EVL2642-R-00A

1A Bidirectional Active Balancer for 5 Li-Ion Battery Cells Evaluation Board

DESCRIPTION

The EVL2642-R-00A is an evaluation board designed for applications using four MP2642 active balancers that are actively balancing five Li-Ion battery cells. The MP2642 is a highly integrated, bidirectional active balancer that enables high-current charge redistribution between two series cells within a battery pack, while minimizing energy loss and heat. For large battery systems, active balancers can dramatically speed up the balancing process with high efficiency and allow for capacity recovery in stacks of mismatched batteries.

Each individual MP2642 device can be controlled to move charge between two battery cells. In buck-balancing mode, the MP2642 transfers charge from the upper cell to the lower cell, and in boost-balancing mode, the MP2642 transfers charge from the lower cell to the upper cell. Each MP2642 device can support up to 1A of net balancing current.

By interleaving multiple MP2642 devices across groups of cells and controlling the mode of each device, charge can be transferred to or from a target cell to the other four battery cells.

To guarantee safe operation, the MP2642 evaluation board has cell over-voltage protection (OVP), under-voltage protection (UVP), and thermal shutdown protection.

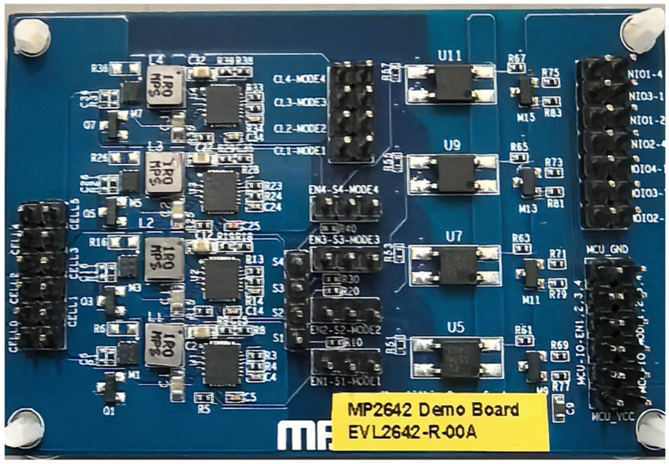
PERFORMANCE SUMMARY

Specifications are at T_A = 25°C, unless otherwise noted.

Parameter	Conditions	Value
Buck-balancing Mode		
CU operating voltage (V_{CU})		3.8V to 16V
Max CL operating voltage (V_{CL})		4.35V
Upper cell-balance current (I_{UBC})		Up to 1A
Boost-Balancing Mode		
CL under-voltage lockout (UVLO) (V_{CL_UVLO})	Rising/falling	2.4V/2.1V
Maximum CU voltage (V_{CU_MAX})		Up to 15V
Lower cell-balance current (I_{LBC})		Up to 1A

MPL Optimized Performance with MPS Inductor MPL-AL4020 Series

EVL2642-R-00A EVALUATION BOARD



LxWxH (7.6cmx4.7cmx1.3cm)

Board Number	MPS IC Number
EVL2642-R-00A	MP2642GR

QUICK START GUIDE

Each MP2642 has three basic operating modes: standby, buck-balancing mode, and boost-balancing mode. Before operation begins, configure the MP2642's buck-balancing current and boost-balancing current, as well as the over-voltage (OV) limit in boost-balancing mode. Each MP2642 has a fixed under-voltage (UV) limit of 2.4V and a 150°C thermal shutdown protection threshold.

The EVL2642-R-00A is an evaluation board designed for applications using four MP2642 devices that are actively balancing 5 Li-ion battery cells. Figure 1 shows the charge transfer diagram between cells using the MP2642.

