

# TPS658xxEVM Integrated Single-Cell, Lithium-Ion Battery- and Power-Management IC With I2C, LED Drives, Two Synchronous Buck, Boost, and Multiple LDOs

This user's guide is an easy-to-use document that describes the equipment, hardware, software, setup, and a step-by-step procedure to evaluate the features of the TPS65800/810/820/825. The power IC is designed to handle 2 A of input current from the adaptor and up to a 3.5-A discharge from the battery. The charger algorithm is designed to charge a single-cell, Li-ion or Li-polymer battery. The buck, boost, and LDO supplies typically run off of the OUT (system) pin which is available on the IC and is powered from the AC, USB, or battery.

#### Contents

|   | •••••••   |    |
|---|---|----|
| 1 | TPS65800/810/820/825 Charger and Power-Management Evaluation Module | 2  |
| 2 | Test Summary  | 4  |
| 3 | Getting Started With Evaluation                                     | 7  |
| 4 | Software Feature Description  | 7  |
| 5 | Interrupts Software LEDs  | 16 |
| 6 | Schematic   | 17 |
| 7 | Physical Lavouts  | 18 |

#### List of Figures

| 1<br>2 | TPS65810EVM Assembly (Similar to Other Versions) |    |
|--------|--|----|
| 3      | Charger Section                                  | 8  |
| 4      | Buck and Boost Converters Section                |    |
| 5      | LDO Section                                      | 11 |
| 6      | Analog to Digital Converter Section              | 12 |
| 7      | PWM Drivers and RGB Drivers Section              | 14 |
| 8      | Register Map Section                             | 15 |
| 9      | GPIO and Mask Control Section                    | 16 |
| 10     | Board Layout Top Layer                           |    |
| 11     | Board Layout Layer 2                             | 18 |
| 12     | Board Layout Layer 3                             | 19 |
| 13     | Board Layout Bottom Layer                        | 19 |
| 14     | Board Layout Top Assembly Layer                  | 20 |

#### List of Tables

| 1 | TPS65800/810/820/825 Outputs and Operational Range | 3  |
|---|--|----|
| 2 | Performance Specification Summary                  | 4  |
| 3 | HPA129A BOM – TPS65800/810                         | 21 |
| 4 | HPA184A BOM – TPS65820/825                         | 24 |



# 1 TPS65800/810/820/825 Charger and Power-Management Evaluation Module

#### 1.1 Background

The TPS65800/810/820/825 is designed to provide, in a single monolithic IC, flexible charge and system power-path management for a USB-port and AC-adapter supply; as well as multiple power supply outputs, and a number of value-added circuit options to supply an integrated solution for applications powered by one Li-ion or Li-polymer cell, and requiring multiple voltage rails. The TPS65800/810/820/825 features two highly efficient, step-down converters targeted at providing the core voltage, and peripheral I/O rails in a processor-based system. Both converters enter a low-power mode at light load for maximum efficiency across the widest possible range of load currents. The TPS65800/810/820/825 also integrates a boost-type LED driver, six LDO regulators (five programmable and one fixed), one programmable SIM interface LDO, and an integrated backup block for a battery/rechargeable capacitor. The TPS65800/810/820/825 powers the system while independently charging the battery. This feature reduces the charge and discharge cycles on the battery and allows for proper charge termination and system operation with an absent or defective battery pack. The system can instantaneously turn on using an external power source in the case of a deeply discharged battery pack. The TPS65800/810/820/825 automatically selects the USB port or the AC adapter as the power source for the system. In the USB configuration, the host can select from the two preset charge rates of 100 mA and 500 mA. The TPS65800/810/820/825 dynamically adjusts the USB charge rate based on system load to stay within the 100-mA or 500-mA charge rates. In the AC-adapter configuration, an external resistor sets the magnitude of the charge current. The TPS65800/810/820/825 charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal charge timer provides a backup safety for charge termination. The TPS65800/810/820/825 automatically re-starts the charge if the battery voltage falls below an internal threshold.

The TPS65800/810/820/825 also features an 8-channel (2 external), 10-bit, successive-approximation A/D converter with external trigger capabilities performing single, multiple, and continuous readings; and, returning maximum, minimum, or continuous average values. It also has three programmable general-purpose input output (GPIO) ports . GPIO3 is programmed by default as a trigger for the A/D converter. Two general-purpose PWM drivers and an RGB driver, with programmable current, are also included to provide a highly integrated solution suitable for hand-held and other portable applications.

The TPS65810 is similar to the TPS65800, but has a few changes as follows:

- 1. The switcher and LDO outputs may have different default values and may be enabled or disabled differently. See Table 1 for differences.
- 2. The USB boot up is disabled, and ISET2 defaults to high (500-mA current limit level).
- 3. The charger defaults to off.
- 4. The TS current bias is turned off, so external biasing is required to create a battery temperature feedback voltage.
- 5. I2C and read state of GPIO1/2/3.
- 6. Hot Reset reloads register defaults values and internal pullup resistor on HOT\_RESET removed (external resistor is on EVM).
- 7. I2C machine reads interrupt fix.
- 8. SM1/2 default enable control changed from GPIO1 and I2C to GPIO1 or I2C.

The TPS65820 is based on the TPS65800 with a few changes. See the application report <u>SLVA248</u> for the differences among the TPS65800/810/820. The most noticeable difference is on power up, the <u>CE</u> bit is set for battery-only operation. To operate off the AC adapter input, the AC, USB, or the 2.75-A maximium option has to be selected.

2

TPS65800/810/820/825 Charger and Power-Management Evaluation Module

#### Table 1. TPS65800/810/820/825 Outputs and Operational Range<sup>(1)</sup>

|         | 1   |  |            | 1                       |                        |                         |                        | i                  | 1     | 1     |       |
|---------|-----|--|------------|-------------------------|------------------------|-------------------------|------------------------|--------------------|-------|-------|-------|
| Supply  | Pin | Туре   | VOUT       | TPS65800                | )/810/820/825          | TF                      | PS65810                | I <sub>O</sub> MAX | Acc % | Steps | Eff % |
|         |     |  | (V)        | V <sub>оUT</sub><br>(V) | Default<br>EN/DISabled | V <sub>OUT</sub><br>(V) | Default<br>EN/DISabled | (mA)               |       |       |       |
| SM1     | 44  | Buck converter   | 0.6–1.8    | 1.24                    | Enabled                | 1.24                    | Enabled                | 600                | 3     | 32    | 90    |
| SM2     | 49  | Buck converter   | 1.0–3.4    | 1.8                     | Enabled                | 3.32                    | Enabled                | 600                | 3     | 32    | 90    |
| SM3     | 42  | Boost output   | 5–25       | Current<br>driven       | Disabled               | Current<br>driven       | Disabled               | 25                 | 10    | 256   | 80    |
| SIM     | 5   | General-purpose LDO                                    | 1.8 or 3.0 | 1.8 <sup>(2)</sup>      | Disabled               | 2.5                     | Enabled                | 8                  | 5     | 2     | _     |
| LDO_PM  | 10  | General-purpose LDO (only active if AC or USB present) | 3.3        | 3.3                     | Enabled                | 3.3                     | Enabled                | 20                 | 5     | Fixed | -     |
| LDO0    | 32  | General-purpose LDO disabled by default                | 3.3        | 3.3                     | Disabled               | 3.3                     | Disabled               | 150                | 3     | Fixed | _     |
| LDO1    | 37  | General-purpose LDO                                    | 1.25–3.3   | 2.85                    | Enabled                | 1.25                    | Disabled               | 150                | 3     | 8     | _     |
| LDO2    | 33  | General-purpose LDO                                    | 1.25–3.3   | 3.3                     | Enabled                | 3.3                     | Disabled               | 150                | 3     | 8     | _     |
| LDO3    | 28  | High PSRR LDO  | 1.224-4.4  | 1.25 <sup>(3)</sup>     | Enabled                | 1.5                     | Disabled               | 100                | 3     | 128   | _     |
| LDO4    | 27  | High PSRR LDO  | 1.224-4.4  | 2.8                     | Enabled                | 1.8                     | Disabled               | 100                | 3     | 128   | _     |
| LDO5    | 26  | High PSRR LDO  | 1.224–4.4  | 2.75                    | Enabled                | 3.1                     | Enabled                | 100                | 3     | 128   | -     |
| RTC_OUT | 4   | Linear regulator and charger                           | 3.1        | 3.1 <sup>(4)</sup>      | Enabled                | 1.5                     | Enabled                | 8                  | 5     | Fixed | -     |
| PWM     | 34  | PWM (adjustable frequency and duty cycle)              |            |                         |                        |                         |                        | 150                |       |       | mA    |

All output can be controlled and programmed by an I2C-compatible interface. Temperature range is  $-40^{\circ}$ C to  $85^{\circ}$ C. TPS65825 SIM has two selections, 1.8 and 2.8 VDC. The IC defaults to 2.8 VDC. (1)

(2)

(3) TPS65825 LDO3 defaults to 1.5 VDC.

(4) TPS65820/825 RTC\_OUT defaults to 2.6 VDC but 3.1 VDC can be selected.



# 1.2 Performance Specification Summary

This section summarizes the performance specifications of the EVM. Table 2 gives the performance specifications of the EVM.

| Specification                        | Test Conditions | Min                   | Тур | Max                | Units |
|--------------------------------------|-----------------|-----------------------|-----|--------------------|-------|
| Input DC Voltage, V <sub>I(DC)</sub> |                 | V <sub>REG</sub> +0.5 | 5.0 | 6 <sup>(1)</sup>   | Volts |
| Battery Charge Current, IO(CHG)      |                 |                       |     | 1.5 <sup>(1)</sup> | Amps  |
| Power Dissipation                    | Pin-Pout        |                       |     | 5                  | Watts |

# 2 Test Summary

This section shows the test setups used and the features available in evaluating the EVM.

