Voltage

Rearranging Equation 3 and inserting the application parameters yields Equation 18.

$$\frac{R1}{R2} = \frac{13.5\ V}{1.146\ V} - 1 = 10.78 \quad (18)$$

Standard values of R1 = 820 kΩ and R2 = 75 kΩ result in a nominal output voltage of 13.68 V and satisfy the recommendation that the value R1 be lower than 1 MΩ.

8.2.2.4 Output Capacitor Selection

For best output voltage filtering, a low ESR output capacitor is recommended. Ceramic capacitors have a low ESR value, but tantalum capacitors can be used as well, depending on the application. A 22-µF ceramic output capacitor works for most applications. Higher capacitor values can be used to improve the load transient regulation. See Table 6 for the selection of the output capacitor.

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Rearranging Equation 6 and inserting the application parameters, the minimum value of output capacitance is given by Equation 19.

$$C_O = \frac{1 - 0.69}{(1.2\ \text{MHz})(10\ \text{mV})}\left(1.8\ \text{A} - 0.45\ \text{A} - \left(\frac{13.5\ \text{V} - 5\ \text{V}}{3.9\ \mu\text{H}}\right)\left(\frac{1 - 0.69}{1.2\ \text{MHz}}\right)\right) = 20.3\ \mu\text{F} \quad (19)$$

The closest standard value is 22 µF. In practice, TI recommends connecting an additional 1-µF capacitor directly to the SUP pin to ensure a clean supply to the internal circuitry that runs from this supply voltage.

8.2.2.5 Input Capacitor Selection

For good input voltage filtering, low ESR ceramic capacitors are recommended. A 22-µF ceramic input capacitor is sufficient for most applications. For better input voltage filtering, this value can be increased. See Table 6 for input capacitor recommendations. Equivalent parts can also be used.

Table 6. Input and Output Capacitance Selection

CAPACITANCE	VOLTAGE RATING	MANUFACTURER	PART NUMBER	SIZE
22 µF	16 V	Taiyo Yuden	EMK325BY226MM	1206
22 µF	6.3 V	Taiyo Yuden	JMK316BJ226	1206

8.2.2.6 Compensation

From Table 2, it can be seen that the recommended values for C9 and R9 when V_I = 5 V are 2.2 nF and 0 Ω respectively, and that a feedforward zero at 11.2 kHz must be added.

Rearranging Equation 7 yields Equation 20.

$$C15 = \frac{1}{2\pi f_{co}(R1)} \quad (20)$$

Inserting f_{co} = 11.2 kHz and R1 = 820 kΩ yields .

$$C15 = \frac{1}{2\pi(11.2\ \text{kHz})(820\ \text{k}\Omega)} = 17\ \text{pF}$$

In this case, a standard value of 22 pF was used.

8.2.2.7 Negative Charge Pump

8.2.2.7.1 Choosing the Output Capacitance

Rearranging Equation 9 and inserting the application parameters, the minimum recommended value of C3 is given by Equation 21.

$$C3 = \frac{I_O}{2fV_{O(PP)}} = \frac{20\ \text{mA}}{2(1.2\ \text{MHz})(100\ \text{mV})} = 83\ \text{nF} \quad (21)$$

In this application, a capacitor of 330 nF was used to allow the same value to be used for all charge pump capacitors.

8.2.2.7.2 Choosing the Flying Capacitance

A minimum flying capacitance of 100 nF is recommended. In this application, a capacitor of 330 nF was used to allow the same value to be used for all charge pump capacitors.

8.2.2.7.3 Choosing the Feedback Resistors

The ratio of R3 to R4 required to generate an output voltage of –5 V is given by Equation 22.

$$R3 = -\left(\frac{V_O}{V_{(REF)}}\right)R4 = -\left(\frac{-5\ \text{V}}{1.213\ \text{V}}\right)R4 = (4.122)R4 \quad (22)$$

Values of R3 = 620 kΩ and R4 = 150 kΩ generate a nominal output voltage of –5.014 V and load the REF pin with only 8 µA.

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8.2.2.7.4 Choosing the Diodes

The average forward current in D2 and D3 is equal to the output current and therefore a maximum of 20 mA. The peak repetitive forward current in D2 and D3 is equal to twice the output current and therefore less than 40 mA.

The BAT54S comprises two Schottky diodes in a small SOT-23 package and easily meets the current requirements of this application.

8.2.2.8 Positive Charge Pump

8.2.2.8.1 Choosing the Flying Capacitance

A minimum flying capacitor of 330 nF is recommended.

8.2.2.8.2 Choosing the Output Capacitance

Rearranging Equation 10 and inserting the application parameters yields Equation 23.

$$C4 = \frac{(20\ mA)}{2(1.2\ MHz)(100\ mV)} = 83\ nF \tag{23}$$

In this application, a nominal value of 330 nF was used to allow the same value to be used for all charge pump capacitors.

8.2.2.8.3 Choosing the Feedback Resistors

Rearranging Equation 8 and inserting the application parameters yields Equation 24.

$$\frac{R5}{R6} = \frac{23\ V}{1.214\ V} - 1 = 17.95 \tag{24}$$

Standard values of 1 MΩ and 56 kΩ result in a nominal output voltage of 22.89 V.

8.2.2.8.4 Choosing the Diodes

The average forward current in D4 and D5 is equal to the output current and therefore a maximum of 20 mA. The peak repetitive forward current in D4 and D5 is equal to twice the output current and therefore less than 40 mA.

8.2.2.9 Gate Voltage Shaping

Rearranging Equation 13 and inserting $I_{(ADJ)}$ = 200 µA and slope = 10 V/µs yields Equation 25.

$$C10 = \frac{I_{(ADJ)}}{slope} = \frac{200\ \mu A}{10\ V/\mu s} = 20\ pF \tag{25}$$

The closest standard value for C10 is 22 pF.

8.2.2.10 Power-On Sequencing

Rearranging Equation 12 and inserting $t_{d1} = t_{d2}$ = 1 ms and V_{ref2} = 1.213 V, yields Equation 26.

$$C11 = C12 = \frac{(5\ \mu A)(2.5\ ms)}{1.213\ V} = 10.31\ nF \tag{26}$$

10 nF is the closest standard value.

8.2.2.11 Fault Delay

Rearranging Equation 14 and inserting $t_{d(FDLY)}$ = 45 ms yields Equation 27.

$$C_{FDLY} = \frac{45\ ms}{450\ k\Omega} = 100\ nF \tag{27}$$

100 nF is a standard value.

