

Compact TFT LCD Bias IC for Monitor with VCOM Buffer, Voltage Regulator for Gamma Buffer and Reset Function

Check for Samples: [TPS65148](#)

FEATURES

- 2.5V to 6V Input Voltage Range
- Up to 18V Boost Converter With 4A Switch Current
- 630kHz/1.2MHz Selectable Switching Frequency
- Adjustable Soft-Start for the Boost Converter
- Gate Driver for External Input-to-Output Isolation Switch
- 0.5% Accuracy Voltage Regulator for Gamma Buffer
- Gate Voltage Shaping

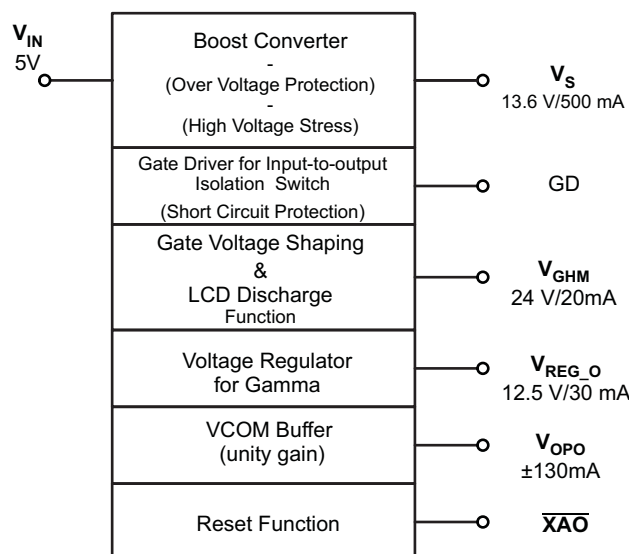
- VCOM Buffer
- Reset Function ($\overline{\text{XAO}}$ Signal)
- LCD Discharge Function
- Overvoltage Protection
- Overcurrent Protection
- Thermal Shutdown
- 32-Pin 5*5mm QFN Package

APPLICATIONS

- Monitor
- TV (5V Input Voltage)

DESCRIPTION

The TPS65148 offers a compact power supply solution designed to supply the LCD bias voltages required by TFT (Thin Film Transistor) LCD panels running from a typical 5 V supply rail. The device integrates a high power step-up converter for V_S (Source Driver voltage), an accurate voltage rail using an integrated LDO to supply the Gamma Buffer ($V_{\text{REG_O}}$) and a Vcom buffer driving the LCD backplane. In addition to that, a gate voltage shaping block is integrated. The V_{GH} signal (Gate Driver High voltage) supplied by an external positive charge pump, is modulated into V_{GHM} with high flexibility by using a logic input VFLK and an external discharge resistor connected to the RE pin. Also, an external negative charge pump can be set using the boost converter of the TPS65148 to generate V_{GL} (Gate Driver Low voltage). The integrated reset function together with the LCD discharge function available in the TPS65148 provide the signals enabling the discharge of the LCD TFT pixels when powering-off. The device includes safety features like overcurrent protection (OCP) and short-circuit protection (SCP) achieved by an external input-to-output isolation switch, as well as overvoltage protection (OVP) and thermal shutdown.



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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.

ORDERING INFORMATION⁽¹⁾

| T _A | ORDERING | PACKAGE | PACKAGE MARKING |
|----------------|-------------|------------|-----------------|
| –40°C to 85°C | TPS65148RHB | 32-pin QFN | TPS65148 |

- (1) The RHB package is available taped and reeled. For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

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

| | VALUE | UNIT |
|---|-------------------------------|------|
| Input voltage range VIN ⁽²⁾ | –0.3 to 6.5 | V |
| Voltage range on pins COMP, EN, FB, FREQ, GD, HVS, REG_FB, RHVS, SS, VDET, VDPM, VFLK, XAO ⁽²⁾ | –0.3 to 6.5 | V |
| Voltage on pins OPI, OPO, REG_I, REG_O, SUP, SW ⁽²⁾ | –0.3 to 20 | V |
| Voltage on pins RE, VGH, VGHM ⁽²⁾ | –0.3 to 36 | V |
| ESD rating HBM | 2 | kV |
| ESD rating MM | 200 | V |
| ESD rating CDM | 500 | V |
| Continuous power dissipation | See Thermal Information Table | |
| Storage temperature range | –65 to 150 | °C |

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground terminal.

THERMAL INFORMATION

| THERMAL METRIC ⁽¹⁾ | | TPS65148 | UNITS |
|--------------------------------|--|----------|-------|
| | | RHB | |
| | | 32 PINS | |
| θ _{JA} ⁽²⁾ | Junction-to-ambient thermal resistance | 37.1 | °C/W |
| θ _{JCtop} | Junction-to-case (top) thermal resistance | 38.7 | |
| θ _{JB} | Junction-to-board thermal resistance | 9.4 | |
| ψ _{JT} | Junction-to-top characterization parameter | 0.5 | |
| ψ _{JB} | Junction-to-board characterization parameter | 10.4 | |
| θ _{JCbot} | Junction-to-case (bottom) thermal resistance | 2.6 | |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](http://www.ti.com/lit/zip/spra953).
- (2) θ_{JA}, given for High-K PCB board.

RECOMMENDED OPERATING CONDITIONS

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

| | MIN | TYP | MAX | UNIT |
|--|-----|-----|-----|------|
| V _{IN} | 2.5 | | 6 | V |
| V _S , V _{SUP} , V _{REG_I} | 7 | | 18 | V |
| V _{GH} | 15 | | 35 | V |
| T _A | –40 | | 85 | °C |
| T _J | –40 | | 125 | °C |

ELECTRICAL CHARACTERISTICS

$V_{IN} = 5\text{ V}$, $V_{REG_I} = V_S = V_{SUP} = 13.6\text{ V}$, $V_{REG_O} = 12.5\text{ V}$, $V_{OPI} = 5\text{ V}$, $V_{GH} = 23\text{ V}$, $T_A = -40^\circ\text{C}$ to 85°C , typical values are at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|---|-------|-------|-------|------------------|
| SUPPLY | | | | | | |
| V_{IN} | Input voltage range | | 2.5 | | 6 | V |
| I_{QVIN} | Operating quiescent current into VIN | Device not switching, $V_{FB} = 1.240\text{ V} + 5\%$ | | 0.23 | 0.5 | mA |
| I_{QSUP} | Operating quiescent current into SUP | Device not switching, $V_{FB} = 1.240\text{ V} + 5\%$ | | 3 | 6 | mA |
| I_{QVGH} | Operating quiescent current into VGH | $V_{GH} = 24\text{ V}$, VFLK = 'high' | | 30 | 60 | μA |
| I_{QREG_I} | Operating quiescent current into REG_I | REG_O = 'open', $V_{REG_FB} = 1.240\text{ V} + 5\%$ | | 0.05 | 3 | μA |
| I_{SDVIN} | Shutdown current into VIN | $V_{IN} = 6\text{ V}$, EN = GND | | 35 | 70 | μA |
| I_{SDSUP} | Shutdown current into SUP | $V_{IN} = 6\text{ V}$, EN = GND, $V_{SUP} = 6\text{ V}$ | | 1 | 2.5 | μA |
| I_{SDVGH} | Shutdown current into VGH | $V_{IN} = 6\text{ V}$, EN = GND, $V_{GH} = 6\text{ V}$ | | 20 | 40 | μA |
| I_{SDREG_I} | Shutdown current into REG_I | $V_{IN} = 6\text{ V}$, EN = GND, $V_{REG_I} = 6\text{ V}$, $V_{REG_O} = 4.9\text{ V}$ | | 4 | 10 | μA |
| V_{UVLO} | Under-voltage lockout threshold | V_{IN} rising | 2.1 | | 2.3 | V |
| | | Hysteresis | | 0.1 | | |
| T_{SD} | Thermal shutdown | Temperature rising | | 150 | | $^\circ\text{C}$ |
| T_{SDHYS} | Thermal shutdown hysteresis | | | 14 | | $^\circ\text{C}$ |
| LOGIC SIGNALS EN, FREQ, VFLK, HVS | | | | | | |
| I_{LEAK} | Input leakage current | EN = FREQ = VFLK = HVS = 6 V | | | 0.1 | μA |
| V_{IH} | Logic high input voltage | $V_{IN} = 2.5\text{ V}$ to 6 V | 2 | | | V |
| V_{IL} | Logic low input voltage | $V_{IN} = 2.5\text{ V}$ to 6 V | | | 0.4 | V |
| BOOST CONVERTER (V_S) | | | | | | |
| V_S | Output voltage boost converter | | | | 18 | V |
| V_{OVP} | Overvoltage protection | V_S rising | 18.2 | 19 | 19.8 | V |
| V_{FB} | Feedback regulation voltage | | 1.228 | 1.240 | 1.252 | V |
| I_{FB} | Feedback input bias current | $V_{FB} = 1.240\text{ V}$ | | | 0.1 | μA |
| gm | Transconductance error amplifier gain | | | 107 | | $\mu\text{A/V}$ |
| $r_{DS(on)}$ | N-channel MOSFET on-resistance | $V_{IN} = V_{GS} = 5\text{ V}$, $I_{SW} = \text{'current limit'}$ | | 0.12 | 0.18 | Ω |
| | | $V_{IN} = V_{GS} = 3.3\text{ V}$, $I_{SW} = \text{'current limit'}$ | | 0.14 | 0.22 | |
| I_{LEAK_SW} | SW leakage current | EN = GND, $V_{SW} = 18.5\text{ V}$ | | | 30 | μA |
| I_{LIM} | N-Channel MOSFET current limit | | 4.0 | 4.8 | 5.6 | A |
| I_{SS} | Softstart current | $V_{SS} = 1.240\text{ V}$ | | 10 | | μA |
| f | Switching frequency | FREQ = 'high' | 0.9 | 1.2 | 1.5 | MHz |
| | | FREQ = 'low' | 470 | 630 | 790 | kHz |
| | Line regulation | $V_{IN} = 2.5\text{ V}$ to 6 V , $I_{OUT} = 1\text{ mA}$ | | 0.015 | | %/V |
| | Load regulation | $I_{OUT} = 0\text{ A}$ to 1.3 A | | 0.22 | | %/A |
| LDO - VOLTAGE REGULATOR FOR GAMMA BUFFER (V_{REG_O}) | | | | | | |
| V_{REG_O} | LDO output voltage range | | 7 | | 17.6 | V |
| V_{REG_FB} | Feedback regulation voltage | $V_{REG_I} = 10\text{ V}$ to 18 V , $REG_O = REG_FB$, $I_{REG_O} = 1\text{ mA}$, $T_A = -40^\circ\text{C}$ to 85°C | 1.228 | 1.240 | 1.252 | V |
| | | $V_{REG_I} = 10\text{ V}$ to 18 V , $REG_O = REG_FB$, $I_{REG_O} = 1\text{ mA}$, $T_A = 25^\circ\text{C}$ | 1.234 | 1.240 | 1.246 | |
| I_{REG_FB} | Feedback input bias current | $V_{REG_FB} = 1.240\text{ V}$ | | | 0.1 | μA |
| I_{SC_REG} | Short circuit current limit | $V_{REG_I} = 18\text{ V}$, $REG_O = REG_FB = \text{GND}$ | | | 90 | mA |
| V_{DO} | Dropout voltage | $V_{REG_I} = 18\text{ V}$, $I_{REG_O} = 30\text{ mA}$ | | | 400 | mV |
| | Line regulation | $V_{REG_I} = 13.6\text{ V}$ to 18 V , $I_{REG_O} = 1\text{ mA}$ | | 0.003 | | %/V |
| | Load regulation | $I_{REG_O} = 1\text{ mA}$ to 50 mA | | 0.28 | | %/A |
| GATE VOLTAGE SHAPING (V_{GHM}) | | | | | | |
| I_{DPM} | Capacitor charge current VDPM pin | | | 20 | | μA |
| $r_{DS(on)M1}$ | VGH to VGHM $r_{DS(on)}$ (M1 PMOS) | VFLK = 'high', $I_{VGHM} = 20\text{ mA}$, $V_{GH} = 20\text{ V}$ | | 13 | 25 | Ω |
| $r_{DS(on)M2}$ | VGHM to RE $r_{DS(on)}$ (M2 PMOS) | VFLK = 'low', $I_{VGHM} = 20\text{ mA}$, $V_{GHM} = 7.5\text{ V}$ | | 13 | 25 | Ω |

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ELECTRICAL CHARACTERISTICS (continued)