# 2.1 EQUIPMENT – SM1/SM2, LDO, and Battery Load Boards not Provided

- 1. Computer running Windows XP and the attached software.
- 2. EV2300 HPA002 I2C communication box, USB cable and I2C 4-lead cable.
- 3. SM1/2 load board;  $10-\Omega$ , 1-W resistor load for each output TB1-1/2 and TB2-1/2. See Figure 2.
- LDO load board: 33-Ω, 1-W each for J4-LDO0 to A1 GND, J5-LDO1 to A1 GND, J7-LDO2 to A1 GND; 511-Ω, 0.5-W pullup resistors J10-LED\_PWM to TP29-SYS\_OUT and PWM to TP29-SYS\_OUT; 51-Ω, 1-W load resistors for J19-LDO3 to A2 GND, J18-LDO4 to A2 GND, J16-LDO5 to A2 GND. See Figure 2.
- 5. Battery-simulated load board: Two 5.6- $\Omega$ , 20-W and one 10- $\Omega$ , 5-W resistors in parallel and connected TB7-1/2 (~2.19  $\Omega$ ). See Figure 2.
- 6. Dual power supply, 0-V to 5-V adjustable range, 0-A to 3-A adjustable current limit
- 7. Scope

4

8. DMM meter(s).

<sup>(1)</sup> The AC and USB FETs are rated for 18 VDC (all other pens are <6.5 V, see data sheet) but typically this high rating is for transients protection and not for normal operation. The thermal layout on this PCB is optimal and can dissipate up to 5 W with an ambient of 35°C, before the internal junction temperature reaches 125°C. If it is desired to apply DC voltages above 6 V, the charging and load currents may have to be reduced to stay below the 125°C junction temperature. The IC automatically reduces the charging current, with its thermal loop, once the temperature reaches ~12°C. Any further load reduction (on switchers or LDOs) has to be done manually to reduce the junction temperatures. The 125°C threshold is somewhat hard to reach unless the input voltage is high along with high load current, which is not typical.</p>



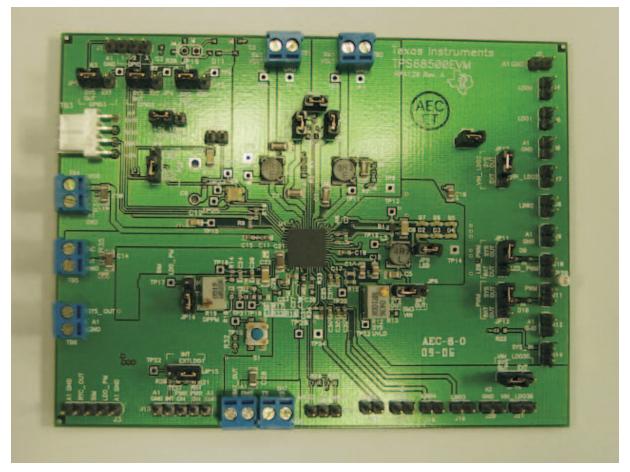


Figure 1. TPS65810EVM Assembly (Similar to Other Versions)

# 2.2 Equipment Setup

- Verify that the jumpers are in the correct location. JP5/4/3/8/15/12/11/13/6/16 are to be set to SYS-OUT, JP7 to +5V, JP14 to RES, JP15 to LDO1, and JP1/2/17/18/9; apply jumper across the two pins. See Figure 1.
- 2. Adjust POT R19 until TP16/A1gnd reads 37K, using DMM.
- 3. Adjust POT R12 fully clockwise.
- Connect the loads shown in Figure 2. These are suggested loads, but the user can substitute any load that is within the specification of the IC. The PWM and LED\_PWM are open-drain outputs and require a external pullup resistor to OUT (System Power). TB6-1 or TP29 can be used as a source for SYS\_OUT.
- 5. Connect the battery-simulated load board shown in Figure 2 below UUT; leave bias supply off. A single-cell Li-ion battery can be used in place of the simulated battery if quick battery voltage adjustment is not needed for evaluation. The battery supply should be the first supply on and the last supply off to avoid putting the BAT output on an unpowered external supply. A power Schottky diode can be placed in series with the positive lead (anode to P/S+) of the battery supply to protect the supply, if necessary.
- 6. Connect USB cable to computer's USB port and the other end to the EV2300 box. Connect the I2C cable between the EV2300 box and the UUT to TB3
- Preset P/S#1 to 5.1 VDC+/-0.1VDC, Current Limit to 2.5A, P/S#2 to 3.5VDC+/-0.1VDC, Current Limit to 2.5A, turn off supplies, connect P/S#1 to TB5-1&2 (+ to AC), and connect P/S#2 to TB7-1&2 (+ to BAT\_OUT). See Figure 2.
- 8. See the following Software Installation description for directions on installing drivers and application

5

#### Test Summary

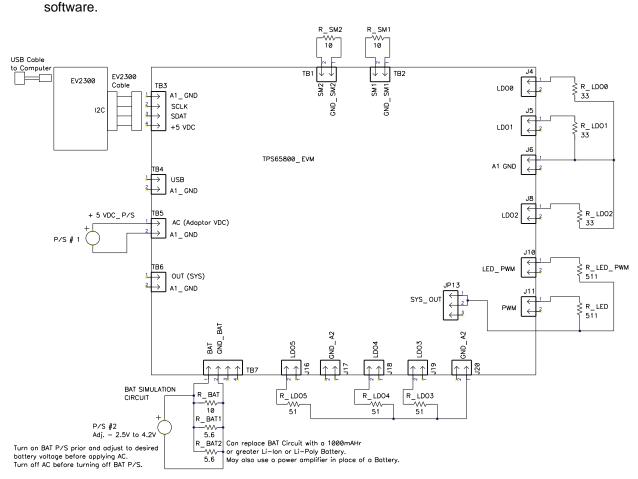


Figure 2. Equipment and EVM Setup

#### 2.3 Software Installation

The following steps install the TPS65800/810 orTPS65820/825 evaluation software:

- 1. Insert CD ROM into a CD ROM drive.
- 2. Select the CD ROM drive using My Computer or File Manager.
- 3. Select the ReadMeFirst.txt file.
- 4. Follow the instructions to install USB drivers for EV2300.
- 5. After installing the USB drivers for EV2300, double-click on the Setup.exe icon that is under the Software/TPS65800, TPS65810, TPS65820, and/or TPS65825 folder.
- 6. The setup program installs a Windows<sup>™</sup> application group. Follow the on-screen instructions until completion.

# 2.4 Starting the Program

6

If the EV2300 is connected to the USB port and the EV2300 drivers installed correctly, then the evaluation software is ready to use. Go to the Getting Started with Evaluation section that follows before starting the application. Close the application if it is open. If the program was installed at its default location, it can be found at Start | Texas Instruments | TPS658xx, where xx is 00, 10, 20, or 25 folder.

# **3 Getting Started With Evaluation**

The evaluation of the TPS65800/810/820/825 is reasonably intuitive when using the software application and the EVM hardware. The user guide is not a step-by-step procedure but an explanation of the result of each software feature. It is highly recommended to read through the data sheet to become familiar with the IC to aid in the evaluation of this EVM. The software code performs several steps per task/feature; reading the data sheet is the best way to understand how to execute these features in the proposed product.

This user's guide was written primarily for the TPS65800 but all versions are similar. For a explanation of the differences among the IC versions, see the TI application report *Differences Between the TPS65800/810/820 PMIC Devices* (SLVA248). The TPS65800/820/825 are similar with few changes. The TPS65810 is similar to the TPS65800 but has different defaults, sequencing, and enable/disable settings.

# 3.1 Start-Up

- 1. Verify that the EVM is set up correctly with the jumpers, loads, and supplies connected as described in the setup procedure.
- 2. Turn on the P/S #2 (preset to 3.5 VDC across BAT pins, 2.5-A current ).
- 3. Turn on P/S #1 (preset to 5 V, 2.5-A current limit).
- 4. Launch software under Start | Texas Instruments | TPS65800/810/820/825 EVSW. The application should come up communicating with the EVM.
- 5. The software is organized under 7 TABs. Click through the tabs to see what features the software controls. Although there is no preferred order to the Evaluation, it may be best to evaluate all the features under one TAB at a time. The ADC tab should be left to last because this section may take longer to evaluate.
- 6. If a communication error occurs, check setup for any connection problems. Also check J14 (SYS\_IN) for a low voltage (<1 V). Close the software and relaunch the application. If the software continues to have a problem with the communication, close the application, turn off P/S#1, then P/S #2, and disconnect the USB cable to the USB connection on the EV2300. Reconnect the USB cable, turn on P/S#2, Turn on P/S#1, and launch the software.
- 7. When the evaluation is finished, close the application; turn off P/S#1, and then P/S#2.

# 4 Software Feature Description

# 4.1 Software Description

Top Menu Description:

# File

*Start Data Log*– Allows the opening of a file so that the logging of a registers' contents can be done in a text file. A Close Data Log option appears in its place when logging is occurring. *Exit*– Closes the evaluation software.

I2C

*Read and Write Addresses*– Permits reading to any desired register. If a register allows it, then it can be written.

# Options

*Refresh*– Updates the screen with valid data obtained from the TPS65800/810/820/825. It is useful for when recovering from a loss of I2C communication.

Logging Options- Allows selecting which registers to log and the time interval between each log line.

#### Help

About- Gives information of version release of software.

# 4.2 Charger

The charger section allows the user to monitor and control the charger functions of the TPS65800/810/820/825 (see Figure 3). The TPS65820/825 IC has a unique feature on power up. After the 150-ms USB boot-up, the PMIC defaults to battery power unless the CE pin is written high prior to the boot-up expiring. The CE pin is at address 9\_B0 and is changed via I2C. If the battery is not present and CE is not written high prior to the end of the boot-up, then the system crashes because the BAT pin cannot supply the power. The following controls are available.