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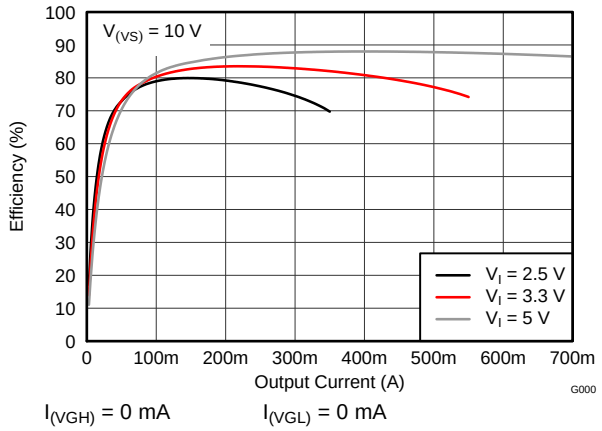
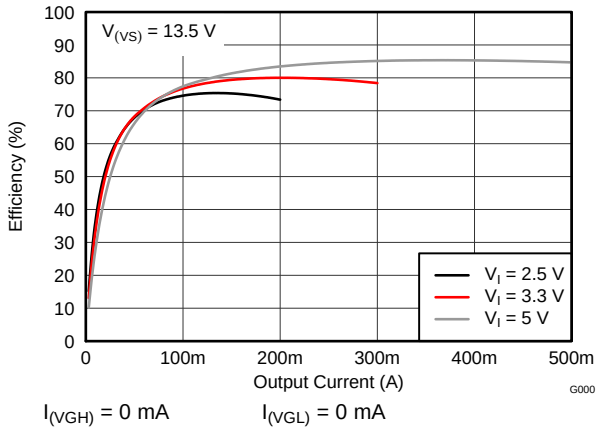
8.2.3 Application Curves



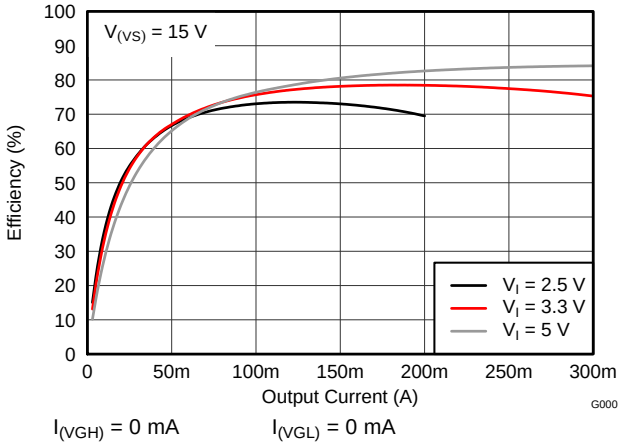
$I_{(VGH)}$ = 0 mA $I_{(VGL)}$ = 0 mA

Figure 18. Boost Converter Efficiency ($V_{(VS)}$ = 10 V, $I_{(VGH)}$ = $I_{(VGL)}$ = 0 mA)



$I_{(VGH)}$ = 0 mA $I_{(VGL)}$ = 0 mA

Figure 19. Boost Converter Efficiency ($V_{(VS)}$ = 13.5 V, $I_{(VGH)}$ = $I_{(VGL)}$ = 0 mA)



$I_{(VGH)}$ = 0 mA $I_{(VGL)}$ = 0 mA

Figure 20. Boost Converter Efficiency ($V_{(VS)}$ = 15 V, $I_{(VGH)}$ = $I_{(VGL)}$ = 0 mA)

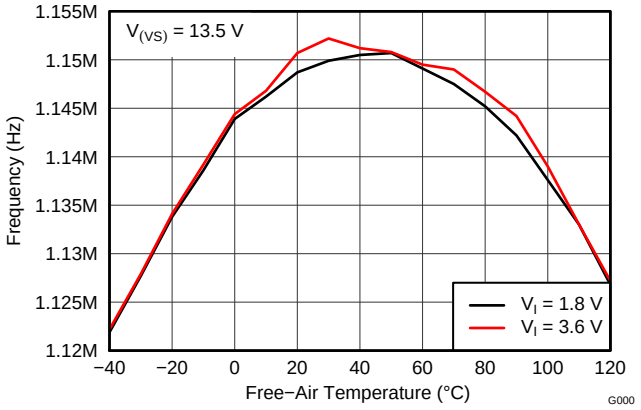


Figure 21. Boost Converter Switching Frequency

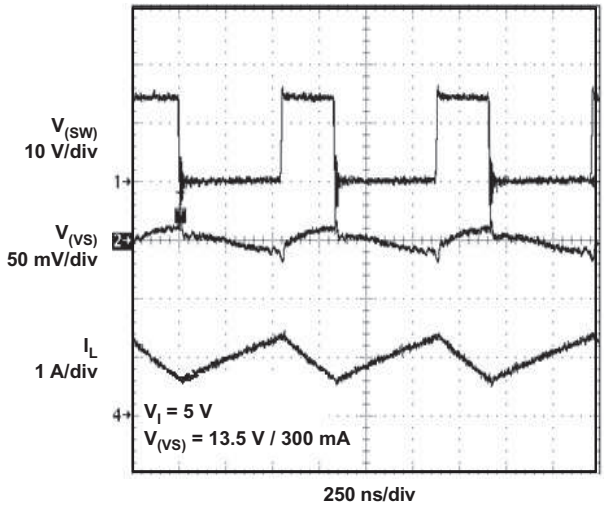


Figure 22. Boost Converter Operation (Nominal Load)

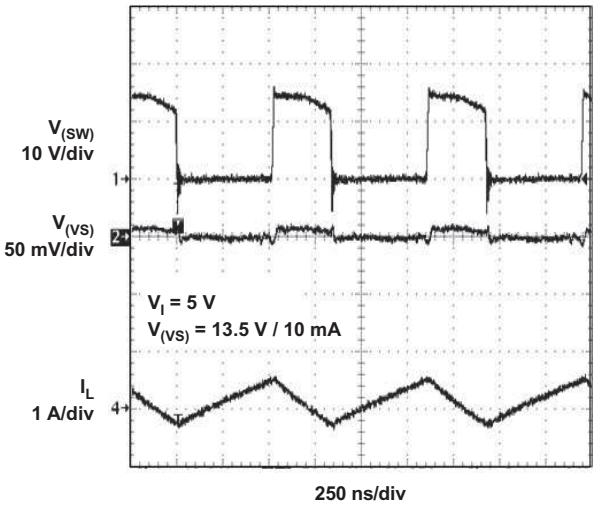


Figure 23. Boost Converter Operation (Light Load)