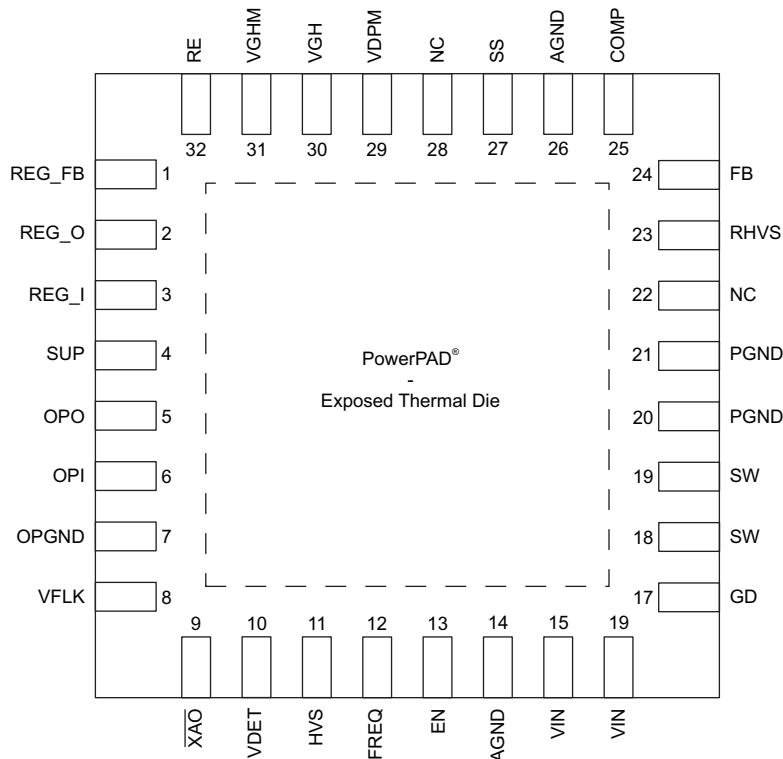
 $V_{IN} = 5\text{ V}$, $V_{REG_I} = V_S = V_{SUP} = 13.6\text{ V}$, $V_{REG_O} = 12.5\text{ V}$, $V_{OPI} = 5\text{ V}$, $V_{GH} = 23\text{ V}$, $T_A = -40^{\circ}\text{C}$ to 85°C , typical values are at $T_A = 25^{\circ}\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|--|-----------|--------------|-------------|------------------|
| RESET FUNCTION (\overline{XAO}) | | | | | | |
| V_{IN_DET} | Operating voltage for V_{IN} | | 1.6 | | 6.0 | V |
| V_{DET} | Threshold voltage | Falling, $V_{IN} = 2.3\text{ V}$ | 1.216 | 1.240 | 1.264 | V |
| V_{DET_HYS} | Threshold hysteresis | | | 65 | | mV |
| $I_{\overline{XAO}(ON)}$ | Sink current capability ⁽¹⁾ | $V_{\overline{XAO}(ON)} = 0.5\text{ V}$ | 1 | | | mA |
| $V_{\overline{XAO}(ON)}$ | Low voltage level | $I_{\overline{XAO}(ON)} = 1\text{ mA}$ | | | 0.5 | V |
| I_{LEAK_XAO} | Leakage current | $V_{\overline{XAO}} = V_{IN} = 3.3\text{ V}$ | | | 2 | μA |
| VCOM BUFFER (V_{COM}) | | | | | | |
| V_{SUP} | V_{SUP} supply range ⁽²⁾ | $V_{SUP} = V_S$ | 7 | | 18 | V |
| V_{OFFSET} | Input offset voltage | $V_{CM} = V_{OPI} = V_{SUP}/2 = 6.8\text{ V}$ | -15 | | 15 | mV |
| I_B | Input bias current | $V_{CM} = V_{OPI} = V_{SUP}/2 = 6.8\text{ V}$ | -1 | | 1 | μA |
| V_{CM} | Common mode input voltage range | $V_{OFFSET} = 10\text{ mV}$, $I_{OPO} = 10\text{ mA}$ | 1 | | $V_S - 1.5$ | V |
| CMRR | Common mode rejection ratio | $V_{CM} = V_{OPI} = V_{SUP}/2 = 6.8\text{ V}$, 1 MHz | | 66 | | dB |
| V_{OL} | Output voltage swing low | $I_{OPO} = 10\text{ mA}$ | | 0.10 | 0.25 | V |
| V_{OH} | Output voltage swing high | $I_{OPO} = 10\text{ mA}$ | $V_S - 1$ | $V_S - 0.65$ | | V |
| I_{sc} | Short circuit current | Source ($V_{OPI} = V_{SUP}/2 = 6.8\text{ V}$, $OPO = GND$) | 90 | 130 | | mA |
| | | Sink ($V_{OPI} = V_{SUP}/2 = 6.8\text{ V}$, $V_{OPO} = V_{SUP} = 13.6\text{ V}$) | 110 | 160 | | |
| I_o | Output current | Source ($V_{OPI} = V_{SUP}/2 = 6.8$, $V_{OFFSET} = 15\text{ mV}$) | | 130 | | mA |
| | | Sink ($V_{OPI} = V_{SUP}/2 = 6.8$, $V_{OFFSET} = 15\text{ mV}$) | | 130 | | |
| PSRR | Power supply rejection ratio | | | 40 | | dB |
| SR | Slew rate | $A_V = 1$, $V_{OPI} = 2\text{ V}_{PP}$ | | 60 | | V/ μs |
| BW | -3db bandwidth | $A_V = 1$, $V_{OPI} = 60\text{ mV}_{PP}$ | | 60 | | MHz |
| GATE DRIVER (GD) | | | | | | |
| I_{GD} | Gate driver sink current | EN = 'high' | | 10 | | μA |
| R_{GD} | Gate driver internal pull up resistance | | | 5 | | k Ω |
| HIGH VOLTAGE STRESS TEST (HVS) | | | | | | |
| R_{HVS} | RHVS pull down resistance | HVS = 'high', $V_{IN} = 2.5\text{ V}$ to 6 V , $I_{HVS} = 100\text{ }\mu\text{A}$ | 400 | 500 | 600 | Ω |
| I_{LEAK_RHVS} | RHVS leakage current | HVS = 'low', $V_{RHVS} = 5\text{ V}$ | | | 0.1 | μA |

(1) External pull-up resistor to be chosen so that the current flowing into \overline{XAO} Pin ($V_{\overline{XAO}} = 0\text{ V}$) when active is below $I_{\overline{XAO_MIN}} = 1\text{ mA}$.

(2) Maximum output voltage limited by the Overvoltage Protection and not the maximum power switch rating of the boost converter.

PIN ASSIGNMENT



TERMINAL FUNCTIONS

| PIN | | I/O | DESCRIPTION |
|------------------|------------------------|-----|---|
| NAME | NO. | | |
| REG_FB | 1 | I | Voltage regulator feedback pin. |
| REG_O | 2 | O | Voltage regulator output pin. |
| REG_I | 3 | I | Voltage regulator input pin. |
| SUP | 4 | I | Input supply pin for the gate voltage shaping and operational amplifier blocks. Also overvoltage protection sense pin. SUP pin must be supplied by V_S voltage. |
| OPO | 5 | O | VCOM Buffer output pin. |
| OPI | 6 | I | VCOM Buffer input pin. |
| OPGND | 7 | | VCOM Buffer analog ground. |
| VFLK | 8 | I | Input pin for charge/discharge signal of V_{GHM} . VFLK = 'low' discharges V_{GHM} through RE pin. |
| \overline{XAO} | 9 | O | Reset function output pin (open-drain). \overline{XAO} signal is active low. |
| VDET | 10 | I | Reset function threshold pin. Connect a voltage divider to this pin to set the threshold voltage. |
| HVS | 11 | I | High Voltage Stress function logic input pin. Apply a high logic voltage to enable this function |
| FREQ | 12 | I | Boost converter frequency select pin. Oscillator is 630 kHz when FREQ is connected to GND and 1.2 MHz when FREQ is connected to VIN. |
| EN | 13 | I | Shutdown control input. Apply a logic high voltage to enable the device. |
| AGND | 14, 26, exposed pad | | Analog ground. |
| VIN | 15, 16 | I | Input supply pin. |
| GD | 17 | O | Gate driver pin. Connect the gate of the boost converter's external input-to-output isolation switch to this pin. |
| SW | 18, 19 | | Switch pin of the boost converter. |
| PGND | 20, 21 | | Power ground. |
| NC | 22, 28 | | Not connected. |

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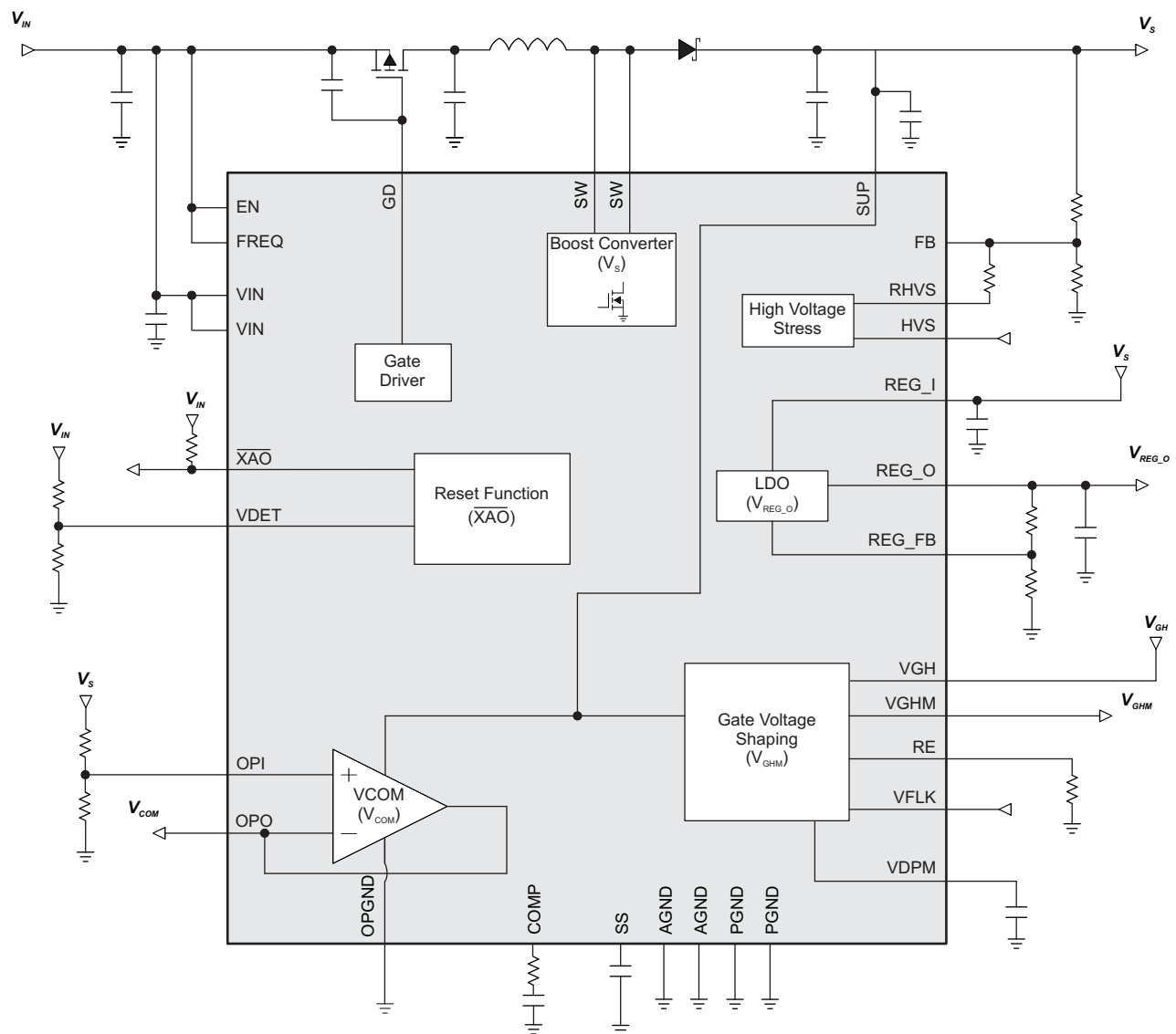
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TERMINAL FUNCTIONS (continued)

| PIN | | I/O | DESCRIPTION |
|------|-----|-----|--|
| NAME | NO. | | |
| RHVS | 23 | | Voltage level set pin. Connect a resistor to this pin to set V_S voltage when HVS = 'high'. |
| FB | 24 | I | Boost converter feedback pin. |
| COMP | 25 | I/O | Boost converter compensation pin. |
| SS | 27 | I/O | Boost soft-start control pin. Connect a capacitor to this pin if a soft-start is needed. Open = no soft-start. |
| VDPM | 29 | I/O | Sets the delay to enable VGHM output. Pin for external capacitor. Floating if no delay needed. |
| VGH | 30 | I | Input pin for the positive charge pump voltage. |
| VGHM | 31 | O | Gate voltage shaping output pin. |
| RE | 32 | | Slope adjustment pin for gate voltage shaping. Connect a resistor to this pin to set the discharging slope of V_{GHM} when VFLK = 'low'. |