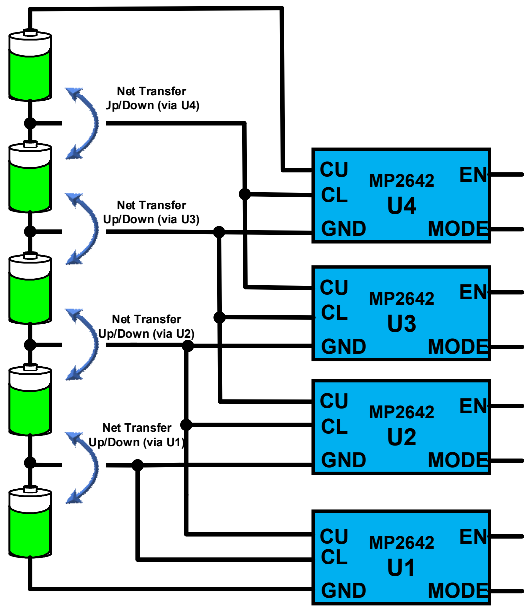


Figure 1: Power Transfer Diagram

Setting the Buck Balancing Current (I_{UBC})

The buck-balancing current is configured via an external resistor (R_{UBC}). R_{UBC} can be calculated with Equation (1):

$$R_{UBC} = \frac{640k\Omega}{3 \times I_{UBC}} \tag{1}$$

The default I_{UBC} has been configured to not exceed 1A using R_{UBC} = 240kΩ.

Setting the Boost-Balancing Current (I_{LBC})

The boost-balancing current is configured via an external resistor (R_{LBC}). R_{LBC} can be estimated with Equation (2):

$$R_{LBC} = \frac{V_{CU} - \eta \times V_{CL}}{\eta \times V_{CL}} \times \frac{640}{3 \times I_{UBC}} \tag{2}$$

Where η is the boost efficiency (typical value = 0.89), and V_{CU} and V_{CL} are the sensed cell voltages when active balancing stops.

The default I_{LBC} has been configured to not exceed 1A using R_{LBC} = 300kΩ, when V_{CU} = 7V, V_{CL} = 3.6V.

Setting the Maximum CU Voltage in Boost-Balancing Mode (V_{CU_MAX})

For safety, the MP2642 exits boost-balancing mode if the overall voltage exceeds a configured threshold. This threshold is set with a resistor divider (consisting of R_U and R_L) across both cells, and it can be calculated with Equation (3):

$$V_{CU\_MAX} = V_{CU\_MAX\_REF} \times \frac{R_U + R_L}{R_L} \quad (3)$$

Where $V_{CU\_MAX\_REF}$ is the MP2642's reference voltage; in this scenario, $V_{CU\_MAX\_REF}$ = 1.2V.

The total resistance of $R_U + R_L$ should be between 1MΩ < $R_U + R_L$ < 10MΩ. The default V_{CU_MAX} has been configured to 8.4V with R_U = 2MΩ and R_L = 330kΩ.

Default Configuration

Table 1 shows the group of resistors (R_{UBC}, R_{LBC}, R_U, and R_L) and their default values for each MP2642 device. The top row shows the parameter that changes based on the resistance.

Table 1: Resistor vs. Parameter Setting vs. IC Number (Default Values in Parentheses)

	I_{UBC}	I_{LBC}	V_{CU_MAX}	V_{CU_MAX}
	R_{UBC}	R_{LBC}	R_U	R_L
U1	R_9 (240kΩ)	R_8 (300kΩ)	R_3 (2MΩ)	R_4 (330kΩ)
U2	R_{19} (240kΩ)	R_{18} (300kΩ)	R_{13} (2MΩ)	R_{14} (330kΩ)
U3	R_{29} (240kΩ)	R_{28} (300kΩ)	R_{23} (2MΩ)	R_{24} (330kΩ)
U4	R_{39} (240kΩ)	R_{38} (300kΩ)	R_{33} (2MΩ)	R_{34} (330kΩ)

MANUAL CONTROL (1)

The simplest method of operating the EVL2642-R-00A is with manual control. It is recommended for new users to use manual control to become familiar with the EVL2642-R-00A's operation. Manual control provides a simple method of cell testing and troubleshooting.