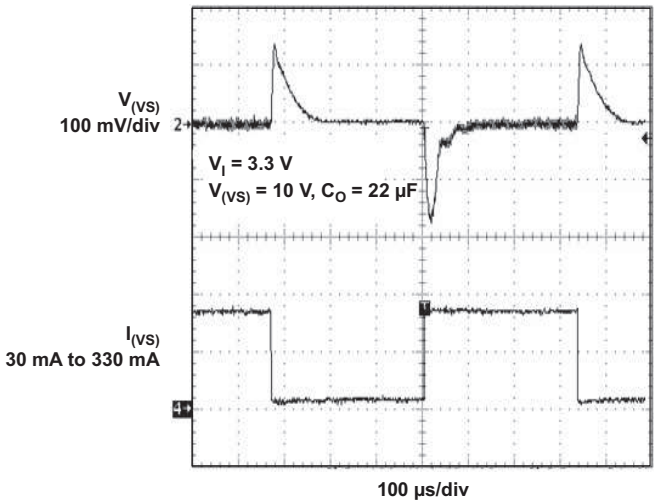


Figure 24. Boost Converter Load Transient Response

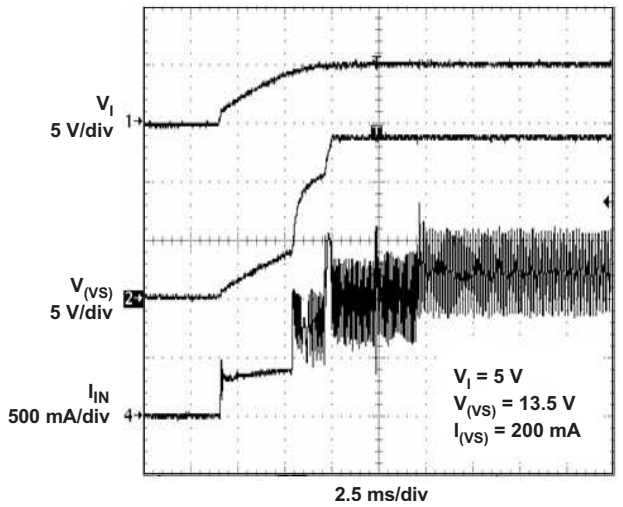


Figure 25. Boost Converter Soft Start

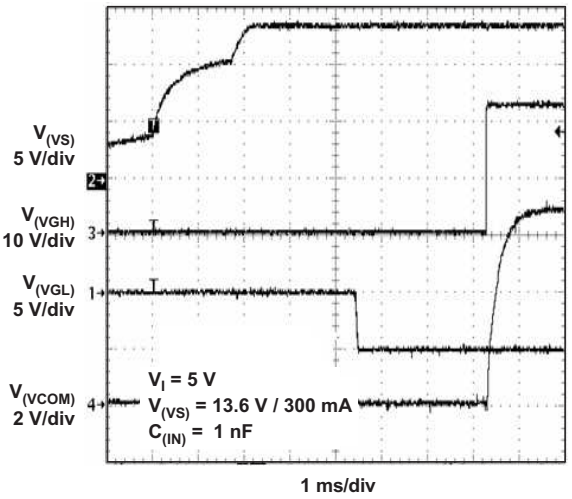


Figure 26. Power-On Sequencing

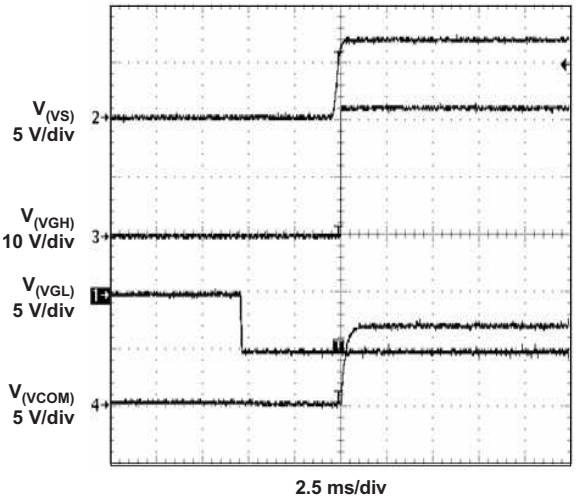


Figure 27. Power-On Sequencing With External Isolation MOSFET

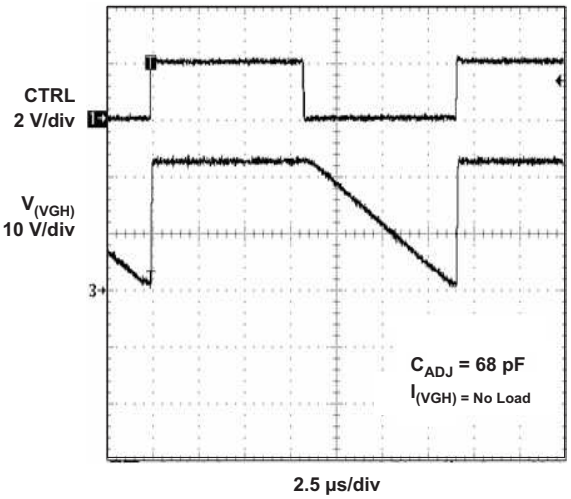


Figure 28. Gate Voltage Shaping

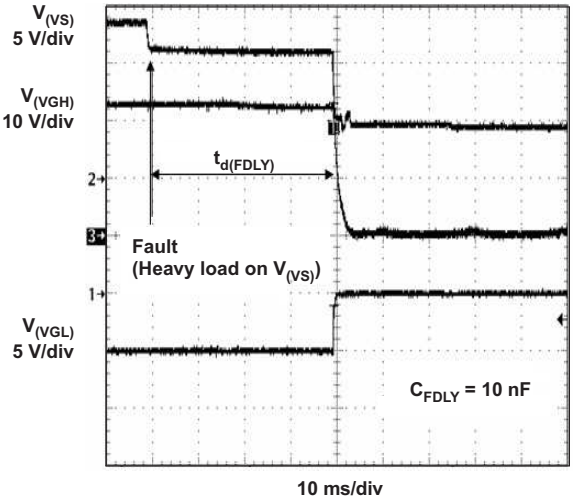


Figure 29. Adjustable Fault Detection Time

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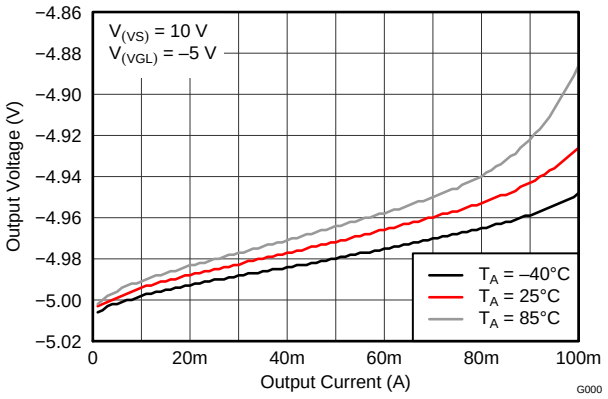

Figure 30. Negative Charge Pump Load Regulation

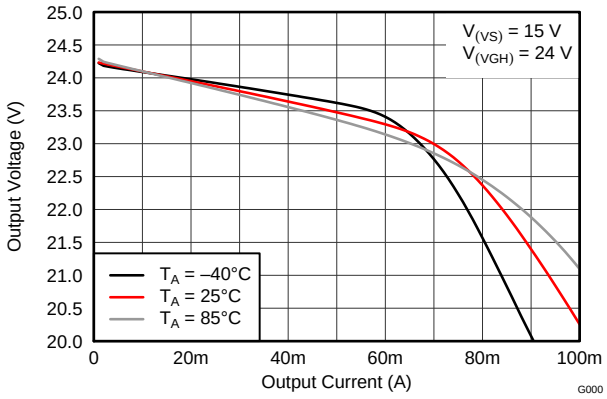

Figure 31. Positive Charge Pump Load Regulation (×2)

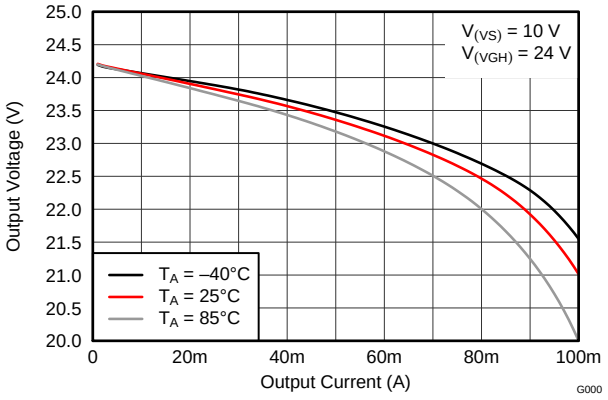

Figure 32. Positive Charge Pump Load Regulation (×3)