- Set Battery Charge Voltage (pulldown window): Default set to 4.2 VDC. To set to 4.36 VDC, select and then confirm yes.
- Set Charge Rate as a percentage of maximum programmed by ISET1 (pulldown window): Select one of four choices 25%, 50%, 75%, or 100% of ISET1 programmed level.
- USB pin input current limit (pulldown window): Select the maximum allowed USB input current level, 100 mA, 500 mA, or 2.75 A (soft internal limit).
- System Power Source (pulldown window): Select AC, USB or Battery or Battery Only (AC/USB disable mode).
- Charge Suspend (box): The user can suspend charge by checking the box.

Charger status indications are:

- Power Good Indicates if voltages at AC or USB inputs are greater than the battery voltage.
- Status Indicates if the charger is in Pre-charge, Fast Charge, Charge Done or Charge Suspend mode.
- Overvoltage Indicates if the AC or USB source are within voltage range.
- Dynamic Power Path Management (DPPM) Powers the system via AC, USB, and/or BAT (see the diagram in Figure 3).

The information windows are data collected and reported by the ADC such as the battery voltage, the system voltage, the IC temperature, and detection of BATT ID resistor.

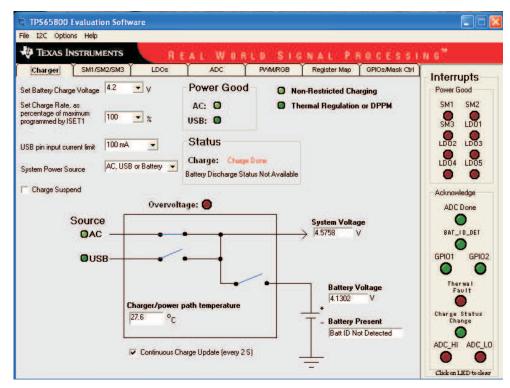


Figure 3. Charger Section

8





# 4.3 SM1/SM2/SM3

For the following descriptions of the buck (SM1 and SM2) and boost (SM3) converters, see Figure 4.

SM1 – Synchronous Buck Converter with programmable output: 0.6 VDC-1.8 VDC:

- SM1 Settings: The buck converter can be set in three modes: Normal, Standby and Disabled.
- SM1 Voltage: The voltage can be set by writing the desired voltage value into the text field and then pressing ENTER. The value is then adjusted to the closest value permitted based on the resolution.
- Stby1 Set: The voltage can be set by writing the desired voltage value into the text field and then pressing ENTER. The value is then adjusted to the closest value permitted based on the resolution.
- Slew Rate: The slew rate when going from standby set voltage to normal set voltage can be selected ranging from 0.15 mV/ $\mu$ s up to the maximum slew rate.
- SM1 Mode: The converter can be programmed for PWM ONLY mode or an AUTO mode that switches between PFM and PWM based on the load.
- The PFM mode can be programmed for low ripple or high efficiency.
- SM1 Discharge Switch Enable: When enabled, applies a resistor to the SM1 output when the output is disabled for discharging the output capacitor.
- GPIO Control Enable (box): When enabled, allows the GPIO1 input to enable or disable the SM1/2 Settings. GPIO1 can be selected to be an active at high- or low-logic level.

SM2 – Synchronous Buck Converter with programmable output: 1 VDC and 3.4 VDC

The SM2 descriptions are the same as SM1 (i.e., Replace SM1 with SM2).

#### SM1/SM2 Common Controls

- GPIO1 Control SM1/SM2 Standby (box): The GPIO1 input signal can control Standby on the SM1/SM2 buck converters if the box is checked, when not using GPIO1 for the enable function.
- Phase Shifting (pulldown window): The buck converters can be phase shifted with respect to each other, in increments of 90°.
- SM1-SM2 Standby: If checked, the SM1/SM2 converters are placed in Standby (does not change SM1 setting selection).

#### SM3 - Boost Converter

The boost converter is used to drive six white LEDs on the EVM board. To control the intensity of the light emitted, simply enter a value between 0 and 100 and click the **Set** button. The value is adjusted to the nearest available resolution.

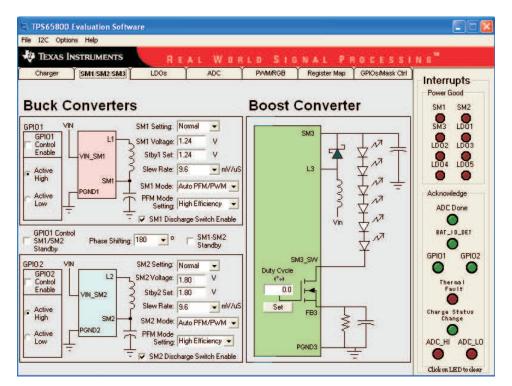


Figure 4. Buck and Boost Converters Section

# 4.4 LDOs — TPS65800 (See Table 1 for Corresponding Outputs for TPS65810/820/825)

For the following descriptions of the LDO settings, see Figure 5

LDO 0: Fixed at 3.3 VDC, the output is disabled on power up and can be enabled by checking the box.

RTC: Fixed at 3.1 VDC, the output is enabled on power up and can be disabled by unchecking the box.

**SIM:** Set to 1.8 VDC, and can be changed to 3 VDC; output is disabled on power up and can be enabled by checking the box.

**LDO 1:** Default set to 2.85 VDC, and the output can be changed, after power up, via I2C by selecting 1 of 8 settings between 1.25 VDC to 3.3 VDC.

**LDO 2:** Default set to 3.3 VDC, and the output can be changed, after power up, via I2C by selecting 1 of 8 settings between 1.25 VDC to 3.3 VDC.

**LDO 3:** Default set to 1.2495 VDC, and the output can be set, after power up, via I2C within the range of 1.22 VDC to 4.46 VDC (128 setting steps).

**LDO 4:** Default set to 2.754 VDC, and the output can be set, after power up, via I2C within the range of 1.22 VDC to 4.46 VDC (128 setting steps).

**LDO 5:** Default set to 2.805 VDC, and the output can be set, after power up, via I2C within the range of 1.22 VDC to 4.46 VDC (128 setting steps).

#### LDO 1-5:

- Output is enabled on power up and comes up to default setting for TPS65800. For TPS65810, outputs are disabled on power up and have to be enabled by I2C for use.
- LDO x Discharge, where x=1-5: If box is checked, a resistor is applied when the output is disabled to discharge the capacitor.
- Enable LDO x, where x=1-5: The output can be disabled by unchecking the box.



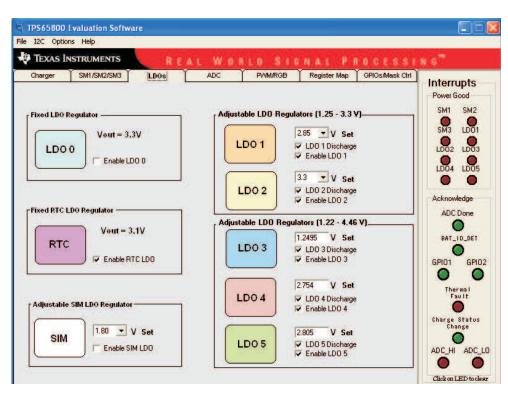


Figure 5. LDO Section

# 4.5 ADC

This section is used to control the functions of the ADC (see Figure 6).

#### MODE:

- Repeat/Non-Repeat (bullet): Continuous conversions or a single conversion
- Start Conversion: Click on button to start single or continuous conversions.
- Stop Conversion (shown when Repeat is selected): Stops continuous conversions

• Delay (Pulldown window): Select 1 of 4 delays between conversions.

# External Signal Trigger (GPIO3 Input Trigger for Data Conversion)

- External Trigger Enable (box): Check box to use the GPIO3 input as a trigger to initiate conversions; otherwise, initiation can be done manually.
- GPIO3 Input (drop-down window): Select Falling or Rising trigger edge.
- Hold Off Enable (Box): If box is checked, then when GPIO3 input signal goes inactive (opposite of what is selected), the data collection is put on hold and then continues once the GPIO3 input signal goes active again. This allows a certain sample size to be collected over a controlled time frame.

#### Reference

- Internal Reference of 2.535 VDC, which is maximum scale for Analog 1 through 5. Analog 6 through 8 are scaled up by a factor of 1.854 because the input to the ADC was divided down by this factor. Analog 1 and 2 are the only *user-defined* external inputs.
- External: Maximum value of 3.5 V; the resolution is based on the external value instead of the internal value and is otherwise similar to the operation previously described.

Analog 1/2 Current Set (pulldown window): Select 1 of 4 current sources.

#### Data Conversions/Control Block/ADC Reading- Continuous and Single

There is a Repeat Mode and a Non-Repeat mode. For best results, use the following steps: *Non-Repeat mode* 

1. Select *Non-Repeat* mode.

11



- 2. Select Input Channel- eight choices from pulldown window.
- 3. Select *ADC\_LO* and *ADC\_HI* alarm thresholds Default settings programmed in EVM software are used unless updated in window.
- 4. Select Sampling mode- eight choices in pulldown window between 1 and 256.
- 5. Select *Wait between conversions* time 16 choices in pulldown window between 0 ms and 20.48 ms.
- 6. Click on Start Conversions button.

Once the ADC is done, it displays the four types of ADC readings available.

#### Repeat mode

- 1. Select Repeat mode.
- 2. Select *Delay* time.
- 3. Select Input Channel- eight choices from pulldown window.
- 4. Select *ADC\_LO* and *ADC\_HI* alarm thresholds Default settings programmed in EVM software are used unless updated in window.
- 5. Select Sampling mode- eight choices in pulldown window between 1 and 256.
- 6. Select *Wait between conversions* time 16 choices in pulldown window between 0 ms and 20.48 ms.
- 7. Click on *Start Conversions* button. When the conversion is stopped after a single conversion or an *alarm fault*, there is an *LED Acknowledgment* for either the ADC Done, the ADC\_HI, or ADC\_LO.
- 8. Allow the ADC to perform conversions for the time desired, and then click on the *Stop Conversions* button or if an ADC\_HI or ADC\_LO alarms is detected, the conversion stops automatically, indicating a High or Low Alarm and will display the ADC readings. Note that if the data collection is interrupted by an alarm fault, the average value is likely wrong, on multiple data samples, because the unread data points are zero.
- 9. Click on *Stop Conversions* button when you are ready to read from the ADC. Once the ADC is done with is current conversion, it displays the four ADC readings.