FUNCTIONAL BLOCK DIAGRAM

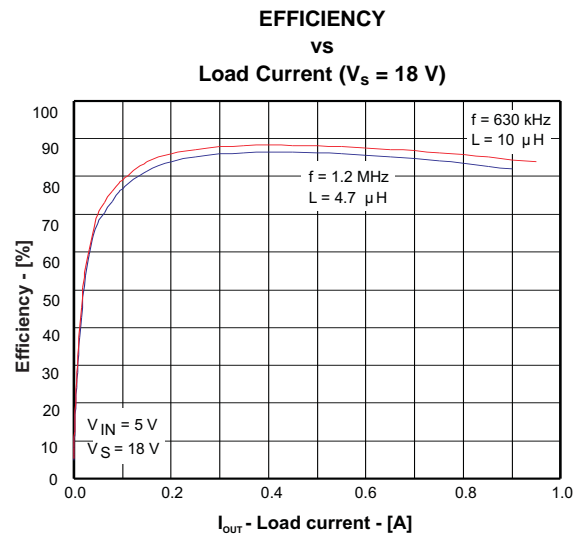
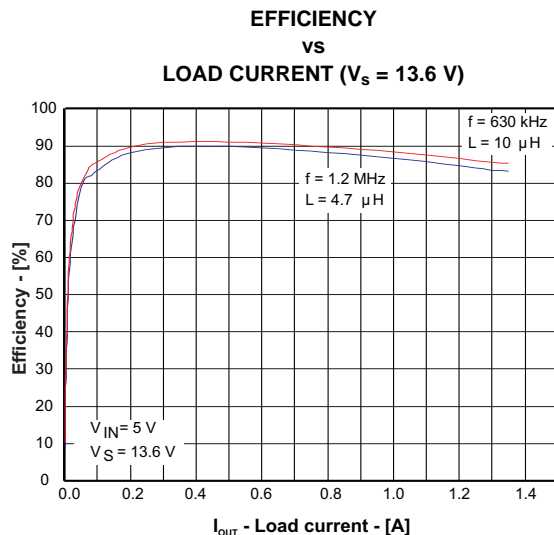


TYPICAL CHARACTERISTICS

TABLE OF GRAPHS

| | | FIGURE |
|--|--|-----------|
| Efficiency vs. Load Current | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ $f = 630\text{ kHz}/1.2\text{ MHz}$ | Figure 1 |
| Efficiency vs. Load Current | $V_{IN} = 5\text{ V}$, $V_S = 18\text{ V}$ $f = 630\text{ kHz}/1.2\text{ MHz}$ | Figure 2 |
| PWM Switching Discontinuous Conduction Mode | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}/2\text{ mA}$ $f = 630\text{ kHz}$ | Figure 3 |
| PWM Switching Continuous Conduction Mode | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}/500\text{ mA}$ $f = 630\text{ kHz}$ | Figure 4 |
| Boost Frequency vs. Load Current | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ $f = 630\text{ kHz}/1.2\text{ MHz}$ | Figure 5 |
| Boost Frequency vs. Supply Voltage | $V_S = 13.6\text{ V}/100\text{ mA}$ $f = 630\text{ kHz}/1.2\text{ MHz}$ | Figure 6 |
| Load Transient Response Boost Converter High Frequency (1.2 MHz) | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ $I_{OUT} = 50\text{ mA} \sim 400\text{ mA}$, $f = 1.2\text{ MHz}$ | Figure 7 |
| Load Transient Response Boost Converter Low Frequency (630 KHz) | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ $I_{OUT} = 50\text{ mA} \sim 400\text{ mA}$, $f = 630\text{ kHz}$ | Figure 8 |
| Boost Converter Output Current Capability | $V_{IN} = 5\text{ V}$, $V_S = 9\text{ V}, 13.6\text{ V}, 15\text{ V}, 18\text{ V}$ $f = 1.2\text{ MHz}$, $L = 4.7\text{ }\mu\text{H}$ | Figure 9 |
| Soft-start Boost Converter | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$, $I_{OUT} = 600\text{ mA}$ | Figure 10 |
| Overvoltage Protection Boost Converter (OVP) | $V_{IN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ | Figure 11 |
| Load Transient Response LDO | $V_{LVIN} = 5\text{ V}$, $V_S = 13.6\text{ V}$ $V_{REG_O} = 12.5\text{ V}$, $I_{LVOUT} = 5\text{ mA} - 30\text{ mA}$ | Figure 12 |
| Gate Voltage Shaping | $V_{GH} = 23\text{ V}$ | Figure 13 |
| XAO Signal and LCD Discharge Function | | Figure 14 |
| Power On Sequencing | | Figure 15 |
| Power Off Sequencing | | Figure 16 |
| Short Circuit Protection (< 114 ms) | | Figure 17 |
| Short Circuit Protection (> 114 ms) | | Figure 18 |

For all the following graphics, the inductors used for the measurements are CDRH127 ($L = 4.7\text{ }\mu\text{F}$) for $f = 1.2\text{ MHz}$, and CDRH127LD ($L = 10\text{ }\mu\text{F}$) for $f = 630\text{ kHz}$.



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BOOST CONVERTER PWM SWITCHING DISCONTINUOUS CONDUCTION MODE

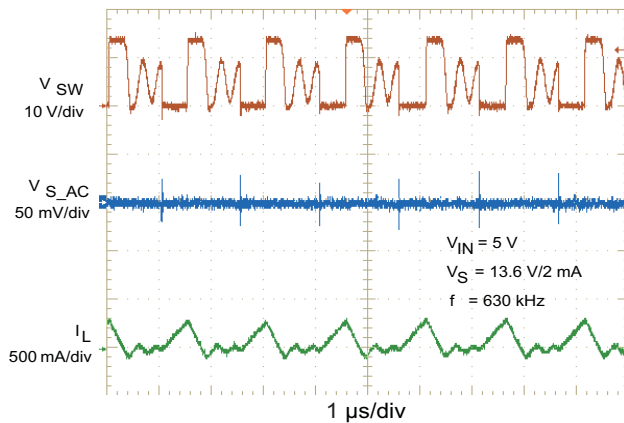


Figure 3.

BOOST CONVERTER PWM SWITCHING CONTINUOUS CONDUCTION MODE

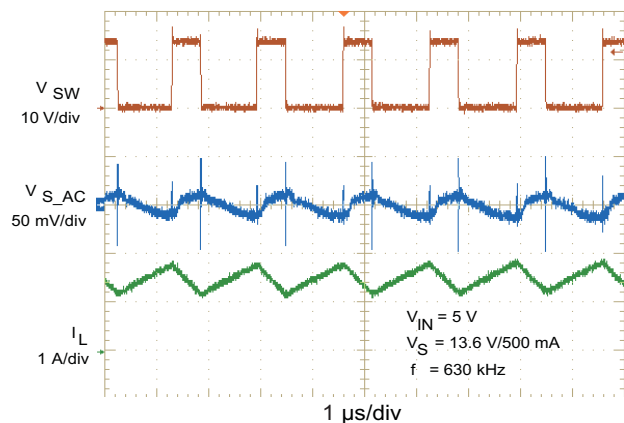


Figure 4.

BOOST CONVERTER FREQUENCY vs LOAD CURRENT

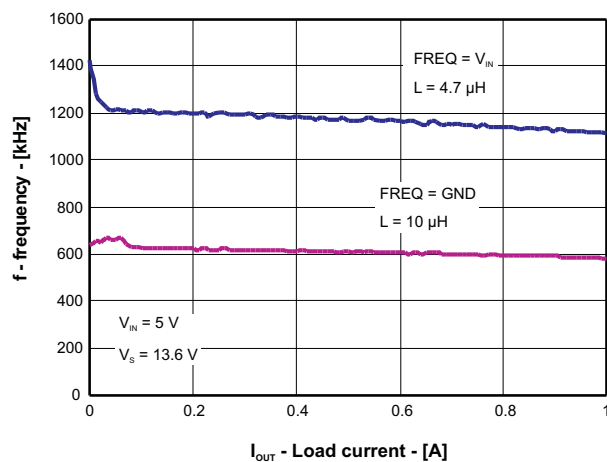


Figure 5.

BOOST CONVERTER FREQUENCY vs SUPPLY VOLTAGE

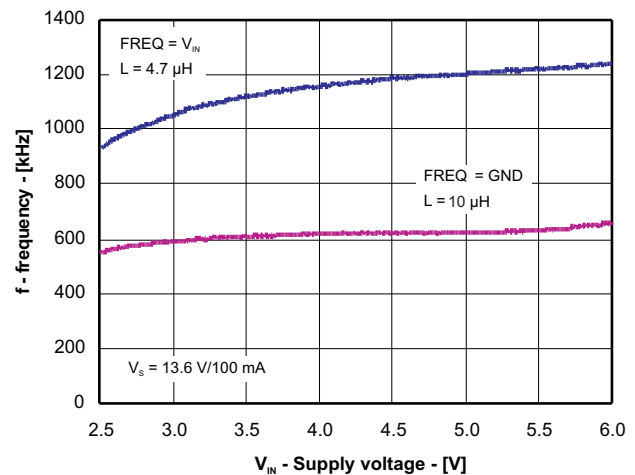


Figure 6.

LOAD TRANSIENT RESPONSE BOOST CONVERTER - HIGH FREQUENCY (1.2 MHz)

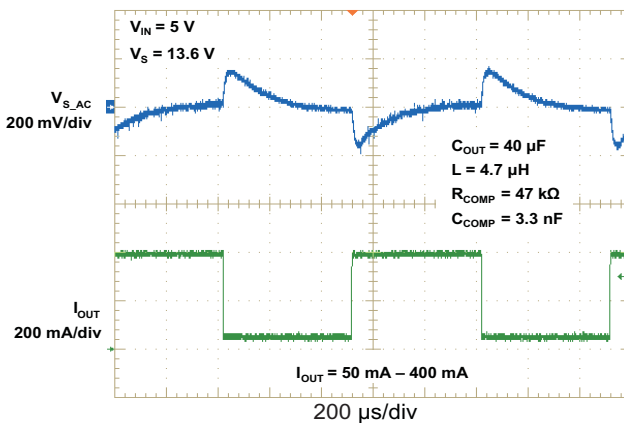


Figure 7.

LOAD TRANSIENT RESPONSE BOOST CONVERTER - LOW FREQUENCY (630 kHz)

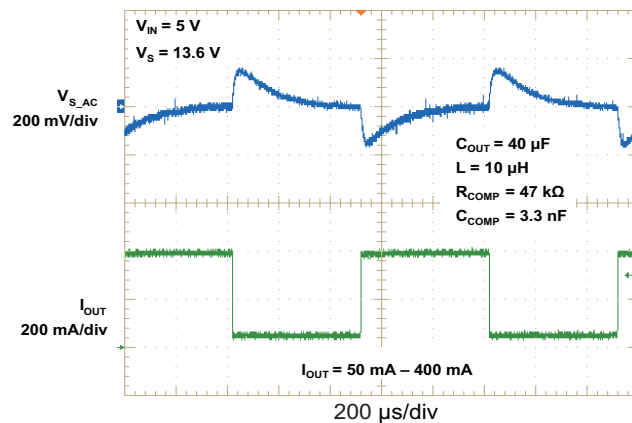


Figure 8.

BOOST CONVERTER OUTPUT CURRENT CAPABILITY

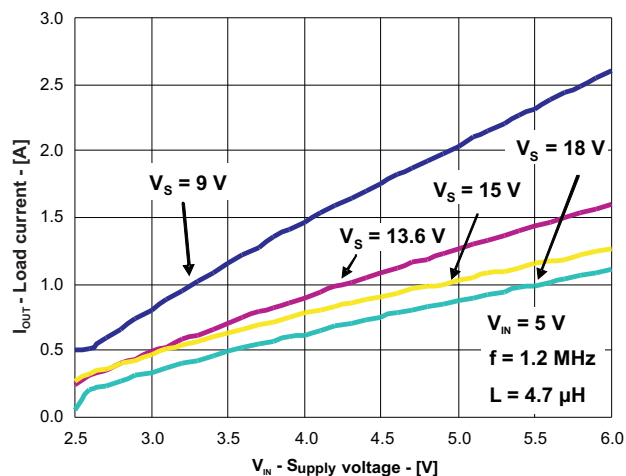


Figure 9.

BOOST CONVERTER SOFT-START

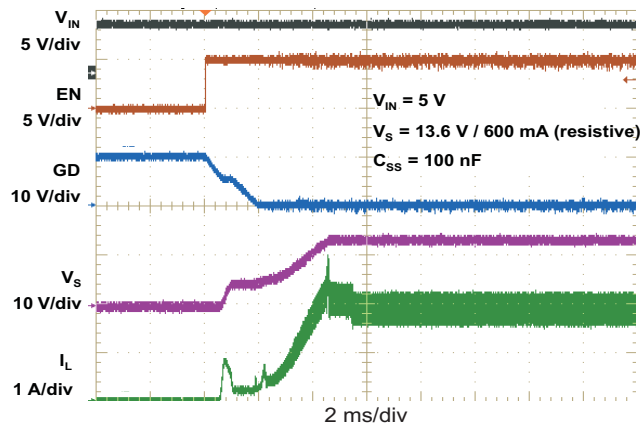


Figure 10.