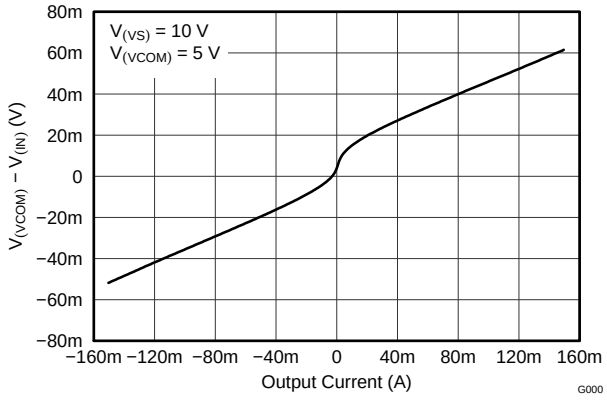

Figure 33. VCOM Buffer Load Regulation

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8.3 System Examples

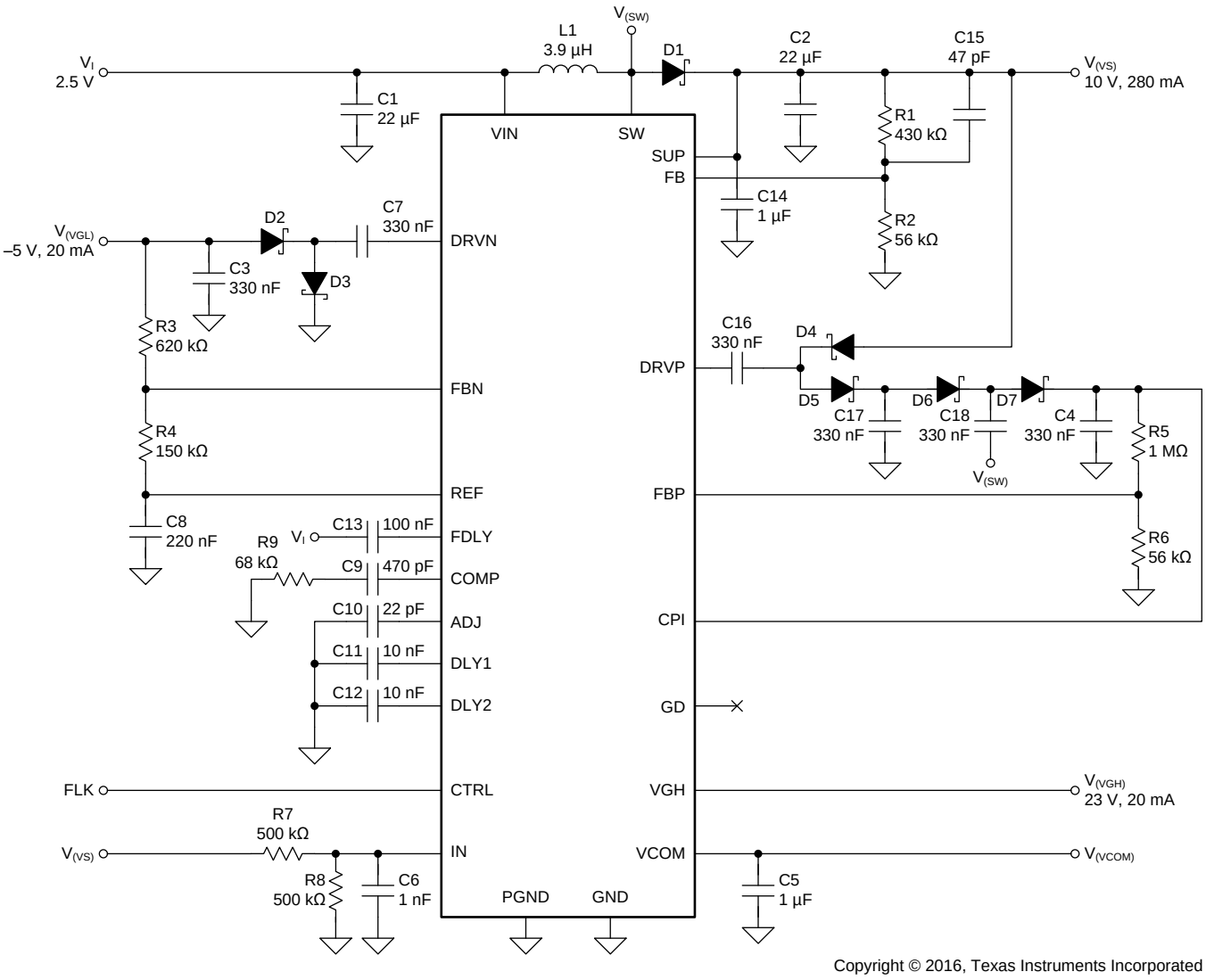

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Figure 34. Notebook LCD Supply Powered from a 2.5-V Rail

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System Examples (continued)