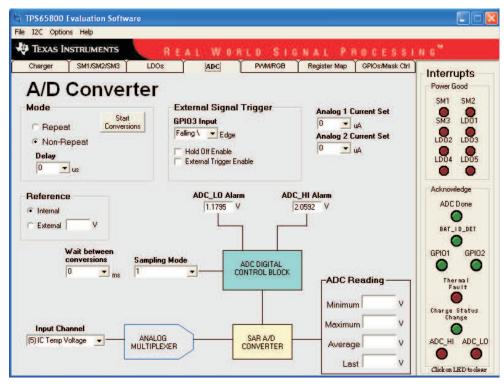


Figure 6. Analog to Digital Converter Section



# 4.6 PWM/RGB

This section is used to control the PWM and the RGB drivers (see Figure 7).

# **PWM Drivers**

- Frequency (pulldown window): Select from eight frequencies between 500 Hz and 15,600 Hz
- Duty Cycle (pulldown window): Select from 16 duty cycles between 6.25% and 100%. The PWM is an open drain and requires an external pullup resistor. A 10% duty cycle pulls the signal low 10% of the period T (t=1/f).
- Enable (box): Check box to enable signal.

#### **LED PWM Drivers**

- Pattern Repeat Frequency: To understand the repeat frequency, set the duty cycle to 0.4% and look at with scope. You should see one pulse per period (122/183 Hz). If the duty cycle is set to 0.8%, there will be two pulses per period and so on, so the repeat pattern is within the selected period (1/122=8.2 ms or 1/183=5.5 ms).
- Duty Cycle (window): You can enter a duty cycle from 0% to 100%. The number entered is updated to the closest value from a list of 256 equal step values.

#### **RGB** Driver

- Common Flash Period (pulldown window): Select from 15 values from 1- to 8-second flash period or continuous.
- Common on time (pulldown window): Select from eight values from 0.1-to-0.6 second for LED(s) on time.
- Phase Delay (pulldown window): During the common on time, the color selected is in phase with red; the other color is out of phase with red. You must observe with the scope because this is not typically visible with the eye.
- Open Loop Current (pulldown window): Select from four constant-current levels from 0 mA to 12 mA. You can visualize the change but is hard to see with the scope because the change in voltage drop across the LED due to the change in current, from 4 mA to 12 mA, is small.
- Red/Green/Blue Intensity (windows): You can enter a duty cycle from 0% to 100%. The number entered is updated to the closest value from a list of 32 equal step values.
- RGB Enable (box): Check this box to enable RGB LEDs. Note that the Open Loop Current level and Red/Green/Blue Intensity values have to be something other than zero for the LEDs to light.



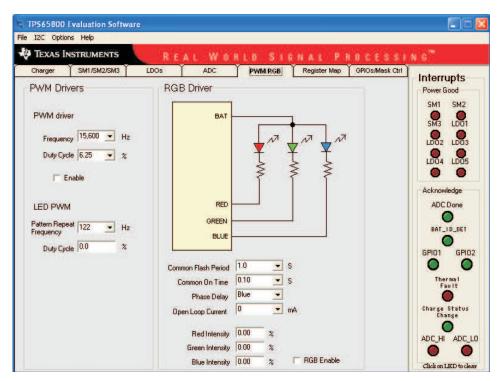


Figure 7. PWM Drivers and RGB Drivers Section

# 4.7 Register Map

This section contains the full register map of the TPS65800/810/820/825 (see Figure 8). The scan reads through all the registers. Registers that permit writes can be written by selecting the corresponding *Data* (*HEX*) grid and writing the desired data in hexadecimal format (i.e., 5F).



| P TEX         | AS INSTRUMENTS    |               | REAL       | WOR           |             | AL P          | ROCESSI    | N 6  |
|---------------|-------------------|---------------|------------|---------------|-------------|---------------|------------|--|
| Charg         | ger X SM1/SM2/SM3 | ε) ι          | DOs Y /    | ADC ]         |             | gister Maj    |            | Interrupts<br>Power Good   |
| Addr<br>(HEX) | Name              | Data<br>(HEX) | Data (BIN) | Addr<br>(HEX) | Name        | Data<br>(HEX) | Data (BIN) | SM1 SM2  |
| 00            | DEVICE_ID         |               |            | 14            | SM2_SET2    |               |            | SM3 LD01   |
| 01            | START_UP          |               |            | 15            | SM2_STANDBY |               |            |  |
| 02            | PGOOD             |               |            | 16            | SM3_SET     |               |            |  |
| 03            | INTMASK1          |               |            | 17            | RGB_FLASH   |               |            | LD04 LD05  |
| 04            | INTMASK2          |               |            | 18            | RGB_RED     |               |            | And a second |
| 05            | INT_ACK1          |               |            | 19            | RGB_GREEN   |               |            | • •  |
| 06            | INT_ACK2          |               |            | 1A            | RGB_BLUE    |               |            | Acknowledge  |
| 07            | RES_MASK          |               |            | 18            | GPI012      |               |            | ADC Done   |
| 08            | SOFT_RESET        |               |            | 10            | GPI03       |               |            |  |
| 09            | CHG_CONFIG        |               |            | 1D            | PWM         |               |            | BAT_ID_DET   |
| 0A            | CHG_STAT          |               |            | 1E            | ADC_SET     |               |            | BHI_TU_UET   |
| 0B            | EN_LDO            |               |            | 1F            | ADC_HI      |               |            |  |
| 0C            | LDO12             |               |            | 20            | ADC_LO      |               |            | GPI01 GPI02  |
| 0D            | LDO3              |               |            | 21            | DHILIM1     |               |            | 0 0  |
| 0E            | LDO4              |               |            | 22            | DHILIM2     |               |            | Thermal<br>Fault   |
| OF            | LDO5              |               |            | 23            | DLOLIM1     |               |            |  |
| 10            | SM1_SET1          |               |            | 24            | DLOLIM2     |               |            | Charge Status  |
| 11            | SM1_SET2          |               |            | 25            | ADC_DELAY   |               |            | Change   |
| 12            | SM1_STANDBY       |               |            | 26            | ADC_WAIT    |               |            | 0  |
| 13            | SM2 SET1          |               |            | 27            | LED_PWM     |               |            | ADC HI ADC LO  |

Figure 8. Register Map Section

# 4.8 GPIOs/Mask CTRL

For the following GPIO/Mask CTRL descriptions, see Figure 9.

# GPIO1

Function (pulldown window): Defines if the GPIO1 is an input or output.

If set as an input, the GPIO1 input signal can be set to control the:

- 1. Enable of SM1 Buck Converter (see SM1/SM2/SM3 tab),
- 2. Enable Standby of SM1/SM2 Buck Converters (see SM1/SM2/SM3 tab), or
- 3. The INT output pin and the GPIO1 LED.

If set as an output, the *Output Level* pulldown window appears, and GPIO1 is set according to the *Output Level* pulldown window.

*Output Level* (pulldown window): Select High or Low to set the level of the GPIO1 output pin (only available if GPIO1 is set as an output).

*GPIO1 Interrupt Source* (box): Check box if you want a GPIO1 input signal to toggle the INT pin and turn on the Acknowledge LED (stays on momentarily until it is read). Only available if GPIO1 is set as an input.

*Interrupt Edge* (pulldown window): Choose Rising or Falling Edge for triggering GPIO1 input interrupt (only available if GPIO1 is set as an input).

#### GPIO2

Function (pulldown window): Defines if the GPIO2 is an input or output

If set as an input, the GPIO2 input signal can be set to control the:

- 1. Enable of SM2 Buck Converter (see SM1/SM2/SM3 tab), or
- 2. The INT output pin and the GPIO2 LED.

If set as an output, the *Output Level* pulldown window appears and GPIO2 is set according to the *Output Level* pulldown window.

*Output Level* (pulldown window): Select High or Low to set the level of the GPIO2 output pin (only available if GPIO2 is set as an output).



#### Interrupts Software LEDs

*GPIO2 Interrupt Source* (box): Check box if you want a GPIO2 input signal to toggle the INT pin and turn on the Acknowledge LED (stays on momentarily until it is read). Only available if GPIO2 is set as an input.

*Interrupt Edge* (pulldown window): Choose Rising or Falling Edge for triggering GPIO2 input interrupt (only available if GPIO2 is set as an input).

#### GPIO3

Function (pulldown window): Defines if the GPIO3 is an input or output.

If set as an input, the GPIO3 input signal triggers the data conversion routine (see SM1/SM2/SM3 tab).

If set as an output, the *Output Level* pulldown window appears and GPIO3 is set according to the *Output Level* pulldown window.

*Output Level* (pulldown window): Select High or Low to set the level of the GPIO3 output pin (Only available if GPIO3 is set as an output).

#### Mask INT Interrupts

Sixteen signals are monitored by the ADC for fault conditions, and on detection of a fault, the ADC toggles the INT pin. If the box of a particular signal is checked (masked), the reporting of that fault via the INT pin is disabled.

#### **Sleep Mode Settings**

The ADC can be put in sleep mode by a fault (voltage out of range) of any one of the eight power output signals. Check the box(s) for the signal(s) that should put the ADC in sleep mode when in fault status.