OVERVOLTAGE PROTECTION BOOST CONVERTER (OVP)

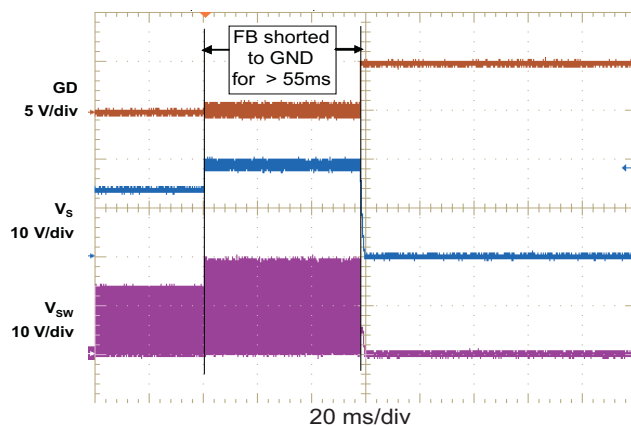


Figure 11.

LOAD TRANSIENT RESPONSE VOLTAGE REGULATOR FOR GAMMA BUFFER

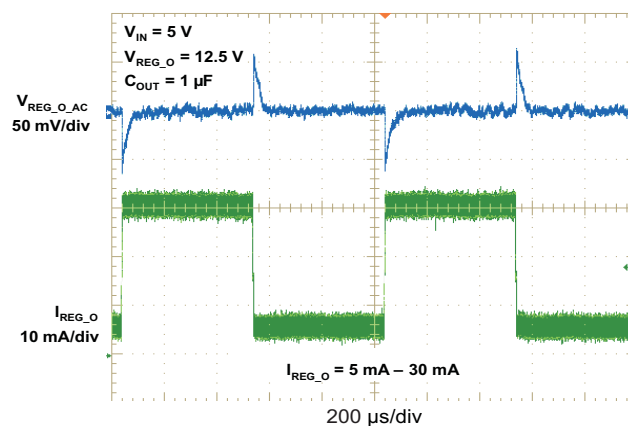


Figure 12.

GATE VOLTAGE SHAPING

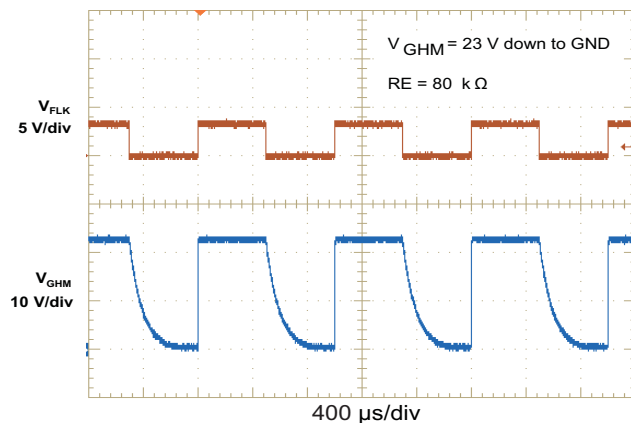


Figure 13.

XAO SIGNAL AND LCD DISCHARGE FUNCTION

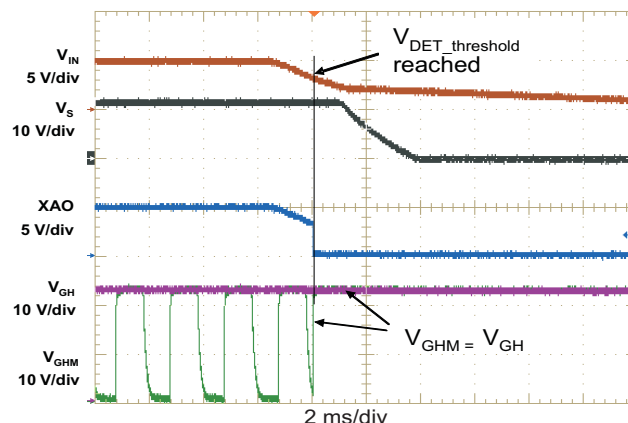


Figure 14.

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POWER ON SEQUENCING

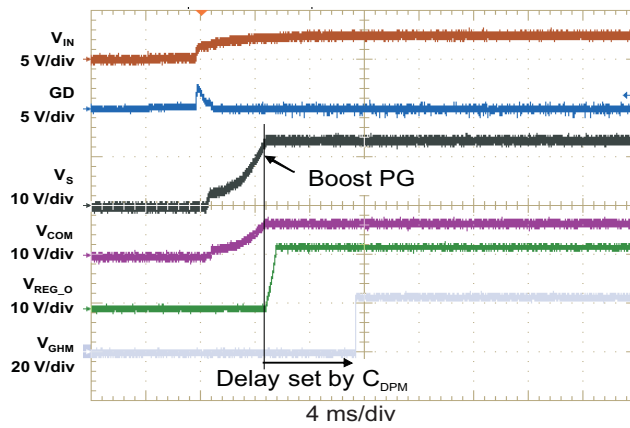


Figure 15.

POWER OFF SEQUENCING

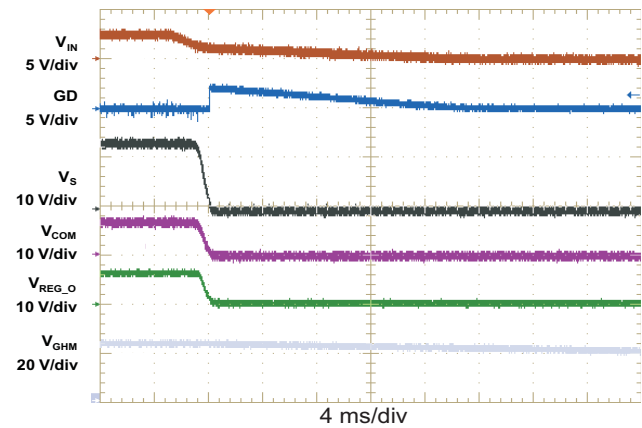


Figure 16.

SHORT CIRCUIT PROTECTION (< 114 ms)

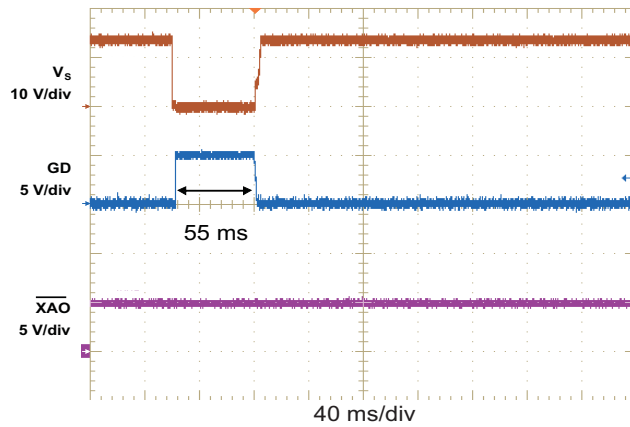


Figure 17.

SHORT CIRCUIT PROTECTION (> 114 ms)

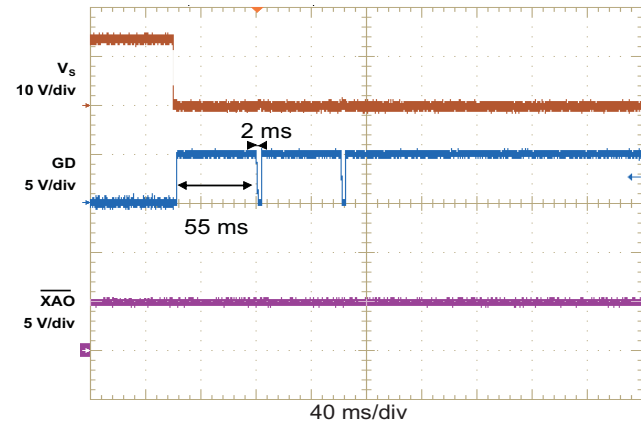


Figure 18.

APPLICATION INFORMATION

BOOST CONVERTER

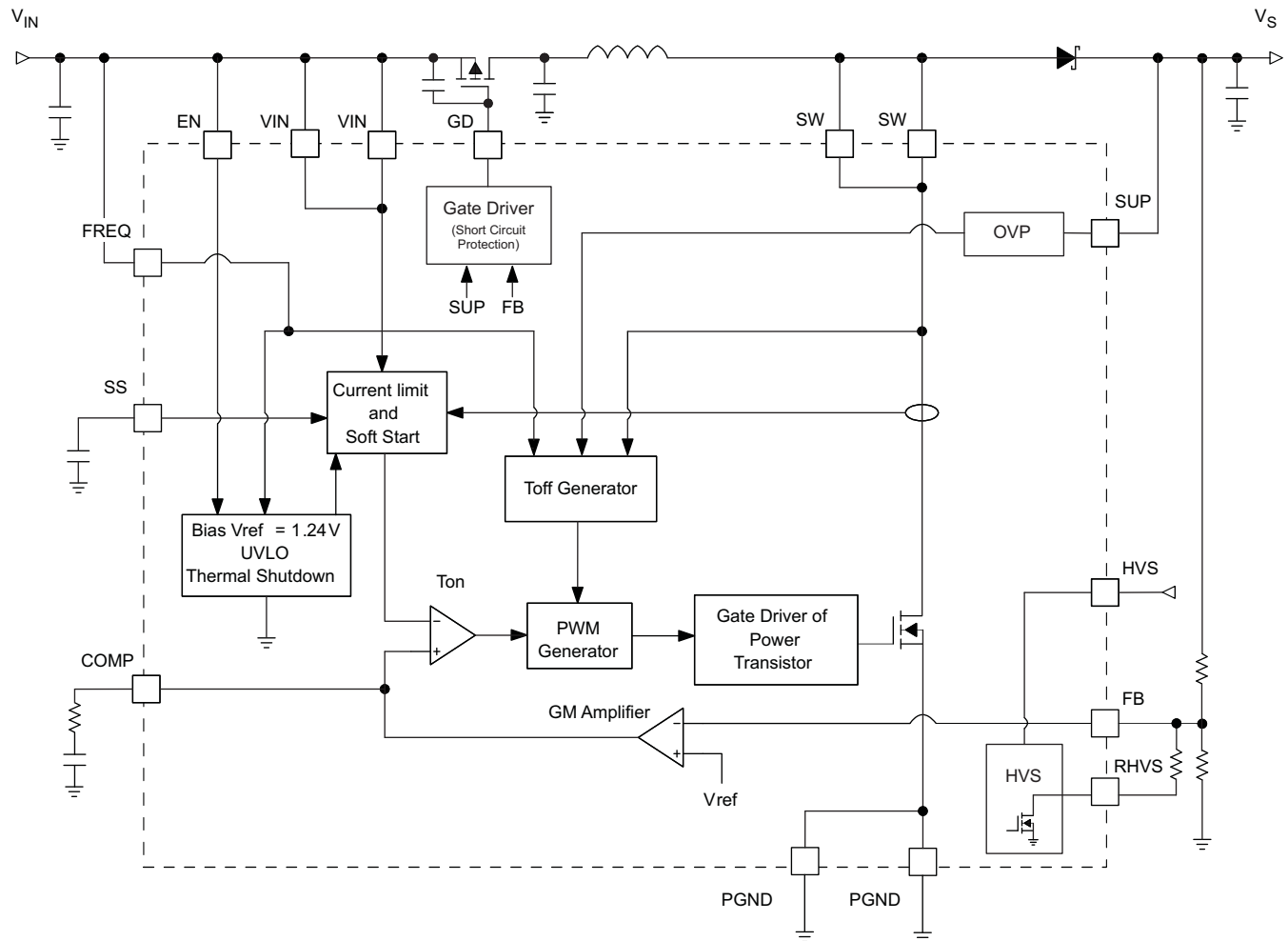


Figure 19. Boost converter block diagram

The boost converter is designed for output voltages up to 18 V with a switch peak current limit of 4 A minimum. The device, which operates in a current mode scheme with quasi-constant frequency, is externally compensated for maximum flexibility and stability. The switching frequency is selectable between 630 kHz and 1.2 MHz and the minimum input voltage is 2.5 V. To limit the inrush current at start-up a soft-start pin is available.

TPS65148 boost converter's novel topology using adaptive off-time provides superior load and line transient responses and operates also over a wider range of applications than conventional converters.

BOOST CONVERTER DESIGN PROCEDURE

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 to use a worst case assumption for the expected efficiency, e.g. 85%.

$$1. \text{ Duty Cycle: } D = \frac{V_{IN} \times \eta}{V_S} \quad (1)$$

$$2. \text{ Inductor ripple current: } \Delta I_L = \frac{V_{IN_min} \times D}{f \times L} \quad (2)$$

$$3. \text{ Maximum output current: } I_{OUT_max} = \left(I_{LIM_min} - \frac{\Delta I_L}{2} \right) \times (1 - D) \quad (3)$$

$$4. \text{ Peak switch current: } I_{swpeak} = \frac{\Delta I_L}{2} + \frac{I_{OUT}}{1 - D} \quad (4)$$

I_{swpeak} = Converter switch current (must be < $I_{LIM_min} = 4$ A)

f = Converter switching frequency (typically 1.2 MHz or 630 kHz)

L = Selected inductor value (from the Inductor Selection section)

η = Estimated converter efficiency (use the number from the efficiency plots or 85% as an estimation)

ΔI_L = Inductor peak-to-peak ripple current

The peak switch current is the steady state current that the integrated switch, inductor and external Schottky diode have to be able to handle. The calculation must be done for the minimum input voltage where the peak switch current is highest.