Note:

1) Manual control bypasses the protection functionality that is provided by the complete battery management system, by directly enabling the active balancers. When using manual control, the user must continuously monitor the status of the cells using a battery monitor system (item 2 in the Required Equipment section). Manual balancing should only be used with constant supervision, and the cells should never be allowed to operate beyond their recommended operating conditions. As cells approach any operating limits, all active balancers that are enabled via manual control should be immediately disabled.

Required Equipment

In addition to the EVL2642-R-00A, manual control requires the following equipment:

1. A five-cell battery pack or pack simulator. When using a real battery pack, observe all precautions on the battery manufacturer's datasheet to ensure that the balancer's settings do not exceed the battery's absolute maximum specifications.
2. A five-channel battery monitor system, such as MPS's EV2793-0000-FP-00A (evaluation system based on the MP2793 battery monitor device). This system monitors the real-time voltage, current, and temperature measurements of each cell while the active balancers are operating. It also allows the user to connect the cells to a charger and/or load for charge and discharge operation with a pack.
3. A low-voltage power supply (3.3V to 5V, 50mA).

Operation

The following steps can be used for manual control of one or more EVL2642-R-00A active balancers. Once enabled, the user should monitor the voltage change in the corresponding cells, being careful not to allow any cells to be balanced beyond the manufactured recommended limits. (2)

Before proceeding, ensure that the battery cells are in good condition and their state-of-charge (SOC) is within the manufactured recommended limits.

Note:

2) The MP2642 active balancers include built-in under-voltage (UV) and over-voltage (OV) limits to disable balancing when the OV or UV threshold is reached.

Step 1: Connect Battery Cells

Follow the battery monitor system instructions to connect up to 5 battery cells in series. Confirm that the battery monitor is accurately monitoring the conditions of each cell.

Connect the series cells to the EVL2642-R-00A (see Figure 2 on page 6). Note that there are two pins available for each cell connection; either pin, or both pins, can be used for each connection. Connect the cells in the following order:

1. Attach the negative terminal of the Cell 1 battery to the CELL0 pin.
2. Attach the terminal between the Cell 1 and the Cell 2 batteries to the CELL1 pin.
3. Attach the terminal between the Cell 2 cell and the Cell 3 batteries to the CELL2 pin.
4. Attach the terminal between the Cell 3 and the Cell 4 batteries to the CELL3 pin.
5. Attach the terminal between the Cell 4 and the Cell 5 batteries to the CELL4 pin.
6. Attach the positive terminal of the Cell 5 battery to the CELL5 pin.

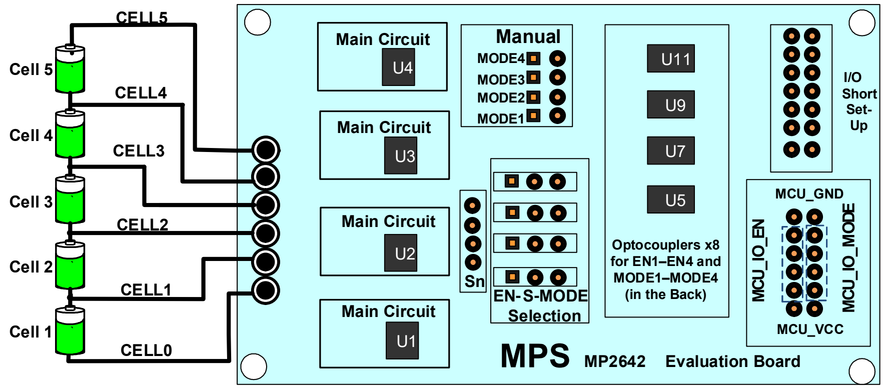


Figure 2: Test Set-Up for 5-Cell Batteries in Series

Step 2: Configure the Balancing Modes

The EVL2642-R-00A includes four onboard jumper pins that configure the operating mode for each of the four MP2642 devices (U1, U2, U3, and U4). Configuring these jumpers does not activate the balancer; Step 5 on page 8 below is required for activation.