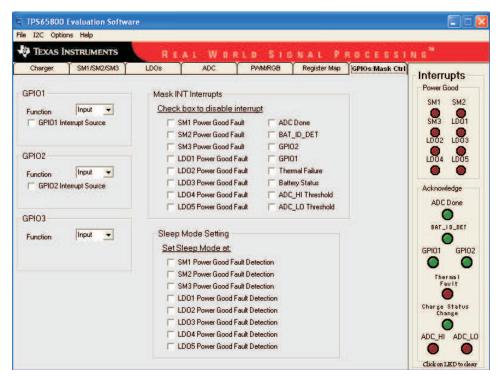


Figure 9. GPIO and Mask Control Section

# 5 Interrupts Software LEDs

This section describes the values of the bits contained in INT\_ACK1 and INT\_ACK2 registers. The INT\_ACK1 contains the Power Good interrupts and INT\_ACK2 contains acknowledgment of interrupts due to events or change of status. Given that the acknowledgments are cleared in the IC once read, the evaluation software manipulates the acknowledgments so that the user can be aware of events that have occurred. So, if an acknowledgment is set in the software, it may not represent the true time value of the corresponding bit.



**Power Good** – These are set if a power-good interrupt occurs caused by any of the following being out of range:

- SM1, SM2, SM3
- LDO1, LDO2, LDO3, LDO4, and LDO5

Acknowledge – These are set if any of the following events occur:

- ADC DONE It is set whenever the ADC has completed conversion without violating the ADC\_HI or ADC\_LO thresholds. To clear the lit LED, click on LED. When operating the software from the ADC section, the software clears the lit LED automatically whenever a conversion is initiated. Given that the event that sets this bit is instantaneous, the software clears the corresponding LED after a user's acknowledgment (click on LED) or to initialize a conversion.
- BAT\_ID\_DET It is set if an external ID resistor that is in battery pack is detected at ANALOG 1 input.
- GPIO\_1 If GPIO1 is set as an input, and the GPIO1 INT SOURCE bit is set, then the GPIO\_1
   Acknowledgment LED toggles for each time that the GPIO1 pin detects a falling edge (in the case that
   the GPIO is set for falling edge) or a rising edge (in the case that the GPIO is set for rising edge).
- GPIO\_2– If GPIO2 is set as an input, and the GPIO2 INT SOURCE bit is set, then the GPIO\_2 Acknowledgment LED toggles for each time that the GPIO2 pin detects a falling edge (in the case that the GPIO is set for falling edge) or a rising edge (in the case that the GPIO is set for rising edge).
- Thermal\_Fault If the IC internal temperature reaches ~155°C, the thermal Fault LED turns on.
- Charge Status Change This bit indicates that the status of the charging has change from one of the following states to another state: precharge, fastcharge, charge pending, and charge done.
- ADC\_HI It is set whenever the ADC conversions are terminated due to exceeding ADC\_HI thresholds. To clear the lit LED, click on LED. When operating the software from the ADC section, the software clears the LED automatically whenever a conversion is initiated. Given that the event that sets this bit is instantaneous, the software clears the corresponding LED after a user's acknowledgment (click on LED) or to initialize a conversion.
- ADC\_LO It is set whenever the ADC conversions are terminated due to measurements captured by the ADC being lower than the ADC\_LO threshold. To clear the lit LED, click on LED. When operating the software from the ADC section, the software clears the LED automatically whenever a conversion is initiated. Given that the event that sets this bit is instantaneous, the software clears the corresponding LED after a user's acknowledgment (click on LED) or to initialize a conversion.

# 6 Schematic

The schematic is appended to the end of this document.



#### 7 Physical Layouts

This section contains the board layout, assembly drawings for the EVM, and the bill of materials table. Only the TPS65800/810EVM layout is shown. The TPS65820/825 is identical except for the reduced package size of the TPS65820/825 IC.

# 7.1 Board Layouts

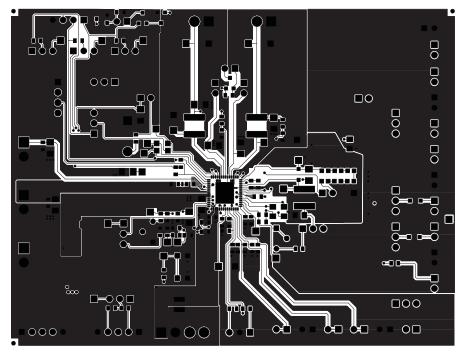


Figure 10. Board Layout Top Layer

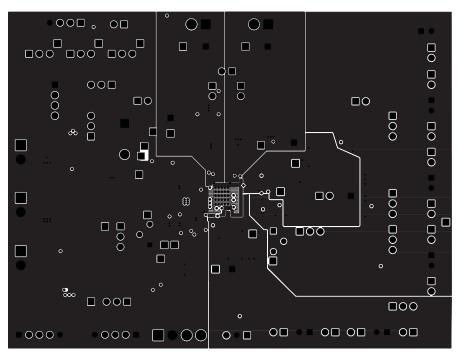


Figure 11. Board Layout Layer 2



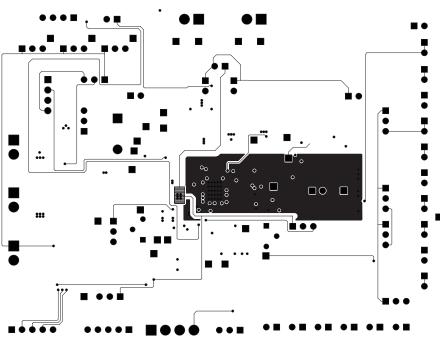


Figure 12. Board Layout Layer 3

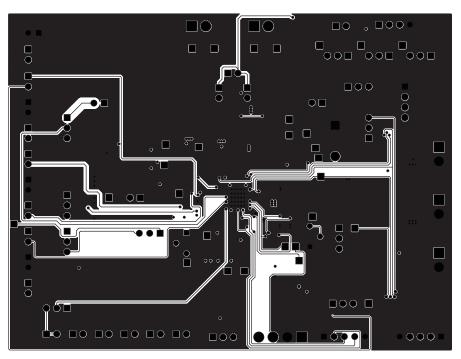


Figure 13. Board Layout Bottom Layer

19

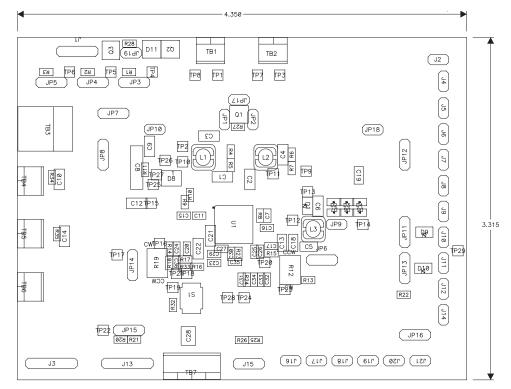


Figure 14. Board Layout Top Assembly Layer



# 7.2 Bill of Materials

Table 3 and Table 4 lists materials required for the EVM.

# Table 3. HPA129A BOM – TPS65800/810

| -001<br>TPS65800 | -002<br>TPS65810 |                             |                  |  |                       |                    |           |
|------------------|------------------|-----------------------------|------------------|--|-----------------------|--------------------|-----------|
| Count            | Count            | Ref Des                     | Value            | Description  | Size                  | Part Number        | MFR       |
| 7                | 7                | C1–C4, C9,<br>C10,C14, C21  | 10 μF            | Capacitor, Ceramic, 10-µF, 16-V, X5R, 20%              | 1206                  | ECJ-3YB1E106M      | Panasonic |
| 3                | 3                | C11, C15, C27               | 0.22 μF          | Capacitor, Ceramic, 0.22-µF, 16-V, X7R, 10%            | 0603                  | C1608X7R1C224K     | TDK       |
| 3                | 3                | C13, C18, C19               | 4.7 μF           | Capacitor, Ceramic, 10V, X5R, 10%                      | 0805                  | C0805C475K8PACTU   | Kemel     |
| 2                | 2                | C16, C25                    | 1 μF             | Capacitor, Ceramic, 1-µF, 16-V, X7R, 10%               | 0603                  | C1608X7R1C105K     | TDK       |
| 3                | 3                | C17, C24, C36               | 1 nF             | Capacitor, Ceramic, 1-nF, 5-V, X7R, 10%                | 0603                  | C0603C102J5GACTU   | Kemmet    |
| 1                | 1                | C20                         | 0.1 μF           | Capacitor, Ceramic, 0.1 µF, 50-V, X7R, 10%             | 0603                  | C1608X7R1H104K     | TDK       |
| 1                | 1                | C22                         | 1 μF             | Capacitor, Ceramic, 16-V, X5R, 20%                     | 1206                  | ECJ-3YB1E105M      | Panasonic |
| 0                | 0                | C23                         | 0.22 μF          | Capacitor, Ceramic, 0.22- µF, 16-V, X7R, 10%           | 0603                  | C1608X7R1C224K     | TDK       |
| 1                | 1                | C26                         | 0.01 μF          | Capacitor, Ceramic, 0.01- μF, 50-V, X7R, 10%           | 0603                  | C1608X7R1H103K     | TDK       |
| 1                | 1                | C28                         | 22 μF            | Capacitor, Ceramic, 50-V, X5R, 20%                     | 1206                  | ECJ-DV50J226M      | Panasonic |
| 1                | 1                | C29                         | 100 nF           | Capacitor, Ceramic, 0.1-µF, 50-V, X7R, 10%             | 0603                  | C1608X7R1H104K     | TDK       |
| 1                | 1                | C30                         | 4.7 μF           | Capacitor, Ceramic, 4.7-µF, 6.3-V, X5R, 20%            | 0603                  | ECJ-1VB0J475M      | Panasonic |
| 0                | 0                | C31, C35                    | 1 nF             | Capacitor, Ceramic, 1-nF, 50-V, NPO, 10%               | 0603                  | C0603C102J5GACTU   | Kemmet    |
| 1                | 1                | C12                         | 2.2 μF           | Capacitor, Ceramic, 2.2-µF, 6.3-V, X5R, 10%            | 0805                  | C0805C225K9PACTU   | Kemmet    |
| 3                | 3                | C32–C34                     | 2.2 μF           | Capacitor, Ceramic, 2.2 µF, 6.3-V, X5R, 20%            | 0603                  | C1608X5R0J225M     | TDK       |
| 1                | 1                | C5                          | 10 μF            | Capacitor, Ceramic, 1 µF, 6.3-V, X5R, 10%              | 0805                  | C0805C106K9PACTU   | Kemmet    |
| 2                | 2                | C6, C9                      | 1 μF             | Capacitor, Ceramic, 10 µF, 25 V, X7R, 10%              | 1206                  | C3216X7R1C105/0.85 | TDK       |
| 1                | 1                | C7                          | 100 pF           | Capacitor, Ceramic, 100-pF, 50-V, NPO, 10%             | 0603                  | C0603C101J5GACTU   | Kemmet    |
| 0                | 0                | C8                          | SUPER            | Capacitor, Through Hole, User's Option                 |                       | User's Option      | Mil-Max   |
| 3                | 3                | D1, D9, D10                 | ZHCS400          | Diode, Schottky, 400 mA, 40-V                          | SOD323                | ZHCS400            | Zelex     |
| 1                | 0                | D11                         | BAT54A           | Diode, Dual Schottky, 300-mA, 30-V                     | SOT23                 | BAT54A             | ST        |
| 6                | 6                | D2–D7                       | WHITE            | Diode, LED, White, 20-mA                               | 0603                  | 160-1720-1-ND      | Liteon    |
| 1                | 1                | D8                          | QTLP650D-<br>RGB | Diode, LED, Red, Green, Blue 30-20-20-mA, Common anode | 0.118 × 0.134<br>inch | QTLP650D-RGB       | Fairchild |
| 1                | 1                | J1                          | PTC36SAAN        | Header, 4-pin, 100 mil spacing, (36-pin strip)         | 0.100 × 4             | PTC36SAAN          | Sullins   |
| 1                | 1                | J15                         | PTC36SAAN        | Header, 3-pin, 100 mil spacing, (36-pin strip)         | 0.100 × 3             | PTC36SAAN          |           |
| 17               | 17               | J2, J4–J12, J14,<br>J16–J21 | PTC36SAAN        | Header, 2-pin, 100 mil spacing, (36-pin strip)         | 0.100 × 2             | PTC36SAAN          |           |
| 2                | 2                | J3, J13                     | PTC36SAAN        | Header, 5-pin, 100 mil spacing, (36-pin strip)         | 0.100 × 5             | PTC36SAAN          |           |