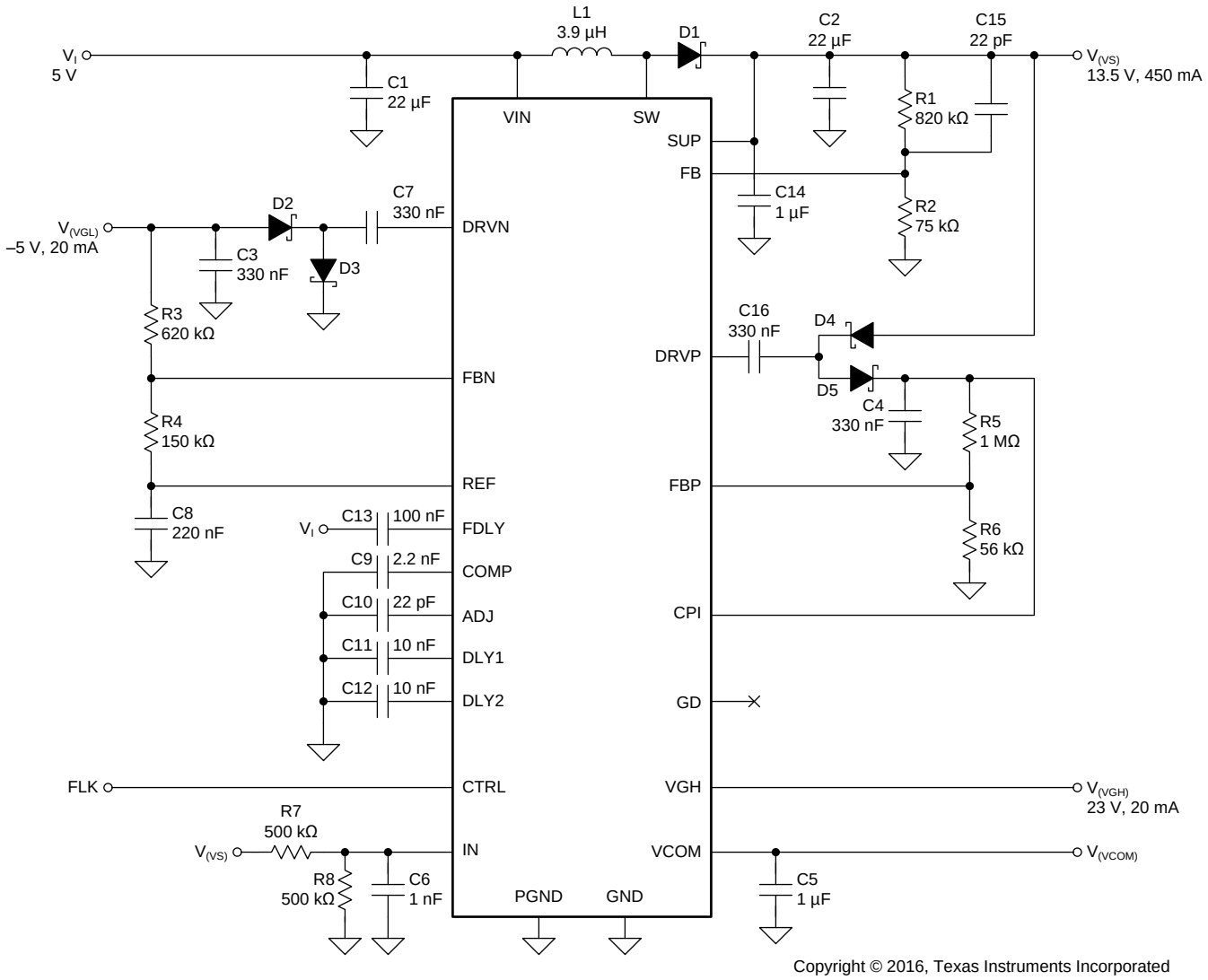

Figure 35. Monitor LCD Supply Powered from a 5-V Rail

System Examples (continued)

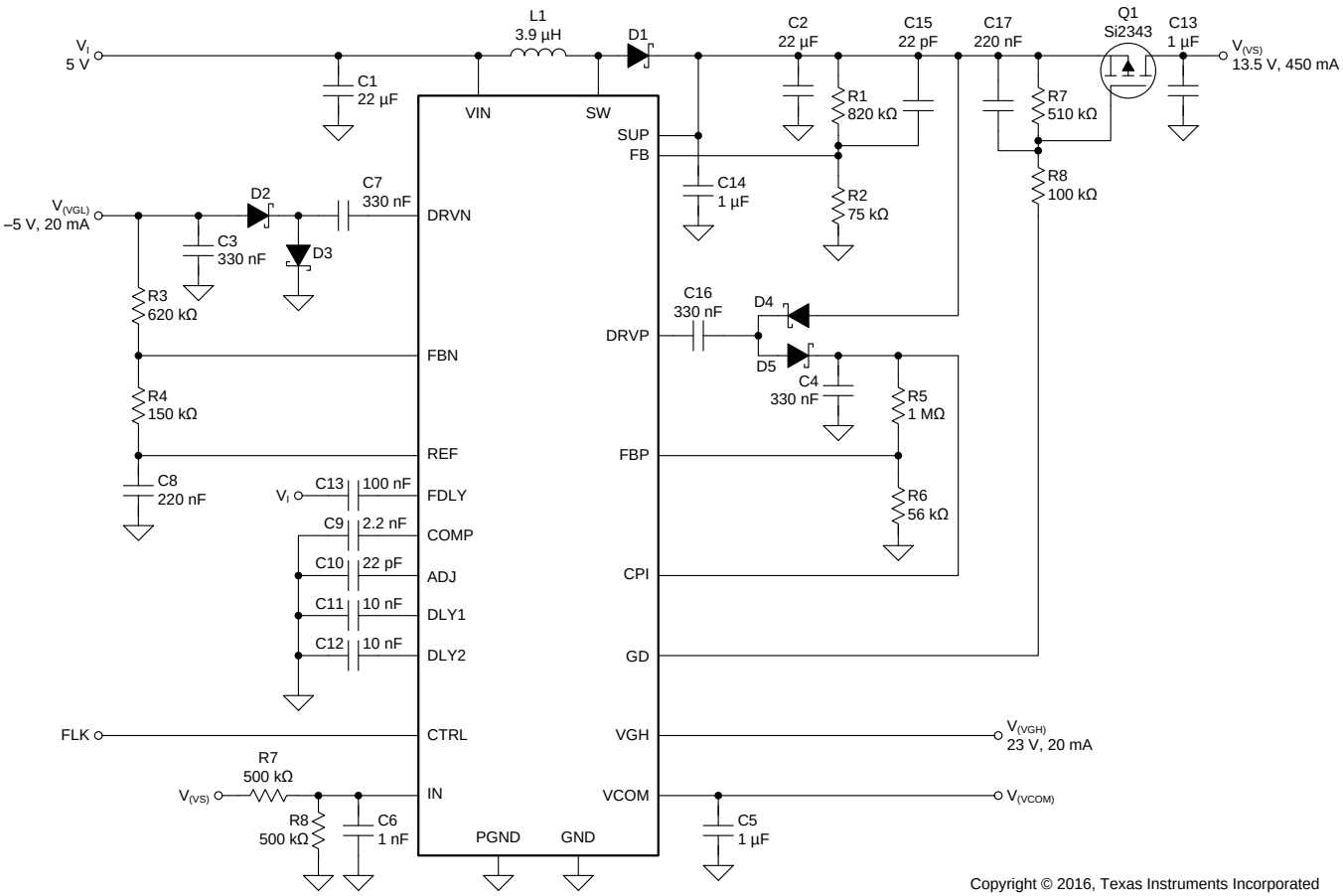

Figure 36. Typical Isolation and Short Circuit Protection Switch for $V_{(VS)}$ Using Q1 and Gate Drive Signal (GD)

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9 Power Supply Recommendations

The TPS65150-Q1 device is designed to operate with input supplies from 1.8 V to 6 V. Like most integrated circuits, the input supply must be stable and free of noise if the full performance of the device is to be achieved. If the input is placed more than a few centimeters away from the device, additional bulk capacitance may be required. The input capacitance shown in the application schematics in this data sheet is sufficient for typical applications.

10 Layout

10.1 Layout Guidelines

The PCB layout is an important step in the power supply design. An incorrect layout could cause converter instability, load regulation problems, noise, and EMI issues. Especially with a switching DC-DC converter at high load currents, too-thin PCB traces can cause significant voltage spikes. Good grounding is also important. If possible, TI recommends using a common ground plane to minimize ground shifts between analog ground (GND) and power ground (PGND). Additionally, the following PCB design layout guidelines are recommended for the TPS65150-Q1 device:

1. Boost converter output capacitor, input capacitor and Power ground (PGND) must form a star ground or must be directly connected together on a common power ground plane.
2. Place the input capacitor directly from the input pin (VIN) to ground.
3. Use a bold PCB trace to connect SUP to the output Vs.
4. Place a small bypass capacitor from the SUP pin to ground.
5. Use short traces for the charge-pump drive pins (DRVN, DRVP) of VGH and VGL because these traces carry switching currents.
6. Place the charge pump flying capacitors as close as possible to the DRVP and DRVN pin, avoiding a high voltage spikes at these pins.
7. Place the Schottky diodes as close as possible to the device and to the flying capacitors connected to DRVP and DRVN.
8. Carefully route the charge pump traces to avoid interference with other circuits because they carry high voltage switching currents .
9. Place the output capacitor of the VCOM buffer as close as possible to the output pin (VCOM).
10. The thermal pad must be soldered to the PCB for correct thermal performance.