Inductor Selection

The main parameter for the inductor selection is the saturation current of the inductor which should be higher than the peak switch current as calculated above with additional margin to cover for heavy load transients. An alternative, more conservative, is to choose the inductor with a saturation current at least as high as the maximum switch current limit of 5.6 A. Another 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. Especially for a boost converter where the inductor is the energy storage element, the type and core material of the inductor influences the efficiency as well. At high switching frequencies 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 between 2% to 10%. For the TPS65148, inductor values between 3.3 μ H and 6.8 μ H are a good choice with a switching frequency of 1.2 MHz. At 630 kHz, inductors between 7 μ H and 13 μ H are recommended. $I_{sat} > I_{swpeak}$ imperatively. Possible inductors are shown in [Table 1](#).

Table 1. Inductor Selection

| L (μ H) | COMPONENT SUPPLIER | COMPONENT CODE | SIZE (LxWxH mm) | DCR TYP (m Ω) | Isat (A) |
|-----------------|--------------------|-------------------|--------------------|--------------------------|-------------|
| 1.2 MHz | | | | | |
| 6.8 | Epcos | B82464G4682M | 10.4 x 10.4 x 4.9 | 20 | 4.3 |
| 4.7 | Coiltronics | UP2B-4R7-R | 14 x 10.4 x 6 | 16.5 | 4.2 |
| 4.7 | Sumida | CDRH124NP-4R7M | 12.3 x 12.3 x 4.5 | 18 | 5.7 |
| 4.7 | Sumida | CDRH127NP-4R7N | 12.3 x 12.3 x 8 | 11.7 | 6.8 |
| 630 kHz | | | | | |
| 10 | Coilcraft | DS3316P-103ML | 12.95 x 9.4 x 5.08 | 80 | 3.5 |
| 10 | Sumida | CDRH8D43NP-100N | 8.3 x 8.3 x 4.5 | 29 | 4.0 |
| 10 | Sumida | CDRH127NP-100N | 12.3 x 12.3 x 8 | 16 | 5.4 |
| 10 | Sumida | CDRH127/LDNP-100M | 12.3 x 12.3 x 8 | 15 | 6.7 |

Rectifier Diode Selection

To achieve high efficiency a Schottky type should be used for the rectifier diode. The reverse voltage rating should be higher than the maximum output voltage of the converter. The averaged rectified forward current I_F , the Schottky diode needs to be rated for, is equal to the output current I_{OUT} :

$$I_F = I_{OUT} \quad (5)$$

Usually a Schottky diode with 2 A maximum average rectified forward current rating is sufficient for most of the applications. Also, the Schottky rectifier has to be able to dissipate the power. The dissipated power is the average rectified forward current times the diode forward voltage V_F .

$$P_D = I_F \times V_F$$

Typically the diode should be able to dissipate around 500mW depending on the load current and forward voltage.

Table 2. Rectifier Diode Selection

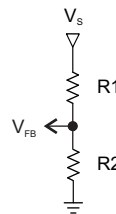
| CURRENT RATING I_F | V_R | V_F / I_F | COMPONENT SUPPLIER | COMPONENT CODE | PACKAGE TYPE |
|----------------------|-------|-------------|--------------------|----------------|--------------|
| 2 A | 20 V | 0.44 V/2 A | Vishay | SL22 | SMA |
| 2 A | 20 V | 0.5 V/2 A | Vishay | SS22 | SMA |

Setting the Output Voltage

The output voltage is set by an external resistor divider. Typically, a minimum current of 50 μ A flowing through the feedback divider is enough to cover the noise fluctuation. The resistors are then calculated with 70 μ A as:

$$R2 = \frac{V_{FB}}{70 \mu A} \approx 18 \text{ k}\Omega$$

$$R1 = R2 \times \left(\frac{V_S}{V_{FB}} - 1 \right)$$



$$\text{with } V_{FB} = 1.240 \text{ V}$$

(6)

Soft-Start (Boost Converter)

To minimize the inrush current during start-up an external capacitor connected to the soft-start pin SS is used to slowly ramp up the internal current limit of the boost converter by charging it with a constant current of typically 10 μ A. The inductor peak current limit is directly dependent on the SS voltage and the maximum load current is available after the soft-start is completed ($V_{SS} = 0.8 \text{ V}$) or V_S has reached its Power Good value, 90% of its nominal value. The larger the capacitor, the slower the ramp of the current limit and the longer the soft-start time. A 100-nF capacitor is usually sufficient for most of the applications. When the EN pin is pulled low, the soft-start capacitor is discharged to ground.

Frequency Select Pin (FREQ)

The digital frequency select pin FREQ allows to set the switching frequency of the device to 630 kHz (FREQ = 'low') or 1.2 MHz (FREQ = 'high'). A higher switching frequency improves the load transient response but reduces slightly the efficiency. The other benefit of a higher switching frequency is a lower output voltage ripple. Usually, it is recommended to use 1.2 MHz switching frequency unless light load efficiency is of major concern.

Compensation (COMP)

The regulation loop can be compensated by adjusting the external components connected to the COMP pin. The COMP pin is the output of the internal transconductance error amplifier. The compensation capacitor will adjust the low frequency gain and the resistor value will adjust the high frequency gain. Lower output voltages require a higher gain and therefore a lower compensation capacitor value. A good start, that will work for the majority of the applications is $R_{COMP} = 47 \text{ k}\Omega$ and $C_{COMP} = 3.3 \text{ nF}$.

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Input Capacitor Selection

For good input voltage filtering low ESR ceramic capacitors are recommended. TPS65148 has an analog input VIN. A 1-μF bypass is required as close as possible from VIN to GND.

Two 10-μF (or one 22-μF) ceramic input capacitor is sufficient for most of the applications. For better input voltage filtering this value can be increased. Refer to [Table 3](#) and typical applications for input capacitor recommendations.

Output Capacitor Selection

For best output voltage filtering a low ESR output capacitor is recommended. Four 10-μF (or two 22-μF) ceramic output capacitors work for most of the applications. Higher capacitor values can be used to improve the load transient response. Refer to [Table 3](#) for the selection of the output capacitor.

Table 3. Rectifier Input and Output Capacitor Selection

| CAPACITOR | VOLTAGE RATING | COMPONENT SUPPLIER | COMPONENT CODE | COMMENTS |
|------------|----------------|--------------------|----------------|------------------|
| 10 μF/0805 | 10 V | Taiyo Yuden | LMK212BJ106KD | C _{IN} |
| 1 μF/0603 | 10 V | Taiyo Yuden | EMK107BJ105KA | VIN bypass |
| 10 μF/1206 | 25 V | Taiyo Yuden | TMK316BJ106ML | C _{OUT} |

To calculate the output voltage ripple, the following equations can be used:

$$\Delta V_C = \frac{V_S - V_{IN}}{V_S \times f} \times \frac{I_{OUT}}{C} \quad \Delta V_{C_ESR} = I_{swpeak} \times R_{C_ESR} \quad (7)$$

ΔV_{C_ESR} can be neglected in many cases since ceramic capacitors provide very low ESR.

Undervoltage Lockout (UVLO)

To avoid misoperation of the device at low input voltages an undervoltage lockout is included that disables the device, if the input voltage falls below 2.0 V.

Gate Drive Pin (GD)

The Gate Drive (GD) allows controlling an external isolation P-channel MOSFET switch. Using a 1-nF capacitor is recommend between the source and the gate of the FET to properly turn it on. GD pin is pulled low when the input voltage is above the undervoltage lockout threshold (UVLO) and when enable (EN) is 'high'. The gate drive has an internal pull up resistor to V_{IN} of typically 5 kΩ. The external P-channel MOSFET must be chosen with V_T < V_{IN_min} in order to be properly turned on.

Overvoltage Protection (OVP)

The main boost converter has an integrated overvoltage protection to prevent the Power Switch from exceeding the absolute maximum switch voltage rating at pin SW in case the feedback (FB) pin is floating or shorted to GND. In such an event, the output voltage rises and is monitored with the OVP comparator over the SUP pin. As soon as the comparator trips at typically 19 V, the boost converter turns the N-Channel MOSFET off. The output voltage falls below the overvoltage threshold and the converter starts switching again. If the voltage on the FB pin is below 90% of its typical value (1.240 V) for more than 55 ms, the device is latched down. The input voltage V_{IN} needs to be cycled to restart the device. In order to detect the overvoltage, the SUP pin needs to be connected to output voltage of the boost converter V_S. XAO output is independent from OVP.

Short Circuit Protection (SCP)

At start-up, as soon as the UVLO is reached and the EN signal is high, the GD pin is pulled 'low'. The feedback voltage of the boost converter V_{FB} as well as the SUP pin voltage (V_S) are sensed. After 2ms, if the voltage on SUP pin has not risen or the FB voltage is below 90% of its typical value (1.240 V), then the GD pin is pulled high for 55ms. After 3 tries, if the device is still in short circuit, it is latched down. The input voltage V_{IN} needs to be cycled to restart the device. The SCP is also valid during normal operation.

Over Current Protection (OCP)

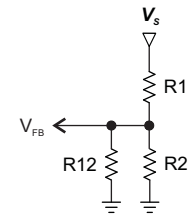
If the FB voltage is below 90% of its typical value (1.240 V) for more than 55 ms, the GD pin is pulled 'high' and the device latched down. The input voltage V_{IN} needs to be cycled to restart the device.

HIGH VOLTAGE STRESS (HVS) FOR THE BOOST CONVERTER

The TPS65148 incorporates a High Voltage Stress test enabled by pulling the logic pin HVS 'high'. The output voltage of the boost converter V_S is then set to a higher output voltage compared to the nominal programmed output voltage. If unregulated external charge pumps are connected via the boost converter, their outputs will increase as V_S increases. This stress voltage is flexible and set by the resistor connected to RHVS pin. With HVS = 'high' the RHVS pin is pulled to GND. The external resistor connected between FB and RHVS (as shown in Figure 19) is therefore put in parallel to the low-side resistor of the boost converter's feedback divider. The output voltage for the boost converter during HVS test is calculated as:

$$V_{S_HVS} = V_{FB} \times \frac{R1+R2 \parallel R12}{R2 \parallel R12}$$

$$R12 = \frac{R1 \times R2}{\left(\frac{V_{S_HVS}}{V_{FB}} - 1 \right) \times R2 - R1}$$



with $V_{FB} = 1.240 \text{ V}$

(8)

If the V_{GH} voltage needs to be set to a higher value by using the HVS test, V_{GH} must be connected to VGH pin without a regulation stage. The V_{GH} voltage will then be equal to V_{S_HVS} times 2 or 3 (depending if a doubler or tripler mode is used for the external positive charge pump). The same circuit changes can be held on the negative charge pump as well if required.

CAUTION

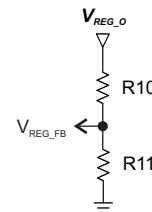
Special caution must be taken in order to limit the voltage on the VGH pin to 35V (maximum recommended voltage).

VOLTAGE REGULATOR FOR GAMMA BUFFER

TPS65148 includes a voltage regulator (Low Dropout Linear Regulator, LDO) to supply the Gamma Buffer with a very stable voltage. The LDO is designed to operate typically with a 4.7 μF ceramic output capacitor (any value between 1 μF and 15 μF works properly) and a ceramic bypass capacitor of minimum 1 μF on its input REG_I connected to ground. The output of the boost converter V_S is usually connected to the input REG_I. The LDO has an internal softstart feature of 2 ms maximum to limit the inrush current. As for the boost converter, a minimum current of 50 μA flowing through the feedback divider is usually enough to cover the noise fluctuation. The resistors are then calculated with 70 μA as:

$$R11 = \frac{V_{REG_FB}}{70 \mu\text{A}} \approx 18 \text{ k}\Omega$$

$$R10 = R11 \times \left(\frac{V_{REG_O}}{V_{REG_FB}} - 1 \right)$$



with $V_{REG_FB} = 1.240 \text{ V}$

(9)

VCOM BUFFER

The VCOM Buffer power supply pin is the SUP pin connected to the boost converter V_S . To achieve good performance and minimize the output noise, a 1 μF ceramic bypass capacitor is required directly from the SUP pin to ground. The input positive pin OPI is either supplied through a resistive divider from V_S or from an external PMIC. The buffer is not designed to drive high capacitive loads; therefore it is recommended to connect a series resistor at the output to provide stable operation when driving a high capacitive load. With a 3.3 Ω series resistor, a capacitive load of 10 nF can be driven, which is usually sufficient for typical LCD applications.