#### Physical Layouts

#### Table 3. HPA129A BOM - TPS65800/810 (continued)

| -001<br>TPS65800 | -002<br>TPS65810 |                                       |           |  |                     |             |         |
|------------------|------------------|---------------------------------------|-----------|--|---------------------|-------------|---------|
| Count            | Count            | Ref Des                               | Value     | Description                                    | Size                | Part Number | MFR     |
| 6                | 6                | JP1, JP2, JP9,<br>JP10, JP17,<br>JP18 | PTC36SAAN | Header, 2-pin, 100 mil spacing, (36-pin strip) | 0.100 × 2           | PTC36SAAN   | Sullins |
| 1                | 0                | JP19                                  | PTC36SAAN | Header, 2-pin, 100 mil spacing, (36-pin strip) | 0.100 × 2           | PTC36SAAN   | Sullins |
| 12               | 12               | JP3–JP8,<br>JP11–JP16                 | PTC36SAAN | Header, 3-pin, 100 mil spacing, (36-pin strip) | 0.100 × 3           | PTC36SAAN   | Sullins |
| 2                | 2                | L1, L2                                | 3.3 μΗ    | Inductor, SMT, 3.3 H, 1A, 85 m $\Omega$        | 0.185 × 0.185       | CDRH4D-3R3  | Sumida  |
| 1                | 1                | L3                                    | 4.7 μΗ    | Inductor, SMT, 4.7 H, 0.84A, 125 mΩ            | 0.185 × 0.185       | CDRH4D-4R7  | Sumida  |
| 1                | 0                | Q1                                    | IRLML6401 | MOSFET, P-ch, -12V,-3.4A, 50 mΩ                | SOT23               | IRLML6401   | IR      |
| 2                | 0                | Q2, Q3                                | IRLML2402 | MOSFET, N-ch, 20V,1.2A, 250 mΩ                 | SOT23               | IRLML2402   | IR      |
| 8                | 8                | R1–R3, R15,<br>R20, R21, R34,<br>R35  | 100K      | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 0                | 1                | R32                                   | 100K      | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 1                | 1                | R11                                   | 300       | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 1                | 1                | R12                                   | 100K      | Potentiometer, 1/4 Cermet, 12-Turn, Top-Adjust | 0.25 × 0.17<br>inch | 3266W-104   | Bourns  |
| 1                | 1                | R13                                   | 174K      | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 1                | 1                | R14                                   | 22.6K     | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 2                | 2                | R16, R23                              | 1K        | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 2                | 2                | R17, R18                              | 49.9K     | Resistor, Chip. 1/16-W, 1%                     | 0603                | Std         | Std     |
| 1                | 1                | R19                                   | 20K       | Potentiometer, 1/4 Cermet, 12-Turn, Top-Adjust | 0.25 × 0.17<br>inch | 3266W-203   | Bourns  |
| 1                | 1                | R22                                   | 22.1K     | Resistor, Chip, 22.1kΩ, 1/16-W, 1%             | 0603                | Std         | Std     |
| 1                | 1                | R24                                   | 200K      | Resistor, Chip, 1/16-W, 1%                     | 0602                | Std         | Std     |
| 1                | 0                | R27                                   | 200K      | Resistor, Chip, 1/16-W, 1%                     | 0603                | Std         | Std     |
| 1                | 0                | R28                                   | 2Meg      | Resistor, Chip, 1/16-W, 1%                     | 0603                | Std         | Std     |
| 5                | 5                | R4, R6, R25,<br>R26, R33              | 0         | Resistor, Chip, 1/16W, 1%                      | 0603                | Std         | Std     |
| 0                | 0                | R5, R7                                | Optional  | Resistor, Chip, 1/16W, 1%                      | 0603                | Std         | Std     |
| 1                | 1                | R8                                    | 10        | Resistor, Chip, 1/16W, 1%                      | 0603                | Std         | Std     |
| 2                | 2                | R9, R10                               | 2K        | Resistor, Chip, 1/16W, 1%                      | 0603                | Std         | Std     |
| 1                | 1                | S1                                    | (Value)   | Switch, 1P1T, PB Momentary, 100-mA, SM         | 0.19 × 0.18"        | 7914G       | Bourns  |
| 5                | 5                | TB1, TB2,<br>TB4–TB6                  | ED1514    | Terminal Block, 2-pin, 6-A, 3,5 mm             | 0.27 × 0.25         | ED1514      | OST     |

# Table 3. HPA129A BOM - TPS65800/810 (continued)

| -001<br>TPS65800 | -002<br>TPS65810             |                    |  |   |                         |                        |                   |
|------------------|------------------------------|--------------------|--|---|-------------------------|------------------------|-------------------|
| Count            | Count                        | Ref Des            | Value  | Description   | Size                    | Part Number            | MFR               |
| 1                | 1                            | ТВЗ                | 22-05-3041   | Header, Friction Lock Ass'y. 4-pin right angle        | 0.400 × 0.500           | 22-05-3041             | Molex             |
| 1                | 1                            | TB7                | ED1516   | Terminal Block, 4-pin, 6-A, 3,5 mm                    | 0.55 × 0.25<br>inch     | ED1516                 | OST               |
| 1                | 1                            | TP29               | 5012   | Test Point, 0.032 hole                                | 0.25                    |                        | None              |
| 1                | 0                            | U1                 | TPS65800RTQ  | IC, Integrated Handheld Power Solution                | QFN-56                  | TPS65800RTQ            | ТІ                |
| 0                | 1                            | U1                 | TPS65810RTQ  | IC, Integrated Handheld Power Solution                | QFN-56                  | TPS65810RTQ            | ТІ                |
| 17               | 17                           | See Note 5         |  | Shunt, 100-mil, Black                                 | 0.1                     | 929950-00              | 3M                |
| 1                | 1                            | —                  |  | PCB, 4 in $\times$ 3 in $\times$ 0.031 in             |                         | HPA129                 | Any               |
| 1                | 1                            |                    |  |   |                         |                        |                   |
|                  | 2                            | J5 mate            | Connector, Fem   | ale, 0.100 Centers                                    |                         | 22-01-3047             | Molex             |
|                  | 8                            | N/A                | Terminals, Crimp   | Terminals, Crimp, Tin                                 |                         |                        | Molex             |
|                  |                              | N/A                | Wire, Insulated 24 Awg, Red, (18 inches) (±3 inches)(USB_5V) |   |                         | 1854-3                 | Alpha             |
|                  |                              | N/A                | Wire, Insulated 2  |   | 1854-1                  | Alpha                  |                   |
|                  |                              | N/A                | Wire, Insulated 2  | 24 Awg, Black, (18 inches) (±3 inches) (GND)          |                         | 1854-2                 | Alpha             |
|                  |                              | N/A                | Wire, Insulated 2  | 24 Awg, Brown, (18 inches) (±3 inches) (SDA)          |                         | 1854-7                 | Alpha             |
|                  | 1                            | N/A                | Heatsink 1"  |   |                         |                        |                   |
| Notes: 1.        | These assem                  | blies are ESD ser  | nsitive, ESD precauti  | ons shall be observed.                                |                         |                        |                   |
| 2.               | These assem                  | blies must be clea | an and free from flux  | and all contaminants. Use of no clean flux is not acc | eptable.                |                        |                   |
| 3.               | These assem                  | blies must comply  | y with workmanship s   | standards IPC-A-610 Class 2.                          |                         |                        |                   |
| 4.               | Ref designato                | ors marked with a  | n asterisk (**) cannot                                       | be substituted. All other components can be substitu  | uted with equivalent MF | G's components.        |                   |
| 5.               | Apply Shunt a across the two |                    | 15/JP4/JP3/JP8/JP1   | 2/JP11/JP13/JP6/JP16 are to be sent to SYS-OUT, .     | JP7 to +5V, JP14 to RE  | S, and JP1/JP2/JP17/JF | P18/JP9 apply jum |