Select two adjacent cells to balance, and determine the direction of current transfer between these two cells. Moving charge from the higher cell to the lower cell corresponds to buck-balance operation, while moving charge from the lower cell to the higher cell corresponds to boost-balance operation. Use the CLx-MODEx jumper pins according to the mode configuration (Table 2).

Table 2: Operating Mode Configuration

Boost-Balance Jumper [3]	MP2642	Corresponding Cells (Lower/Upper)
CL1-MODE1	U1	Cell 1/Cell 2
CL2-MODE2	U2	Cell 2/Cell 3
CL3-MODE3	U3	Cell 3/Cell 4
CL4-MODE4	U4	Cell 4/Cell 5

Note:

3) If a jumper is installed, then the device operates in boost-balance operation. If there is no jumper, then the device operates in buck-balance operation.

If a corresponding jumper is installed, the active balancer is configured for boost-balance operation. If there is no jumper, the active balancer is configured for boost-balance operation.

Figure 3 shows how to configure the mode using jumpers.

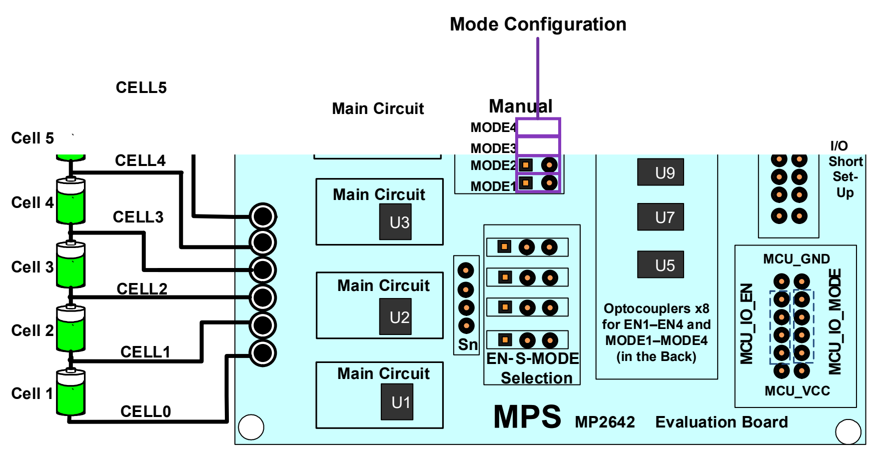


Figure 3: Mode Configuration Using Jumpers

Step 3: Connect the Cells to the Balancers

For added protection, the EVL2642-R-00A includes onboard MOSFETs to keep each MP2642 device's lower cell (CL) and upper cell connections (UL) disconnected from the cells.

When the active balancer chip is enabled for operation, the MOSFETs must be turned on at the same time; in the design, MOSFET control can be combined with enable (EN) control. Figure 4 shows the jumpers that are provided to configure these MOSFETs.

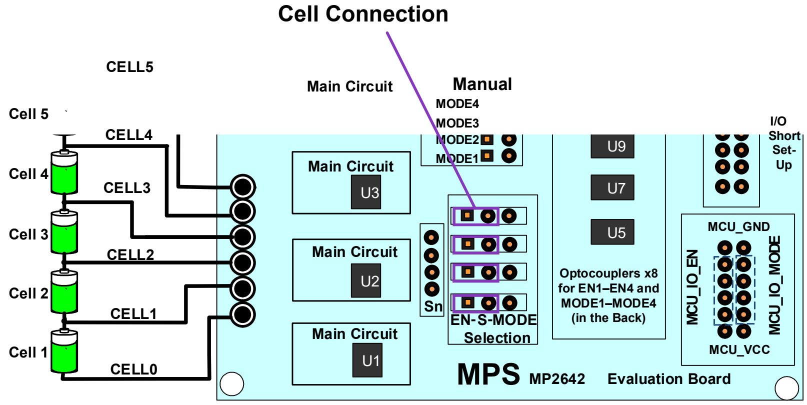


Figure 4: Configuring the Enable Signals to Connect Cells to Balancer

The left side of the EN-S-MODE jumper bank configures each MP2642's ENABLE signal to turn on these MOSFETs, which connect the cells when the corresponding balancer is enabled. Table 3 shows the jumper configurations required to connect the cells for each MP2642 device.