EXTERNAL CHARGE PUMPS

External Positive Charge Pump

The external positive charge pump provides with the below configuration (figure [Figure 20](#)) an output voltage V_{GH} of maximum 3 times the output voltage of the Boost converter V_S . The first stage provides roughly $3 \cdot V_S$ in that configuration, and the second stage is used as regulation whose output voltage is selectable. The operation of the charge pump driver can be understood best with [Figure 20](#) which shows an extract of the positive charge pump driver circuit out of the typical application. The voltage on the collector of the bipolar transistor is slightly equal to $3 \cdot V_S - 4 \cdot V_F$. The next stage regulates the output voltage V_{GH} . A Zener diode clamps the voltage at the desired output value and a bipolar transistor is used to provide better load regulation as well as to reduce the quiescent current. Finally the output voltage on V_{GH} will be equal to $V_Z - V_{be}$.

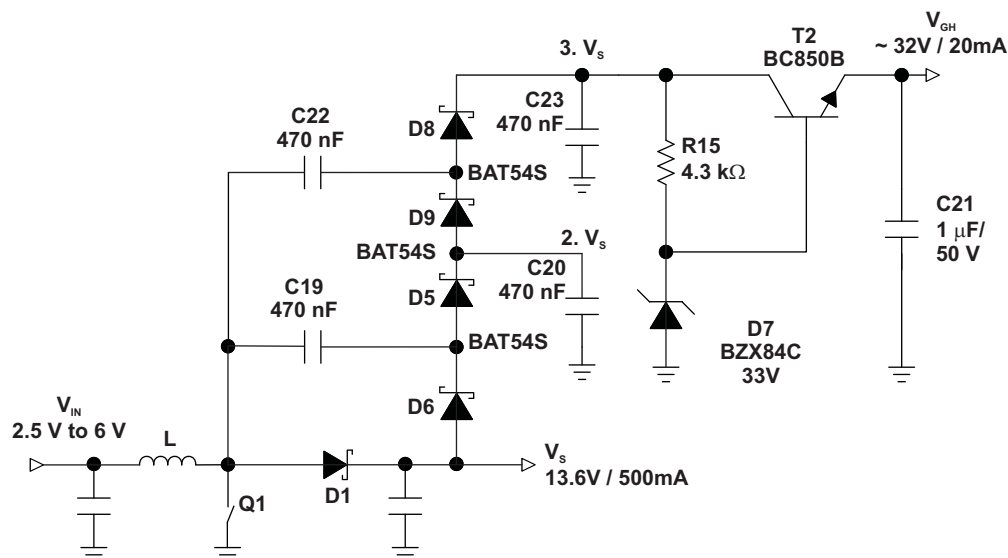


Figure 20. Positive Charge Pump

Doubler Mode: if the V_{GH} voltage can be reached using doubler mode, then the configuration is the same than the one shown in [Figure 28](#).

External Negative Charge Pump

The external negative charge pump works also with two stages (charge pump and regulation). The charge pump provides a negative regulated output voltage. [Figure 21](#) shows the operation details of the negative charge pump. With the first stage, the voltage on the collector of the bipolar transistor is equal to $-V_S + V_F$.

The next stage regulates the output voltage V_{GL} . A resistor and a Zener diode are used to clamp the voltage to the desired output value. The bipolar transistor is used to provide better load regulation as well as to reduce the quiescent current. The output voltage on V_{GL} will be equal to $-V_Z - V_{be}$.

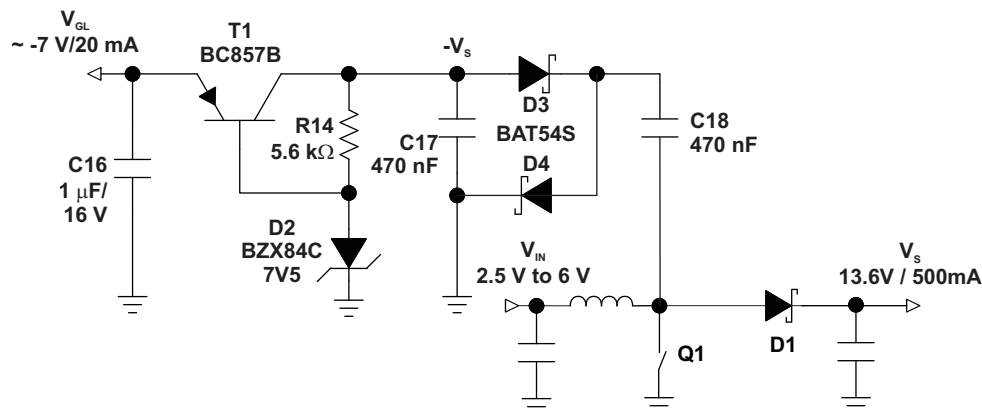


Figure 21. Negative Charge Pump

Components Selection

Capacitors (Charge Pumps)

For best output voltage filtering a low ESR output capacitor is recommended. Ceramic capacitors have a low ESR value but depending on the application tantalum capacitors can be used as well.

The rated voltage of the capacitor has to be able to withstand the voltage across it. Capacitors rated at 50 V are enough for most of the applications. Typically a 470-nF capacitance is sufficient for the flying capacitors whereas bigger values like 1 µF or more can be used for the output capacitors to reduce the output voltage ripple.

| CAPACITOR | COMPONENT SUPPLIER | COMPONENT CODE | COMMENTS |
|-------------|--------------------|----------------|--------------|
| 100 nF/0603 | Taiyo Yuden | HMK107BJ104KA | Flying Cap |
| 470 nF/0805 | Taiyo Yuden | UMK212BJ474KG | Output Cap 1 |
| 1 µF/1210 | Taiyo Yuden | HMK325BJ105KN | Output Cap 2 |

Diodes (Charge Pumps)

For high efficiency, one has to minimize the forward voltage drop of the diodes. Schottky diodes are recommended. The reverse voltage rating must withstand the maximum output voltage V_S of the boost converter. Usually a Schottky diode with 200 mA average forward rectified current is suitable for most of the applications.

| CURRENT RATING I_F | V_R | V_F / I_F | COMPONENT SUPPLIER | COMPONENT CODE | PACKAGE TYPE |
|----------------------|-------|---------------|-------------------------|----------------|--------------|
| 200 mA | 30 V | 0.5 V / 30 mA | International Rectifier | BAT54S | SOT23 |

GATE VOLTAGE SHAPING FUNCTION

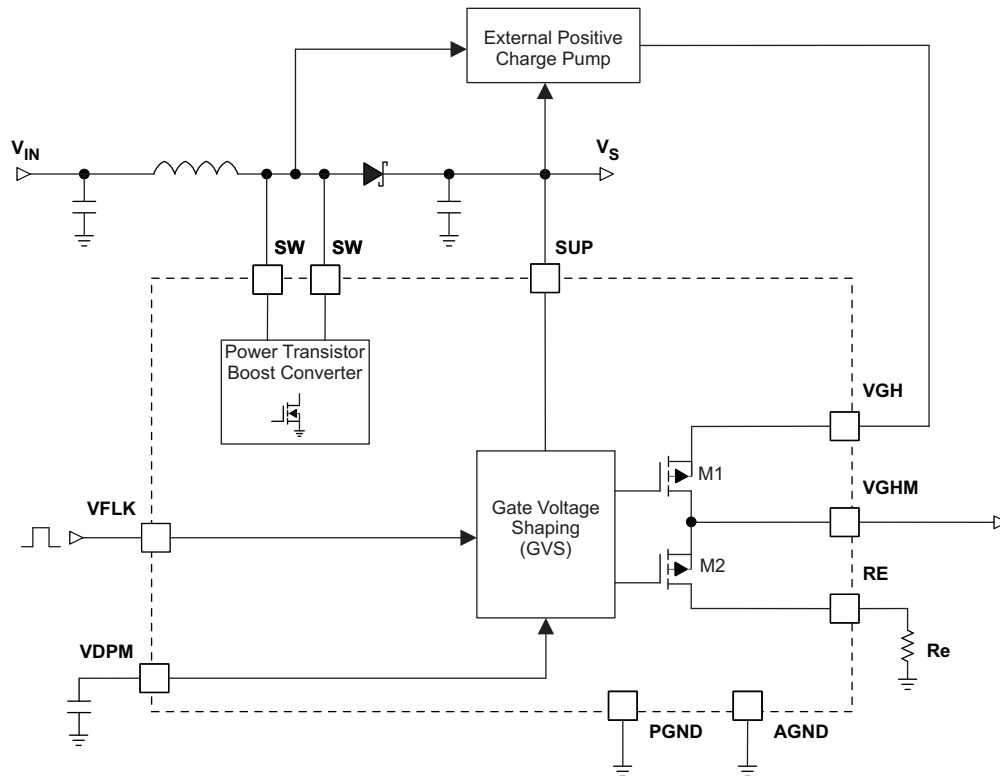


Figure 22. Gate Voltage Shaping Block Diagram

The Gate Voltage Shaping is controlled by the flicker input signal VFLK, except during start-up where it is kept at low state, whatever the VFLK signal is. The VGHM output is enabled once the VDPM voltage is higher than $V_{ref} = 1.240\text{ V}$. The capacitor connected to VDPM (C13 on [Figure 27](#)) pin sets the delay from the boost converter Power Good (90% of its nominal value).

$$C_{VDPM} = \frac{I_{DPM} \times t_{DPM}}{V_{ref}} = \frac{20\text{ }\mu\text{A} \times t_{DPM}}{1.240\text{ V}} \quad (10)$$

VFLK = 'high' $\rightarrow V_{GHM} = V_{GH}$

VFLK = 'low' $\rightarrow V_{GHM}$ discharges through R_e resistor

The slope at which V_{GHM} discharges is set by the external resistor connected to RE, the internal MOSFET $r_{DS(on)}$ (typically 13Ω for M2 – see [Figure 22](#)) and by the external gate line capacitance connected to VGHM pin.

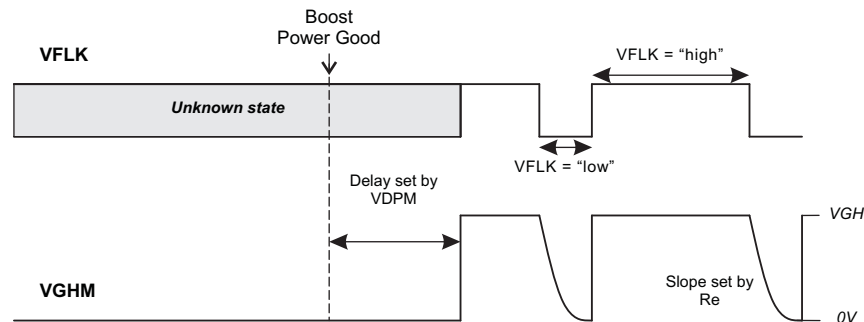


Figure 23. Gate Voltage Shaping Timing

If RE is connected with a resistor to ground (see Figure 23), when VFLK = 'low' V_{G_{GHM}} will discharge from V_{GH} down to 0V. Since 5 × τ (τ = R × C) are needed to fully discharge C through R, we can define the time-constant of the gate voltage shaping block as follow:

$$\tau = (R_E + r_{DS(on)M2}) \times C_{VG_{GHM}}$$

Therefore, if the discharge of C_{V_{GHM}} should finish during V_{FLK} = 'low':

$$t_{\text{discharge}} = 5 \times \tau = t_{V_{FLK}='low'} \Rightarrow R_E = \frac{t_{V_{FLK}='low'}}{5 \times C_{VG_{GHM}}} - r_{DS(on)M2} \quad (11)$$

NOTE

C_{V_{GHM}} and R_{V_{GHM}} form the parasitic RC network of a pixel gate line of the panel. If they are not known, they can be ignored at the beginning and estimated from the discharge slope of V_{G_{GHM}} signal.

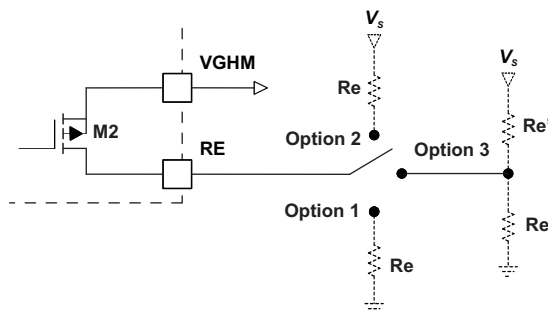


Figure 24. Discharge Path Options for VGHM

Options 2 and 3 from Figure 24 work like option 1 explained above. When M2 is turned on, V_{G_{GHM}} discharges with a slope set by Re from V_{GH} level down to V_S in option 2 configuration and down to the voltage set by the resistor divider in option 3 configuration. The discharging slope is set by Re resistor(s).

NOTE

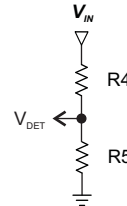
When options 2 or 3 are used, V_{G_{GHM}} is not held to 0V at startup but to the voltage set on RE pin by the resistors Re and Re'.