| Table 4. HPA184A BOM – | TPS65820/825 |
|------------------------|--------------|
|------------------------|--------------|

| -001<br>TPS65820 | -002<br>TPS65825 |                             |                  |   |                    |                    |           |
|------------------|------------------|-----------------------------|------------------|---|--------------------|--------------------|-----------|
| Count            | Count            | Ref Des                     | Value            | Description   | Size               | Part Number        | MFR       |
| 7                | 7                | C1–C4, C9,<br>C10,C14, C21  | 10 μF            | Capacitor, Ceramic, 10-µF, 16-V, X5R, 20%                 | 1206               | ECJ-3YB1E106M      | Panasonic |
| 3                | 3                | C11, C15, C27               | 0.22 μF          | Capacitor, Ceramic, 0.22-µF, 16-V, X7R, 10%               | 0603               | C1608X7R1C224K     | TDK       |
| 3                | 3                | C13, C18, C19               | 4.7 μF           | Capacitor, Ceramic, 10V, X5R, 10%                         | 0805               | C0805C475K8PACTU   | Kemmet    |
| 2                | 2                | C16, C25                    | 1 μF             | Capacitor, Ceramic, 1-µF, 16-V, X7R, 10%                  | 0603               | C1608X7R1C105K     | TDK       |
| 3                | 3                | C17, C24, C36               | 1 nF             | Capacitor, Ceramic, 1-nF, 5-V, X7R, 10%                   | 0603               | C0603C102J5GACTU   | Kemmet    |
| 1                | 1                | C20                         | 0.1 μF           | Capacitor, Ceramic, 0.1 µF, 50-V, X7R, 10%                | 0603               | C1608X7R1H104K     | TDK       |
| 1                | 1                | C22                         | 1 μF             | Capacitor, Ceramic, 16-V, X5R, 20%                        | 1206               | ECJ-3YB1E105M      | Panasonic |
| 0                | 0                | C23                         | 0.22 μF          | Capacitor, Ceramic, 0.22- µF, 16-V, X7R, 10%              | 0603               | C1608X7R1C224K     | TDK       |
| 1                | 1                | C26                         | 0.01 μF          | Capacitor, Ceramic, 0.01- µF, 50-V, X7R, 10%              | 0603               | C1608X7R1H103K     | TDK       |
| 1                | 1                | C28                         | 22 μF            | Capacitor, Ceramic, 50-V, X5R, 20%                        | 1206               | ECJ-DV50J226M      | Panasonic |
| 1                | 1                | C29                         | 100 nF           | Capacitor, Ceramic, 0.1-µF, 50-V, X7R, 10%                | 0603               | C1608X7R1H104K     | TDK       |
| 1                | 1                | C30                         | 4.7 μF           | Capacitor, Ceramic, 4.7-µF, 6.3-V, X5R, 20%               | 0603               | ECJ-1VB0J475M      | Panasonic |
| 0                | 0                | C31, C35                    | 1 nF             | Capacitor, Ceramic, 1-nF, 50-V, NPO, 10%                  | 0603               | C0603C102J5GACTU   | Kemmet    |
| 1                | 1                | C12                         | 2.2 μF           | Capacitor, Ceramic, 2.2-µF, 6.3-V, X5R, 10%               | 0805               | C0805C225K9PACTU   | Kemmet    |
| 3                | 3                | C32–C34                     | 2.2 μF           | Capacitor, Ceramic, 2.2 µF, 6.3-V, X5R, 20%               | 0603               | C1608X5R0J225M     | TDK       |
| 1                | 1                | C5                          | 10 μF            | Capacitor, Ceramic, 10 µF, 6.3-V, X5R, 10%                | 0805               | C0805C106K9PACTU   | Kemmet    |
| 2                | 2                | C6, C9                      | 1 μF             | Capacitor, Ceramic, 1 µF, 25 V, X7R, 10%                  | 1206               | C3216X7R1C105/0.85 | TDK       |
| 1                | 1                | C7                          | 100 pF           | Capacitor, Ceramic, 100-pF, 50-V, NPO, 10%                | 0603               | C0603C101J5GACTU   | Kemmet    |
| 0                | 0                | C8                          | SUPER            | Capacitor, Through Hole, User's Option                    |                    | User's Option      | Mil-Max   |
| 3                | 3                | D1, D9, D10                 | ZHCS400          | Diode, Schottky, 400 mA, 40-V                             | SOD323             | ZHCS400            | Zelex     |
| 1                | 0                | D11                         | BAT54A           | Diode, Dual Schottky, 300-mA, 30-V                        | SOT23              | BAT54A             | ST        |
| 6                | 6                | D2D7                        | WHITE            | Diode, LED, White, 20-mA                                  | 0603               | 160-1720-1-ND      | Liteon    |
| 1                | 1                | D8                          | QTLP650D-<br>RGB | Diode, LED, Red, Green, Blue 30-20-20-mA,<br>Common anode | 0.118 × 0.134 inch | QTLP650D-RGB       | Fairchild |
| 1                | 1                | J1                          | PTC36SAAN        | Header, 4-pin, 100 mil spacing, (36-pin strip)            | 0.100 × 4          | PTC36SAAN          | Sullins   |
| 1                | 1                | J15                         | PTC36SAAN        | Header, 3-pin, 100 mil spacing, (36-pin strip)            | 0.100 × 3          | PTC36SAAN          |           |
| 17               | 17               | J2, J4–J12, J14,<br>J16–J21 | PTC36SAAN        | Header, 2-pin, 100 mil spacing, (36-pin strip)            | 0.100 × 2          | PTC36SAAN          |           |
| 2                | 2                | J3, J13                     | PTC36SAAN        | Header, 5-pin, 100 mil spacing, (36-pin strip)            | 0.100 × 5          | PTC36SAAN          |           |