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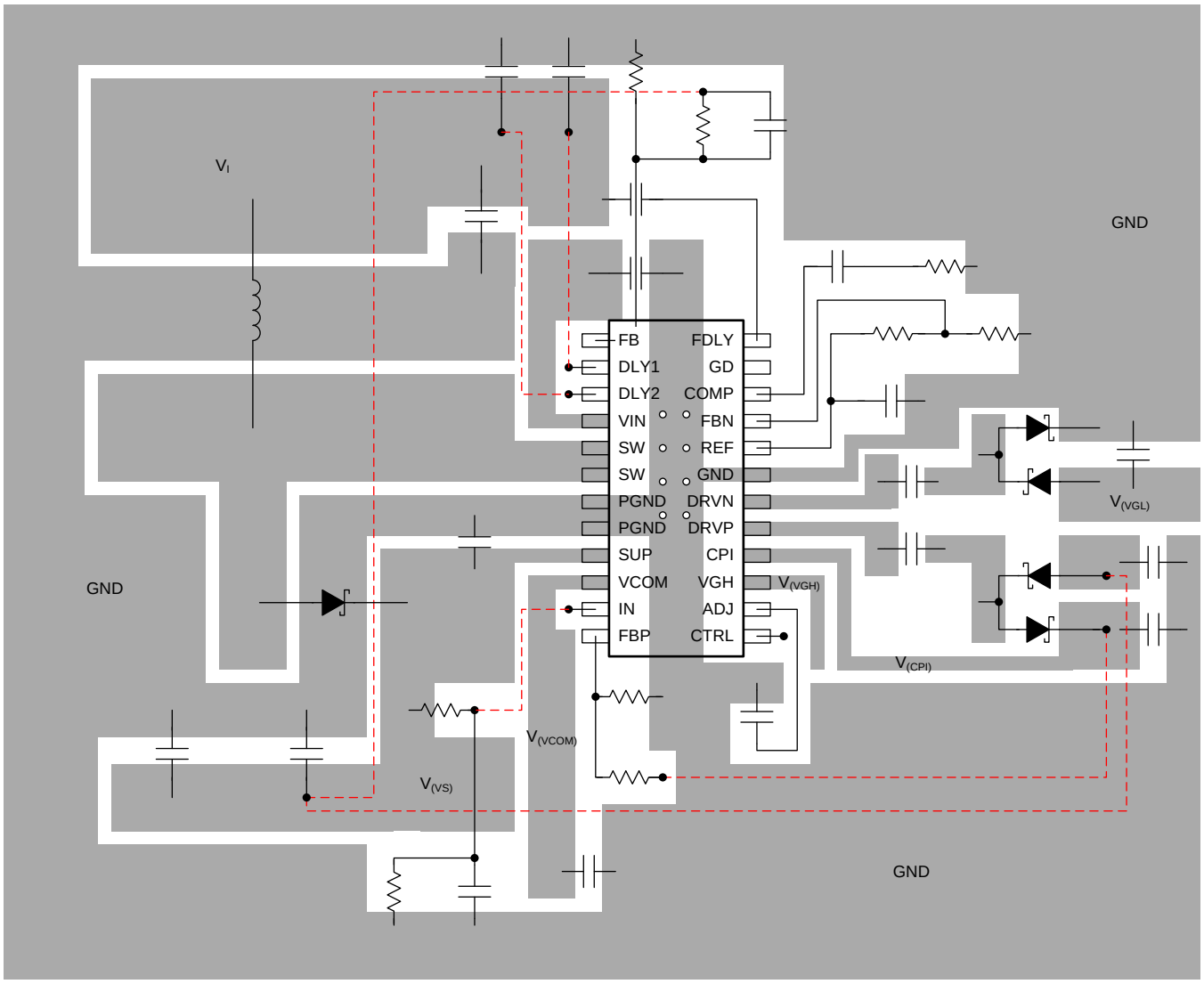
10.2 Layout Example



● Via to inner / bottom signal layer
○ Thermal via to copper pour on inner / bottom signal layer

Figure 37. PCB Layout Example

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11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer

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11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS65150QPWPRQ1	Active	Production	HTSSOP (PWP) | 24	2000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS65150Q
TPS65150QPWPRQ1.A	Active	Production	HTSSOP (PWP) | 24	2000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS65150Q
TPS65150QPWPRQ1.B	Active	Production	HTSSOP (PWP) | 24	2000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS65150Q

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TPS65150-Q1 :

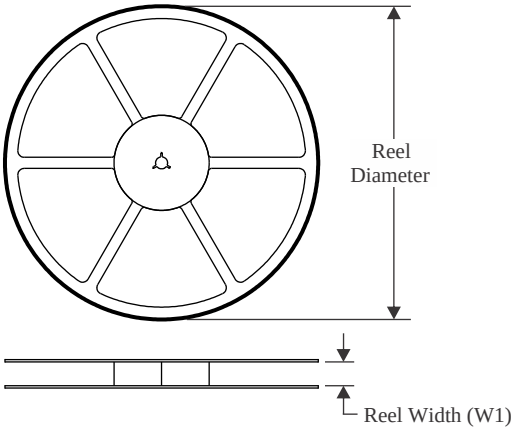
- Catalog : TPS65150

NOTE: Qualified Version Definitions:

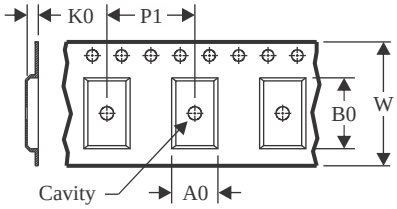
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