Table 3: Cell Connection Configuration

Junctions	Set-Up (4)	Cell Connection
EN1-S1-MODE1	Default	Connects Cell 1/Cell 2 to U1
EN2-S2-MODE2	Default	Connects Cell 2/Cell 3 to U2
EN3-S3-MODE3	Default	Connects Cell 3/Cell 4 to U3
EN4-S4-MODE4	Default	Connects Cell 4/Cell 5 to U4

Note:

4) The EVL2642-R-00A employs this configuration via a resistor on the back of the board.

Step 4: Connect the Power Supply

Connect a 3.3V to 5V supply to the EVL2642-R-00A at the pins labeled MCU_VCC and MCU_GND (see Figure 5). Since this power supply only supplies power for the onboard optocouplers, it can be current-limited to 50mA.

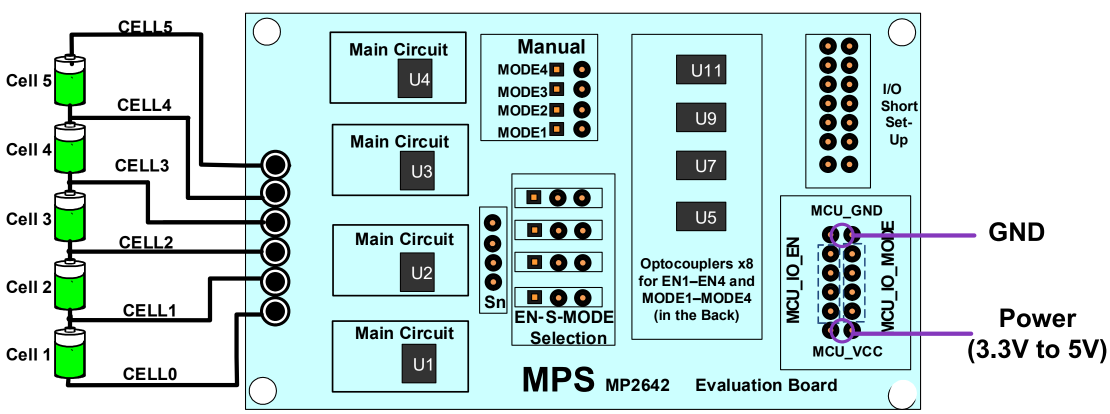


Figure 5: Connect the Power Supply to the Board

Step 5: Enable Individual Balancers

Using a jumper wire, enable the target MP2642 by connecting the corresponding MCU_IO_EN pin to VCC, which turns on the optocoupler.

When the EN signal of the active balancer chip is pulled high, the MCU_IO_EN signal is between the MCU_VCC and MCU_GND, as marked on the board. From low to high, the EN signals from the MCU's I/O ports are EN1, EN2, EN3, and EN4, which enable U1, U2, U3, and U4, respectively.

Figure 6 shows how to enable U1. To disable the active balancers, remove the jumper wire(s) or turn off the power supply.