RESET FUNCTION

The device has an integrated reset function with an open-drain output capable of sinking 1 mA. The reset function monitors the voltage applied to its sense input VDET. As soon as the voltage on VDET falls below the threshold voltage $V_{DET_threshold}$ of typically 1.240 V, the reset function asserts its reset signal by pulling \overline{XAO} low. Typically, a minimum current of 50 μ A flowing through the feedback divider when VDET voltage trips the reference voltage of 1.240 V is required to cover the noise fluctuation. Therefore, to select R4, one has to set the input voltage limit (V_{IN_LIM}) at which the reset function will pull \overline{XAO} to low state. V_{IN_LIM} must be higher than the UVLO threshold. The resistors are then calculated with 70 μ A as:

$$R5 = \frac{V_{DET}}{70 \mu A} \approx 18 \text{ k}\Omega$$

$$R4 = R5 \times \left(\frac{V_{IN_LIM}}{V_{DET}} - 1 \right)$$



with $V_{DET} = 1.240 \text{ V}$

(12)

The reset function is operational for $V_{IN} \geq 1.6\text{V}$:

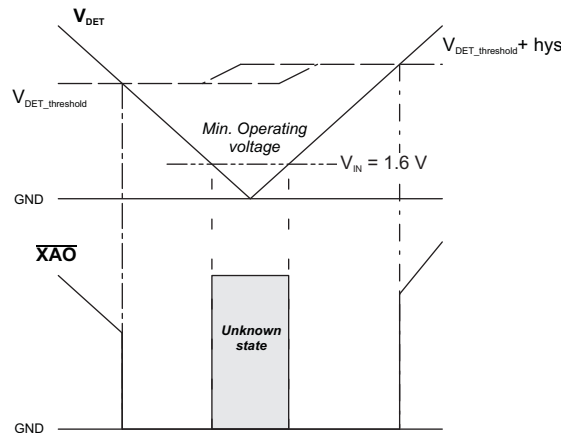


Figure 25. Voltage Detection and \overline{XAO} Pin

The reset function is configured as a standard open-drain output and requires a pull-up resistor. The resistor $R_{\overline{XAO}}$, which must be connected between the \overline{XAO} pin and a positive voltage V_X greater than 2V - 'high' logic level - e.g. V_{IN} , can be chosen as follows:

$$R_{\overline{XAO_min}} > \frac{V_X}{1 \text{ mA}} \quad \& \quad R_{\overline{XAO_max}} < \frac{V_X - 2 \text{ V}}{2 \mu A} \quad (13)$$

THERMAL SHUTDOWN

A thermal shutdown is implemented to prevent damages because of excessive heat and power dissipation. Typically the thermal shutdown threshold for the junction temperature is 150 °C. When the thermal shutdown is triggered the device stops operating until the junction temperature falls below typically 136 °C. Then the device starts switching again. The \overline{XAO} signal is independent of the thermal shutdown.

POWER SEQUENCING

When EN is high and the input voltage V_{IN} reaches the Under Voltage Lockout (UVLO), the device is enabled and the GD pin is pulled low. The boost converter starts switching and the VCOM buffer is enabled. As soon as V_S of the boost converter reaches its Power Good, the voltage regulator for the gamma buffer is enabled and the delay enabling the gate voltage shaping block starts. Once this delay has passed, the VGHM pin output is enabled.

1. GD
2. Boost converter & VCOM Buffer
3. Voltage regulator for Gamma Buffer
4. VGHM (after proper delay)

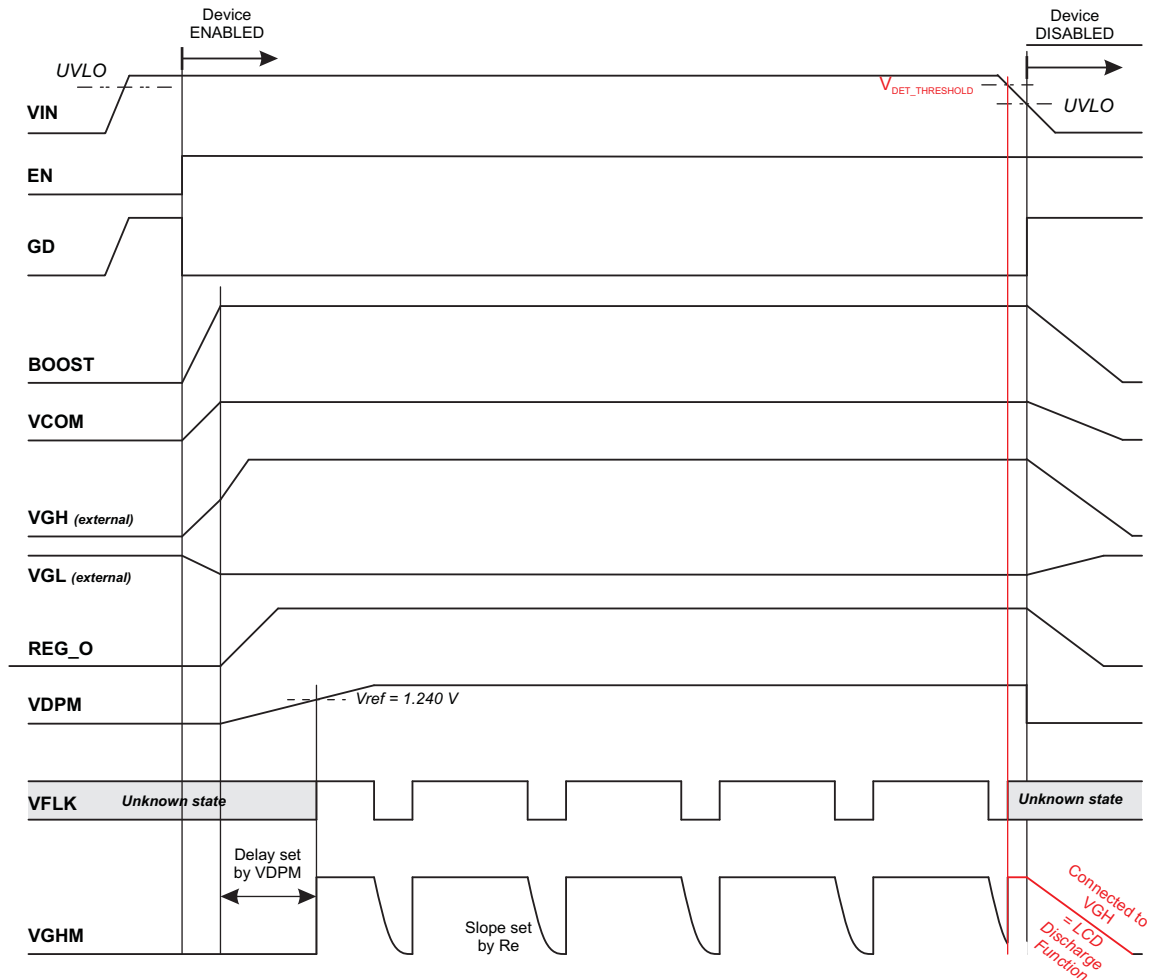


Figure 26. Sequencing TPS65148

Power off sequencing and LCD discharge function

When the input voltage V_{IN} falls below a predefined threshold (set by $V_{DET_THRESHOLD}$ - see Figure 26), \overline{XAO} is driven low and V_{GHM} is driven to V_{GH} . (Note that when V_{IN} falls below the UVLO threshold, all IC functions are disabled except \overline{XAO} and V_{GHM}). Since V_{GHM} is connected to V_{GH} , it tracks the output of the positive charge pump as it decays. This feature, together with \overline{XAO} can be used to discharge the panel by turning on all the pixel TFTs and discharging them into the gradually decaying V_{GHM} voltage. V_{GHM} is held low during power-up.