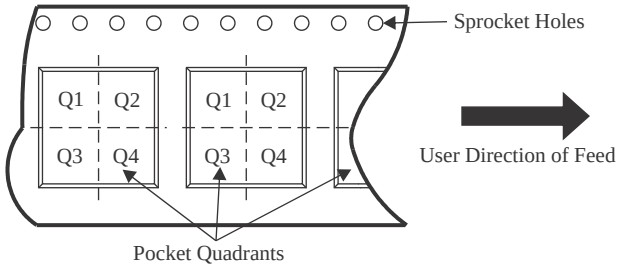


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

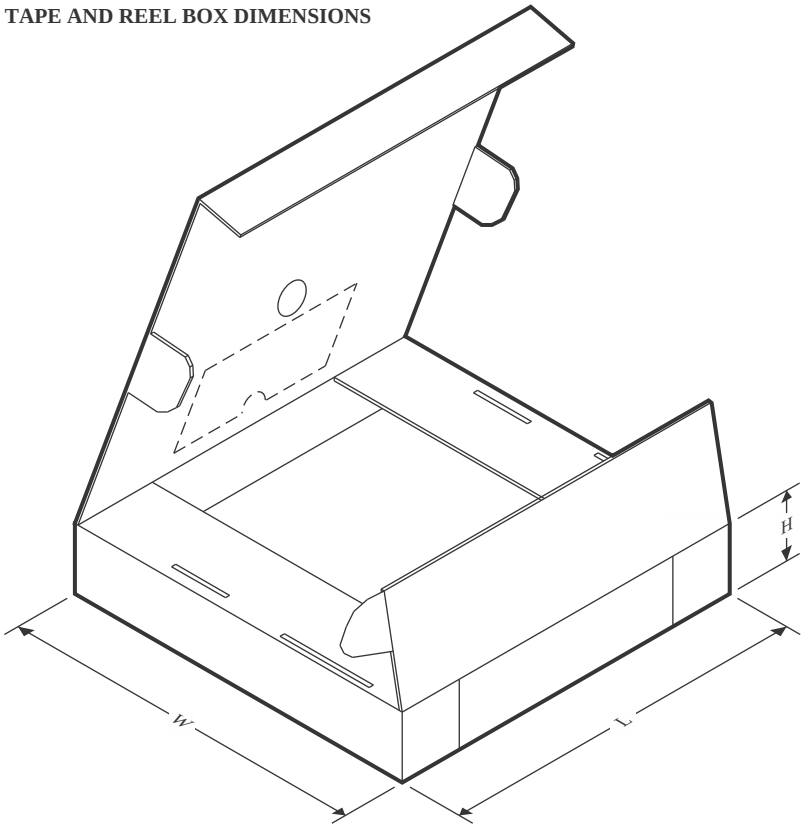
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS65150QPWPRQ1	HTSSOP	PWP	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS65150QPWPRQ1	HTSSOP	PWP	24	2000	350.0	350.0	43.0