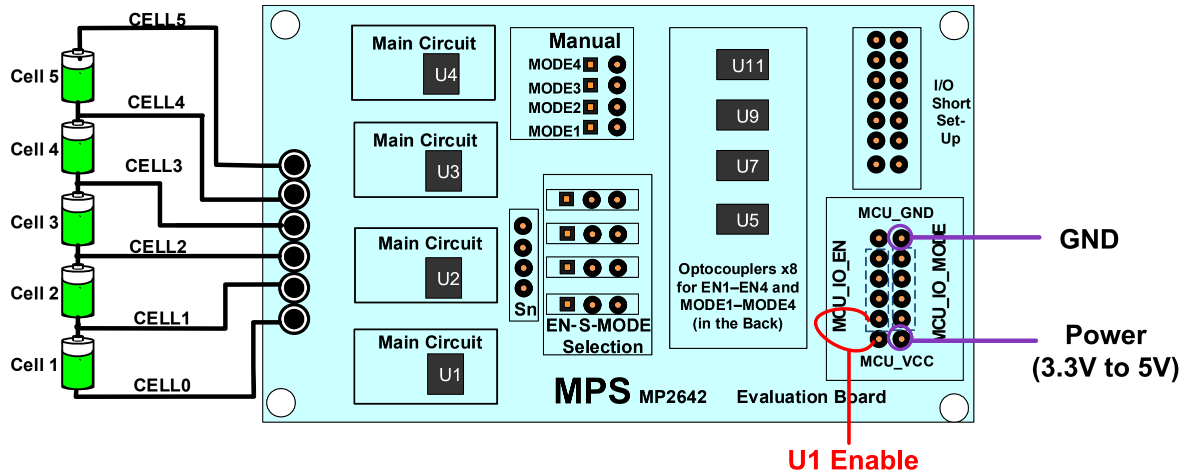


Figure 6: Enable Individual MP2642 (U1) by Connecting MCU_IO_EN to MCU_VCC

AUTOMATIC CONTROL

There are multiple ways to interface to the MP2642 control signals (the hardware configuration) and implement automatic cell balancing (the algorithm). Automatic active balancer control requires a microcontroller unit (MCU) with real-time access to each cell's voltage (for voltage-based balancing) or the SOC (for SOC-based balancing).

According to each cell's conditions, the MCU software (algorithm) determines how to operate each MP2642 device. Based on the algorithm, each MP2642's ENABLE and MODE signals are controlled via the MCU general-purpose input/output (GPIO) signals, or via a battery monitor IC that is controlled by the MCU. (5)

MPS has designed a complete auto-balancing solution that combines MPS' MBMxxS-P50-x complete solution board with the EVL2642-R-00A. The MBMxxS-P50-x provides signals (hardware interface) to control each EVL2642-R-00A balancer, and implements a balancing algorithm within the onboard microprocessor. A USB-based graphical user interface (GUI) is provided for configuration, monitoring, and management. Contact MPS for more details regarding the complete auto-balancing solution and active balancing algorithms.

Note:

5) Since the MP2642 devices are placed along the battery string, each operates at a different common mode, which requires opto-coupler isolation. All MP2642 I/O control signals on the EVL2642-R-00A include opto-coupler isolation. The default logic for each ENABLE and MODE is "low."

Direct MCU Control

The simplest way to control the MP2642 is via the MCU GPIO. Every ENABLE and MODE signal for each MP2642 device has a dedicated signal from the MCU. The EVL2642-R-00A includes onboard isolation and access to all eight control signals (there is one ENABLE and one MODE for each of the four onboard MP2642 devices).

The basic balancing algorithm is summarized below:

1. Measure each cell and determine its imbalance status, such as a voltage or SOC imbalance.
2. If there are imbalanced cells (e.g. one or more cell(s) are high or low):
   A. Determine which balancers must operate in buck-balance mode or boost-balance mode.
   B. Set the individual MODE signals (boost-balance or buck-balance) via the MCU's GPIO.
   C. Set the individual ENABLE signals via the MCU's GPIO.
   D. Disable balancing after a fixed period of balancing, such as 1s or 10s.
3. Repeat until there are no imbalanced cells.

MCU Control with Consolidated Control Signals

As the number of cells in a pack increases, it may become necessary to reduce the number of required MCU GPIOs. Direct MCU mode control and direct MCU enable control are two techniques that reduce the required number of control signals. Subsequently, the balancing algorithm(s) must also be modified to account for this change in control.

Direct MCU Mode Control

With direct MCU mode control, only one MCU GPIO is needed to control all of the MP2642 ENABLE inputs. Each MODE signal is controlled by separate GPIO signals. The individual MP2642 ENABLE inputs are connected together, thereby reducing the required number of MCU signals by nearly 50%.