# Table 4. HPA184A BOM - TPS65820/825 (continued)

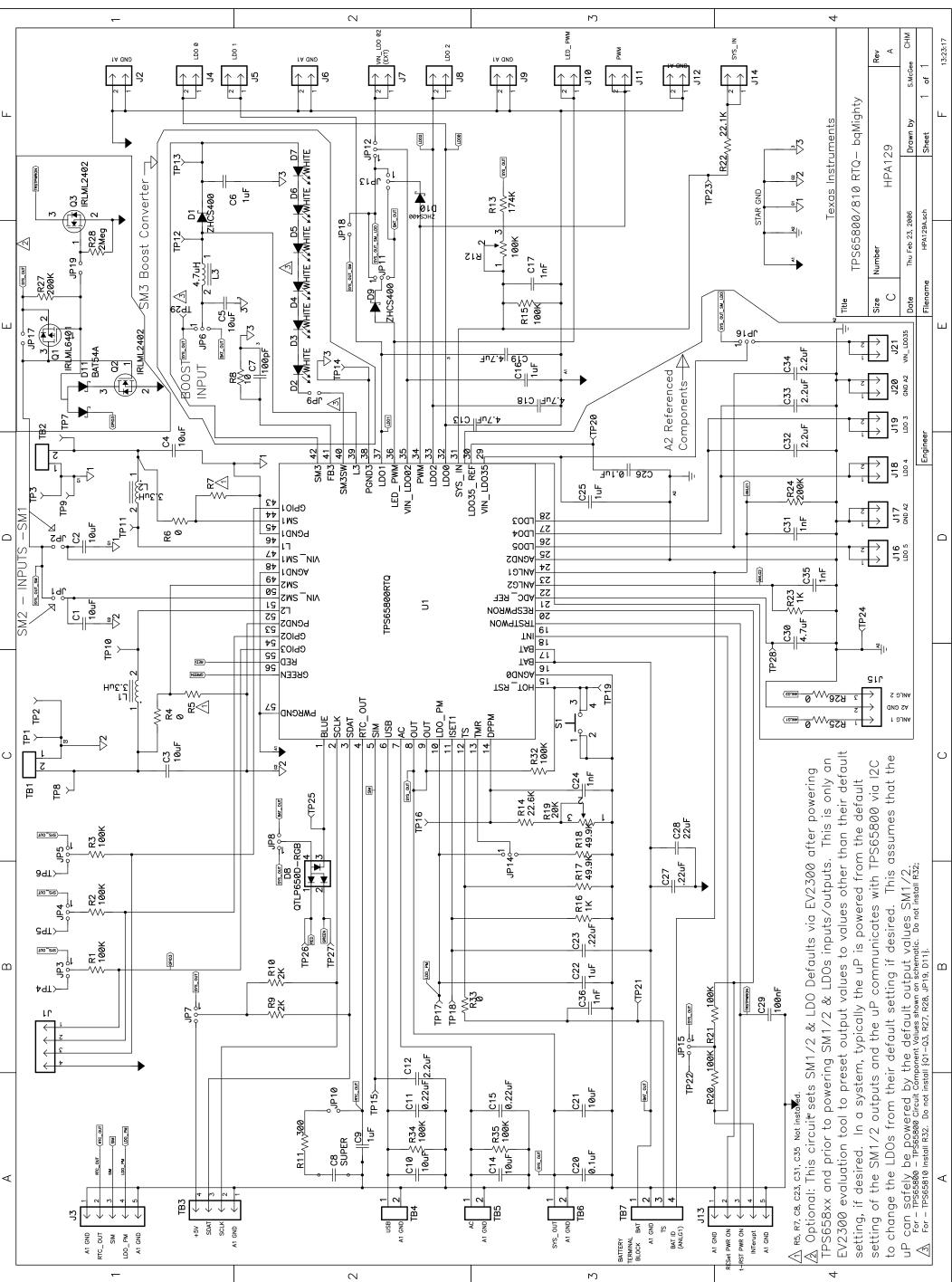
| -001<br>TPS65820 | -002<br>TPS65825 |                                       |            |  |                  |             |         |
|------------------|------------------|---------------------------------------|------------|--|------------------|-------------|---------|
| Count            | Count            | Ref Des                               | Value      | Description                                    | Size             | Part Number | MFR     |
| 6                | 6                | JP1, JP2, JP9,<br>JP10, JP17,<br>JP18 | PTC36SAAN  | Header, 2-pin, 100 mil spacing, (36-pin strip) | 0.100 × 2        | PTC36SAAN   | Sullins |
| 1                | 1                | JP19                                  | PTC36SAAN  | Header, 2-pin, 100 mil spacing, (36-pin strip) | 0.100 × 2        | PTC36SAAN   | Sullins |
| 12               | 12               | JP3–JP8,<br>JP11–JP16                 | PTC36SAAN  | Header, 3-pin, 100 mil spacing, (36-pin strip) | 0.100 × 3        | PTC36SAAN   | Sullins |
| 2                | 2                | L1, L2                                | 3.3 μΗ     | Inductor, SMT, 3.3 H, 1A, 85 m $\Omega$        | 0.185 × 0.185    | CDRH4D-3R3  | Sumida  |
| 1                | 1                | L3                                    | 4.7 μΗ     | Inductor, SMT, 4.7 H, 0.84A, 125 mΩ            | 0.185 × 0.185    | CDRH4D-4R7  | Sumida  |
| 1                | 0                | Q1                                    | IRLML6401  | MOSFET, P-ch, -12V,-3.4A, 50 mΩ                | SOT23            | IRLML6401   | IR      |
| 2                | 2                | Q2, Q3                                | IRLML2402  | MOSFET, N-ch, 20V,1.2A, 250 mΩ                 | SOT23            | IRLML2402   | IR      |
| 8                | 8                | R1–R3, R15,<br>R20, R21, R34,<br>R35  | 100K       | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 0                | 0                | R32                                   | 100K       | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 1                | 1                | R11                                   | 300        | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 1                | 1                | R12                                   | 100K       | Potentiometer, 1/4 Cermet, 12-Turn, Top-Adjust | 0.25 × 0.17 inch | 3266W-104   | Bourns  |
| 1                | 1                | R13                                   | 174K       | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 1                | 1                | R14                                   | 22.6K      | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 2                | 2                | R16, R23                              | 1K         | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 2                | 2                | R17, R18                              | 49.9K      | Resistor, Chip. 1/16-W, 1%                     | 0603             | Std         | Std     |
| 1                | 1                | R19                                   | 20K        | Potentiometer, 1/4 Cermet, 12-Turn, Top-Adjust | 0.25 × 0.17 inch | 3266W-203   | Bourns  |
| 1                | 1                | R22                                   | 22.1K      | Resistor, Chip, 22.1kΩ, 1/16-W, 1%             | 0603             | Std         | Std     |
| 1                | 1                | R24                                   | 200K       | Resistor, Chip, 1/16-W, 1%                     | 0602             | Std         | Std     |
| 1                | 1                | R27                                   | 200K       | Resistor, Chip, 1/16-W, 1%                     | 0603             | Std         | Std     |
| 1                | 1                | R28                                   | 2Meg       | Resistor, Chip, 1/16-W, 1%                     | 0603             | Std         | Std     |
| 5                | 5                | R4, R6, R25,<br>R26, R33              | 0          | Resistor, Chip, 1/16W, 1%                      | 0603             | Std         | Std     |
| 0                | 0                | R5, R7                                | Optional   | Resistor, Chip, 1/16W, 1%                      | 0603             | Std         | Std     |
| 1                | 1                | R8                                    | 10         | Resistor, Chip, 1/16W, 1%                      | 0603             | Std         | Std     |
| 2                | 2                | R9, R10                               | 2K         | Resistor, Chip, 1/16W, 1%                      | 0603             | Std         | Std     |
| 1                | 1                | S1                                    | (Value)    | Switch, 1P1T, PB Momentary, 100-mA, SM         | 0.19 × 0.18"     | 7914G       | Bourns  |
| 5                | 5                | TB1, TB2,<br>TB4–TB6                  | ED1514     | Terminal Block, 2-pin, 6-A, 3,5 mm             | 0.27 × 0.25      | ED1514      | OST     |
| 1                | 1                | ТВЗ                                   | 22-05-3041 | Header, Friction Lock Ass'y. 4-pin right angle | 0.400 × 0.500    | 22-05-3041  | Molex   |

#### Physical Layouts

#### Table 4. HPA184A BOM - TPS65820/825 (continued)

| -001<br>TPS65820  | -002<br>TPS65825   |                   |                                  |  |                  |                         |                    |
|---|--|-------------------|----------------------------------|--|------------------|-------------------------|--------------------|
| Count   | Count  | Ref Des           | Value                            | Description                                  | Size             | Part Number             | MFR                |
| 1   | 1  | TB7               | ED1516                           | Terminal Block, 4-pin, 6-A, 3,5 mm           | 0.55 × 0.25 inch | ED1516                  | OST                |
| 1   | 1  | TP29              | 5012                             | Test Point, 0.032 hole                       | 0.25             |                         | None               |
| 1   | 0  | U1                | TPS65820RTQ                      | IC, Integrated Handheld Power Solution       | QFN-56           | TPS65820RTQ             | TI                 |
| 0   | 1  | U1                | TPS65825RTQ                      | IC, Integrated Handheld Power Solution       | QFN-56           | TPS65825RTQ             | TI                 |
| 17  | 17   | See Note 5        |                                  | Shunt, 100-mil, Black                        | 0.1              | 929950-00               | 3M                 |
| 1   | 1  |                   |                                  | PCB, 4 in $\times$ 3 in $\times$ 0.031 in    |                  | HPA129                  | Any                |
| 1   | 1  | Connector         |                                  |  |                  |                         |                    |
|   | 2  | J5 mate           | Connector, Female, 0.100 Centers |  |                  | 22-01-3047              | Molex              |
|   | 8  | N/A               | Terminals, Crim                  | Terminals, Crimp, Tin                        |                  |                         | Molex              |
|   |  | N/A               | Wire, Insulated 2                | 24 Awg, Red, (18 inches) (±3 inches)(USB_5V) |                  | 1854-3                  | Alpha              |
|   |  | N/A               | Wire, Insulated 2                | 24 Awg, White, (18 inches) (±3 inches) (SCL) |                  | 1854-1                  | Alpha              |
|   |  | N/A               | Wire, Insulated 2                | 24 Awg, Black, (18 inches) (±3 inches) (GND) |                  | 1854-2                  | Alpha              |
|   |  | N/A               | Wire, Insulated 2                | 24 Awg, Brown, (18 inches) (±3 inches) (SDA) |                  | 1854-7                  | Alpha              |
|   | 1  | N/A               | Heatsink 1"                      |  |                  |                         |                    |
| Notes: 1.   | These assem  | blies are ESD sei | nsitive, ESD precaut             | ions shall be observed.                      |                  |                         |                    |
| 2.  | These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.                                  |                   |                                  |  |                  |                         |                    |
| 3.  | 3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.  |                   |                                  |  |                  |                         |                    |
| 4.  | 4. Ref designators marked with an asterisk (**) cannot be substituted. All other components can be substituted with equivalent MFG's components. |                   |                                  |  |                  |                         |                    |
| <ol> <li>Apply Shunt as follows: JP5/JP4/JP3/JP8/JP15/JP12/JP11/JP13/JP6/JP16 are to be sent to SYS-OUT, JP7 to +5V, JF<br/>across the two pins.</li> </ol> |  |                   |                                  |  |                  | RES, and JP1/JP2/JP17/J | P18/JP9 apply jump |

The TPS65800/810EVM schematic appears on the following page. The TPS65820/825EVM schematic is identical but has a reduced-in-size U1 IC (from 8x8 mm to 7x7 mm) and is not shown.



# **EVALUATION BOARD/KIT IMPORTANT NOTICE**

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION

**PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive.

TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit <u>www.ti.com/esh</u>.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

#### **FCC Warning**

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

#### **EVM WARNINGS AND RESTRICTIONS**

It is important to operate this EVM within the input voltage range of 4.3 V to 6 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 125°C. The EVM is designed to operate properly with certain components above 125°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2006, Texas Instruments Incorporated

#### **IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| Products              |                        | Applications       |                           |
|-----------------------|------------------------|--------------------|---------------------------|
| Amplifiers            | amplifier.ti.com       | Audio              | www.ti.com/audio          |
| Data Converters       | dataconverter.ti.com   | Automotive         | www.ti.com/automotive     |
| DSP                   | dsp.ti.com             | Broadband          | www.ti.com/broadband      |
| Interface             | interface.ti.com       | Digital Control    | www.ti.com/digitalcontrol |
| Logic                 | logic.ti.com           | Military           | www.ti.com/military       |
| Power Mgmt            | power.ti.com           | Optical Networking | www.ti.com/opticalnetwork |
| Microcontrollers      | microcontroller.ti.com | Security           | www.ti.com/security       |
| RFID                  | www.ti-rfid.com        | Telephony          | www.ti.com/telephony      |
| Low Power<br>Wireless | www.ti.com/lpw         | Video & Imaging    | www.ti.com/video          |
|                       |                        | Wireless           | www.ti.com/wireless       |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2007, Texas Instruments Incorporated