GENERIC PACKAGE VIEW

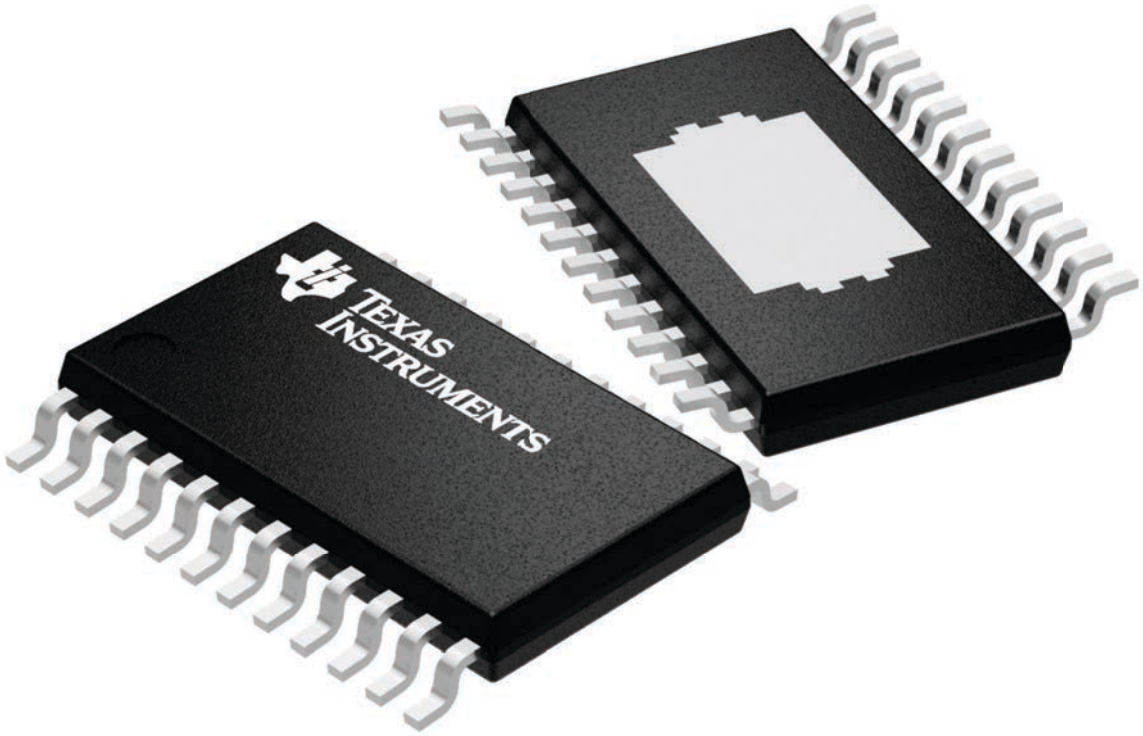
PWP 24

PowerPAD™ TSSOP - 1.2 mm max height

4.4 x 7.6, 0.65 mm pitch

PLASTIC SMALL OUTLINE

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



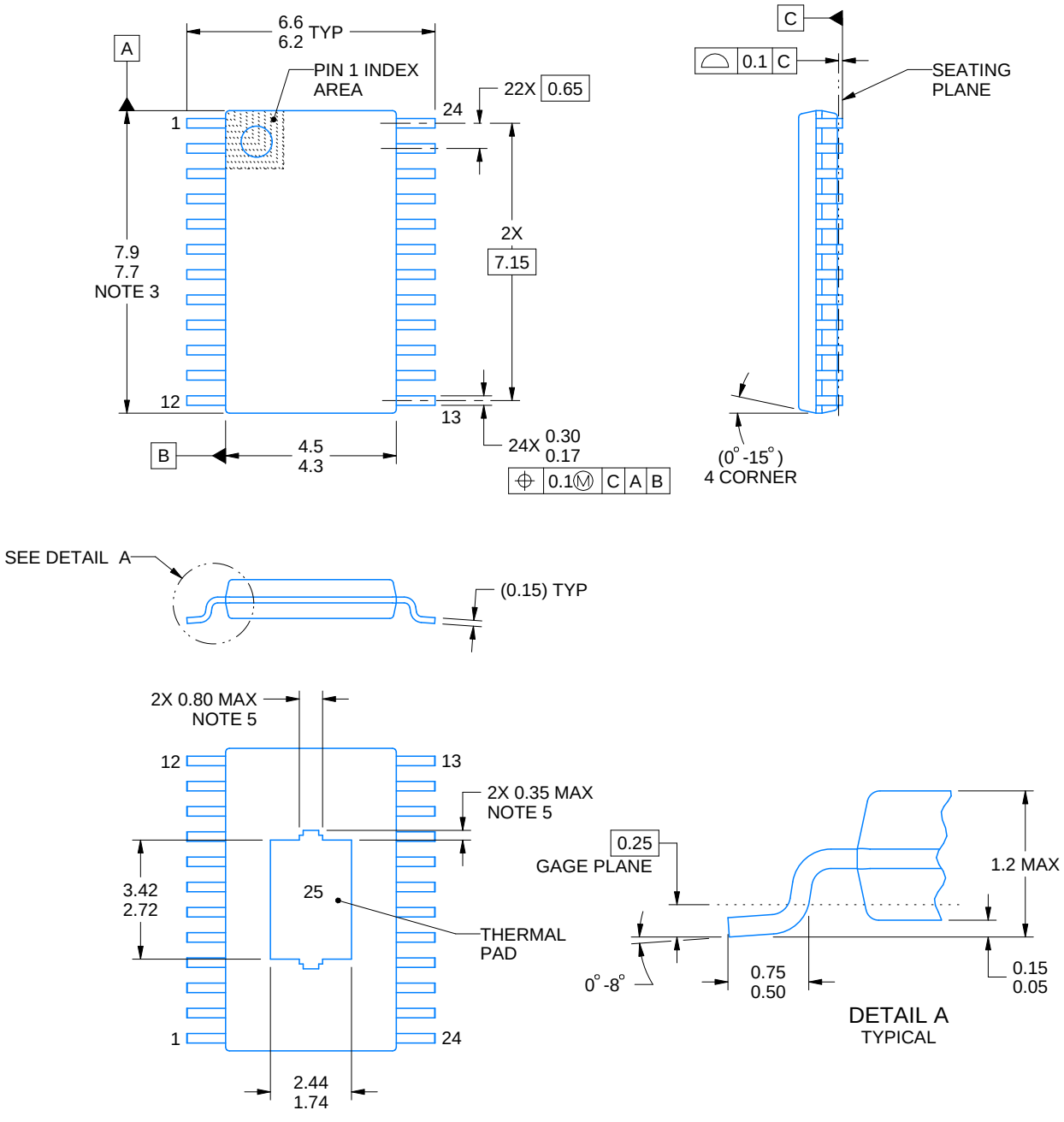
4224742/B

PACKAGE OUTLINE

PWP0024U

PowerPAD™ TSSOP - 1.2 mm max height

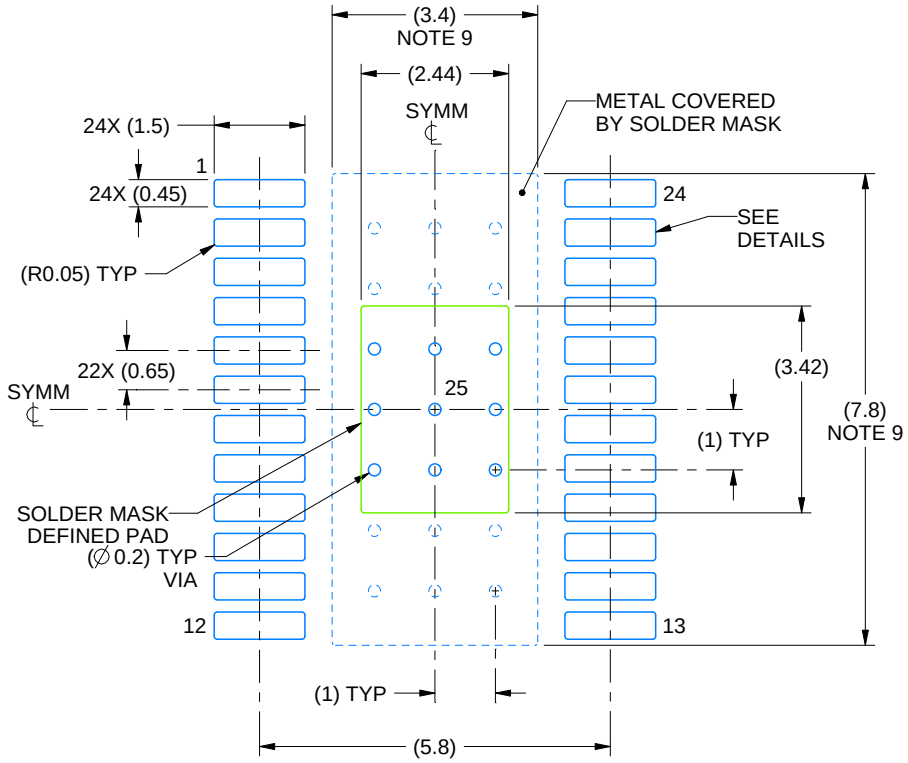
SMALL OUTLINE PACKAGE



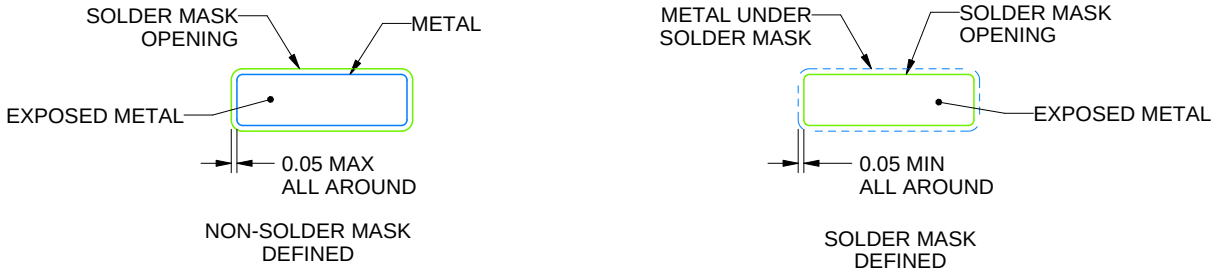
PowerPAD is a trademark of Texas Instruments.

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-153.
5. Features may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 8X

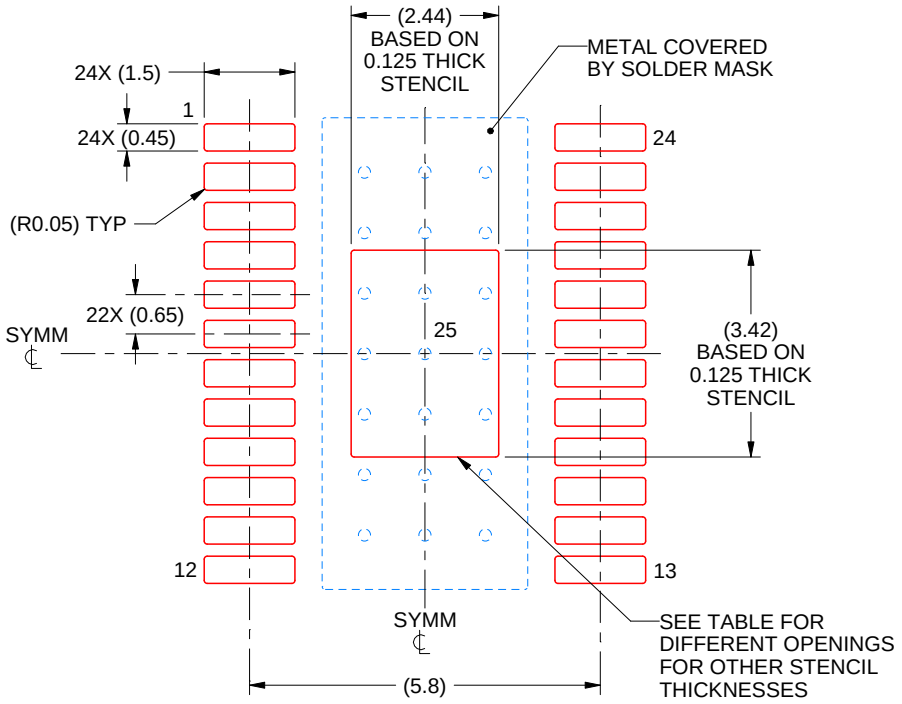


SOLDER MASK DETAILS

4230154/A 10/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Size of metal pad may vary due to creepage requirement.
10. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 8X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	2.73 X 3.82
0.125	2.44 X 3.42 (SHOWN)
0.15	2.23 X 3.12
0.175	2.06 X 2.89

4230154/A 10/2023

NOTES: (continued)

11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

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