The primary tradeoff for this configuration is that all balancers must operate simultaneously. This is generally acceptable, since charge is typically distributed among all cells within the pack (requiring all balancers to operate).

The basic balancing algorithm for direct MCU mode control is described below:

1. Measure each cell and determine its imbalance status, such as a voltage or SOC imbalance.
2. If there are imbalanced cells (e.g. one or more cell(s) are high or low):
   A. Determine which balancers must operate in buck-balance mode or boost-balance mode.
   B. Set all individual MODE signals (boost-balance or buck-balance) via the MCU GPIO.
   C. Set the single ENABLE signal via the MCU GPIO.
   D. Disable balancing after a fixed period, such as 1s or 10s.
3. Repeat until there are no imbalanced cells.

The EVL2642-R-00A includes on board isolation and jumpers that allow the ENABLE input signals to be shorted for this hardware configuration (see Table 4).

Table 4: Direct MCU Mode Control Configuration

Jumper Label	I/O Signal Configuration	Jumper Installed
ENIO1-4	Combine the EN I/O control of U1 and U4	Yes
ENIO1-3	Combine the EN I/O control of U1 and U3	Yes
ENIO1-2	Combine the EN I/O control of U1 and U2	Yes
ENIO2-4	Combine the EN I/O control of U2 and U4	Yes
MOIO4-1	Combine the MODE I/O control of U4 and U1	No
MOIO3-1	Combine the MODE I/O control of U3 and U1	No
MOIO2-1	Combine the MODE I/O control of U2 and U1	No

The four MODE inputs are connected at MCU_IO_MODE1 through MCU_IO_MODE4, and the ENABLE input is connected to MCU_IO_EN1 (see Figure 7).

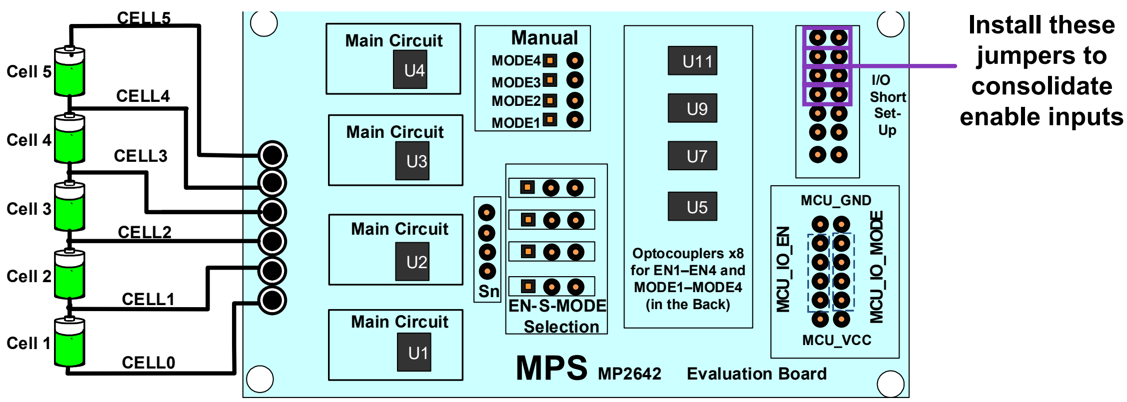


Figure 7: Consolidating the Individual MP2642 Enable Signals for MCU Mode Control

Direct MCU Enable Control

With direct MCU enable control, only one MCU GPIO is necessary to control all of the MP2642 MODE inputs. Each ENABLE signal is controlled by separate GPIO signals. All of the individual MP2642 MODE inputs are connected together, thereby reducing the required number of MCU signals by nearly 50%.

Using this technique, the balancers are not required to operate simultaneously. However, all balancers operating in boost-balance mode must be enabled simultaneously, and all balancers operating in buck-balance mode must be enabled simultaneously. This approach can be advantageous when balancing is limited to adjacent cells, and only a small number of MP2642 devices are needed to achieve complete balance.