APPLICATION INFORMATION

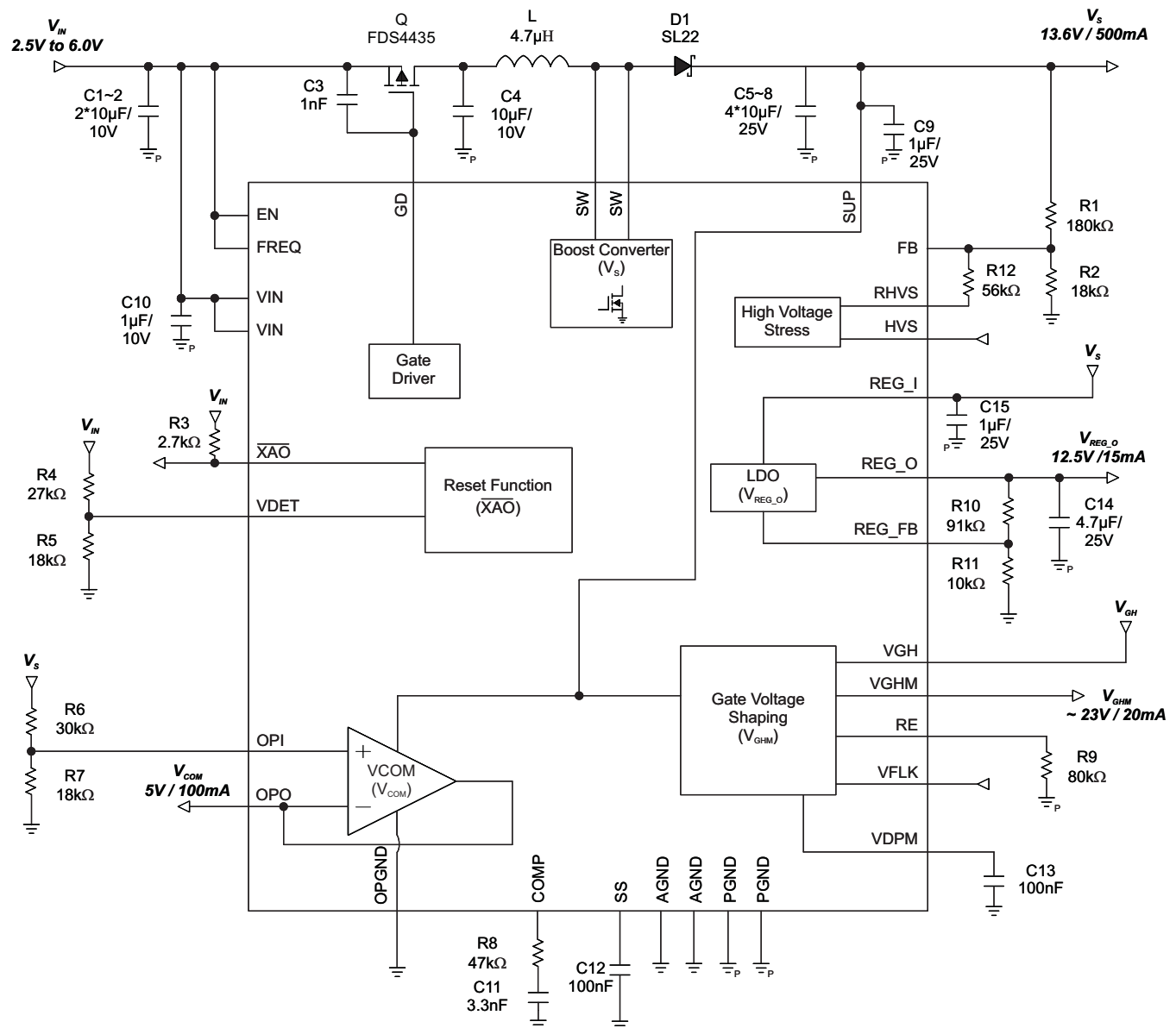


Figure 27. TPS65148 Typical Application

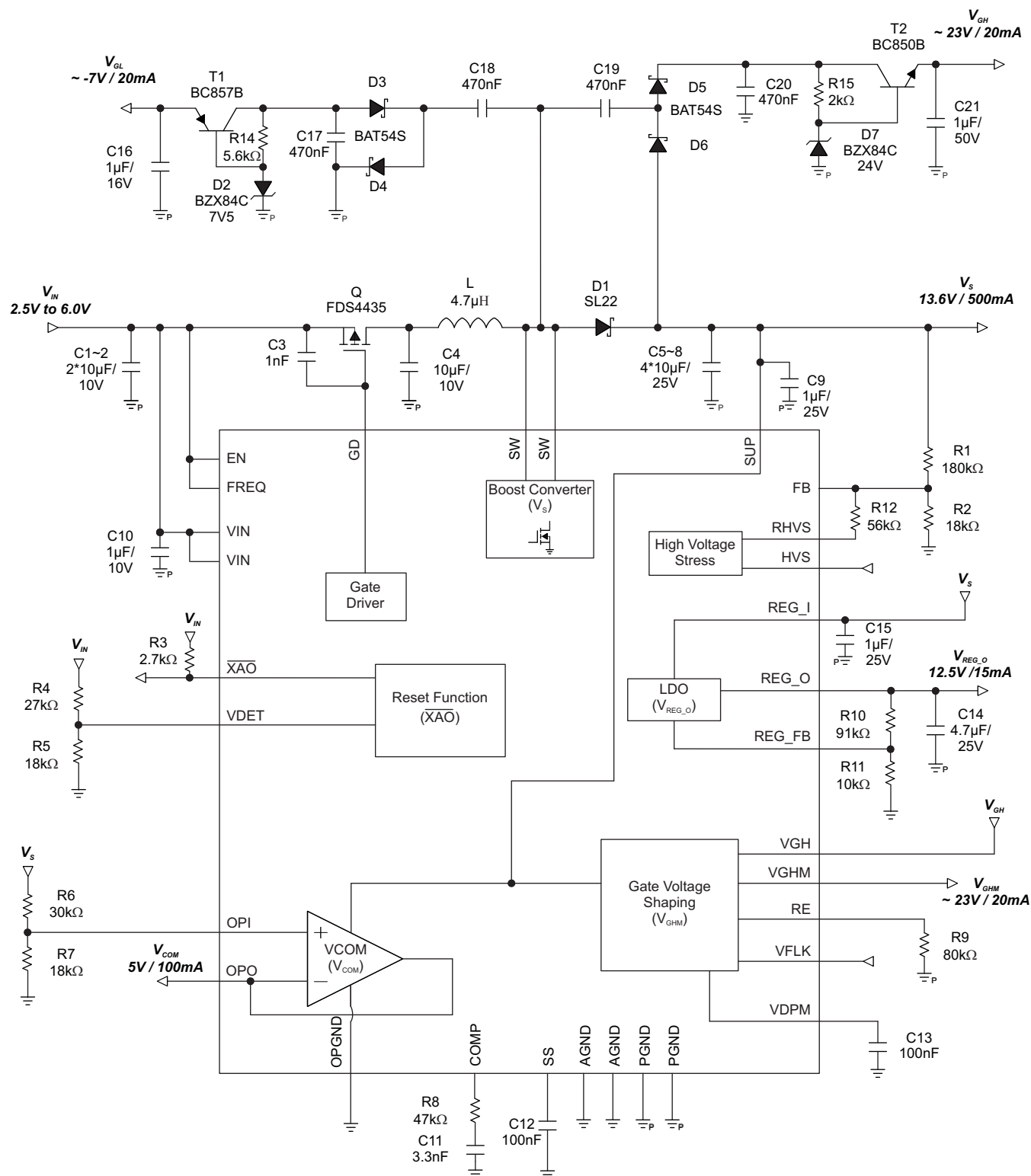


Figure 28. TPS65148 Typical Application with Positive Charge Pump in Doubler Mode Configuration

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS65148RHBR | ACTIVE | VQFN | RHB | 32 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS 65148 | Samples |
| TPS65148RHBT | ACTIVE | VQFN | RHB | 32 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS 65148 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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TAPE AND REEL INFORMATION


*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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS65148RHBR | VQFN | RHB | 32 | 3000 | 330.0 | 12.4 | 5.3 | 5.3 | 1.5 | 8.0 | 12.0 | Q2 |
| TPS65148RHBT | VQFN | RHB | 32 | 250 | 180.0 | 12.4 | 5.3 | 5.3 | 1.5 | 8.0 | 12.0 | Q2 |
| TPS65148RHBT | VQFN | RHB | 32 | 250 | 180.0 | 12.4 | 5.3 | 5.3 | 1.5 | 8.0 | 12.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS

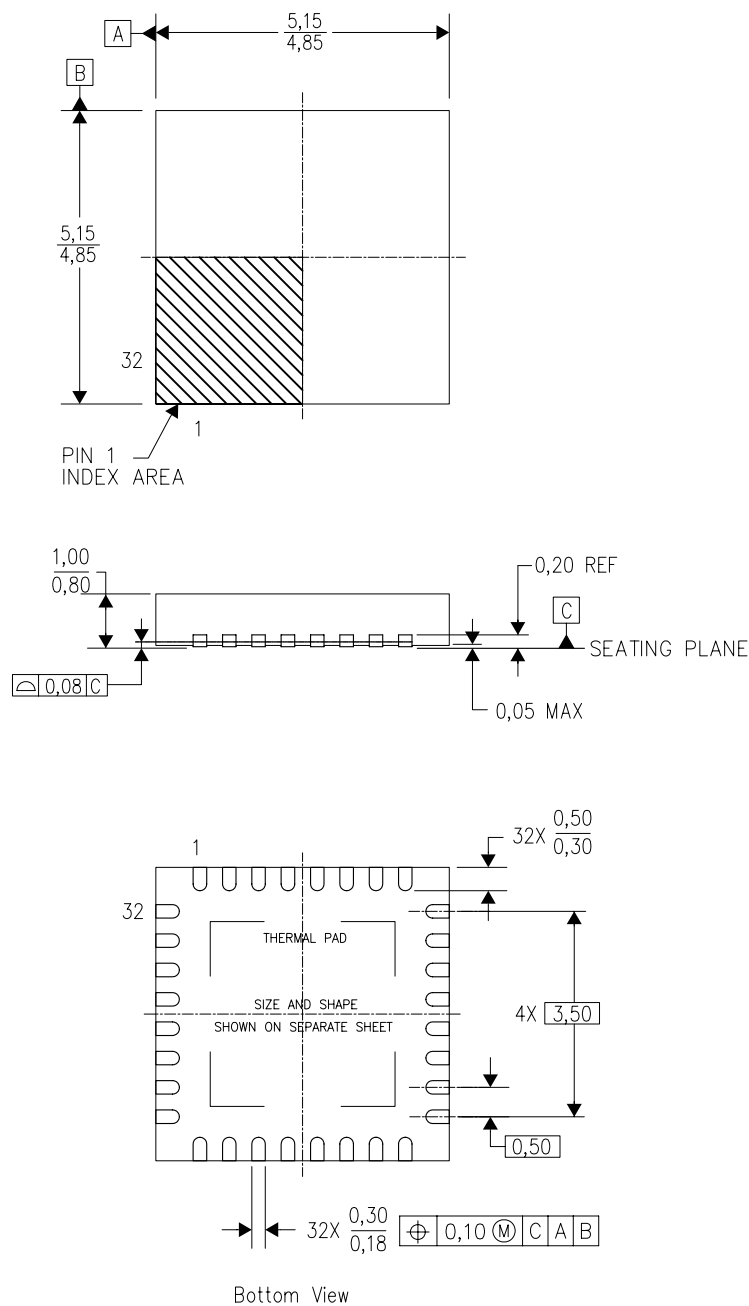


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS65148RHBR | VQFN | RHB | 32 | 3000 | 367.0 | 367.0 | 35.0 |
| TPS65148RHBT | VQFN | RHB | 32 | 250 | 210.0 | 185.0 | 35.0 |
| TPS65148RHBT | VQFN | RHB | 32 | 250 | 210.0 | 185.0 | 35.0 |

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



4204326/D 06/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. QFN (Quad Flatpack No-Lead) Package configuration.
 - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
 - F. Falls within JEDEC MO-220.

RHB (S-PVQFN-N32)

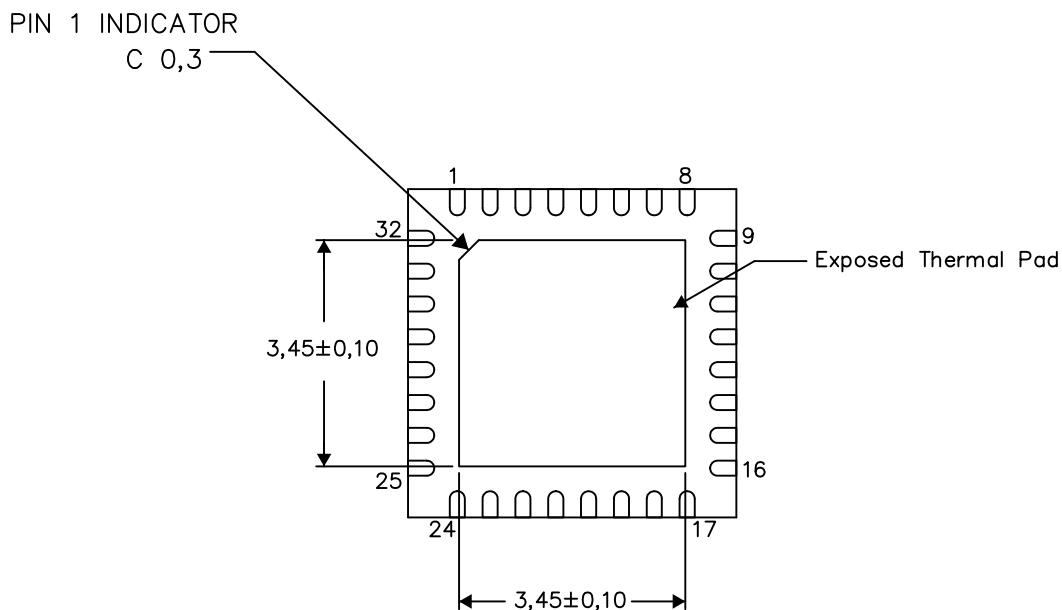
PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

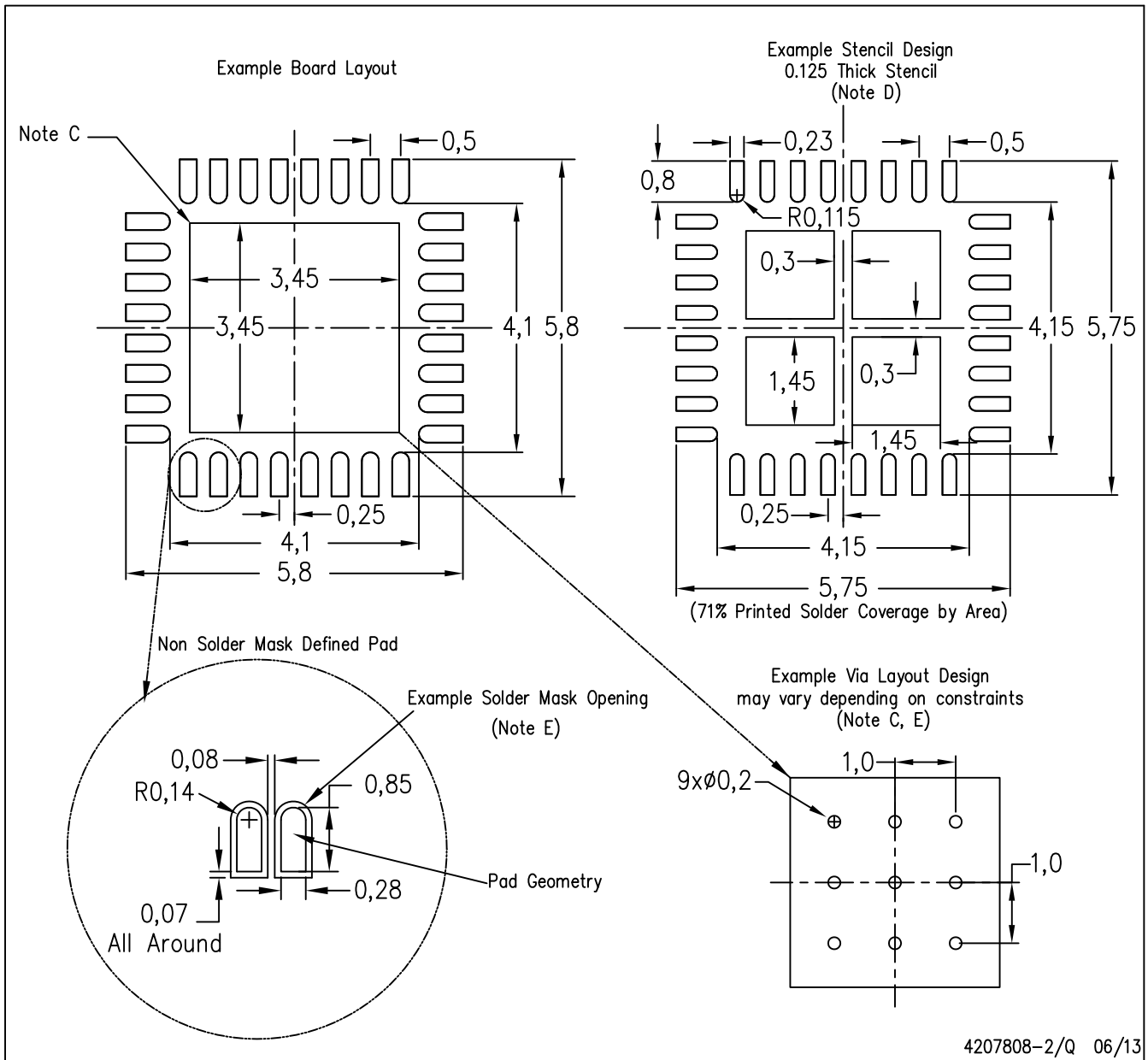
Exposed Thermal Pad Dimensions

4206356-2/Y 06/13

NOTE: A. All linear dimensions are in millimeters

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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