The main tradeoff with direct MCU enable control is that each balancing cycle typically requires two steps (a boost-balance step then a buck-balance step), which increases the balancing time.

The basic balancing algorithm is described below:

1. Measure each cell and determine its imbalance status, such as a voltage or SOC imbalance.
2. If there are imbalanced cells (e.g. one or more cell(s) are high or low):
   A. Determine which balancers must operate in buck-balance mode or boost-balance mode.
   B. Set the single MODE signal to boost-balance mode via the MCU GPIO.
   C. Enable the balancers to operate in boost-balance mode via the individual GPIO signals.
   D. Disable balancing after a fixed period, such as 1s or 10s.
   E. Set the single MODE signal to buck-balance mode via the MCU GPIO.
   F. Enable the balancers to operate in buck-balance via the individual GPIO signals.
   G. Disable balancing after a fixed period, such as 1s or 10s.
3. Repeat until there are no imbalanced cells.

The EVL2642-R-00A includes onboard isolation and jumpers that allow the MODE input signals to be easily shorted for this hardware configuration (see Table 5).

Table 5: Direct MCU Enable Control Configuration

Jumper Label	I/O Signal Configuration	Jumper Installed
ENIO1-4	Combine the EN I/O control of U1 and U4	No
ENIO1-3	Combine the EN I/O control of U1 and U3	No
ENIO1-2	Combine the EN I/O control of U1 and U2	No
ENIO2-4	Combine the EN I/O control of U2 and U4	No
MOIO4-1	Combine the MODE I/O control of U4 and U1	Yes
MOIO3-1	Combine the MODE I/O control of U3 and U1	Yes
MOIO2-1	Combine the MODE I/O control of U2 and U1	Yes

The four ENABLE inputs are connected at MCU_IO_EN1 through MCU_IO_EN4, and the MODE input is connected to MCU_IO_MODE1 (see Figure 8).

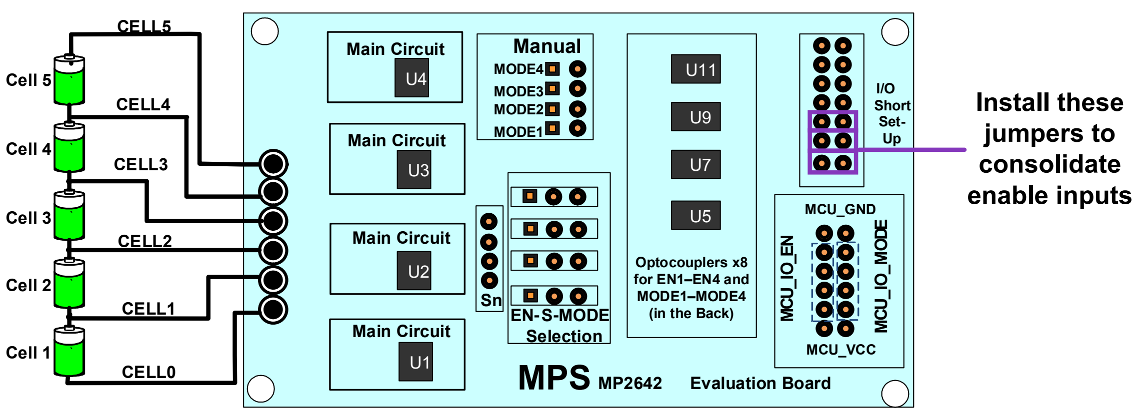


Figure 8: Consolidating the Individual MP2642 Mode Signals for MCU Enable Control

Battery Monitor Control (Advanced Control Technique)

To further reduce the number of MCU GPIOs and eliminate the need for certain optoisolators, the MCU can utilize the passive balancing signals (Sn) from the battery monitor to control the ENABLE or MODE inputs.

The Sn signals are created by the resistor divider(s) between cells when passive balancing is enabled (see Figure 9).

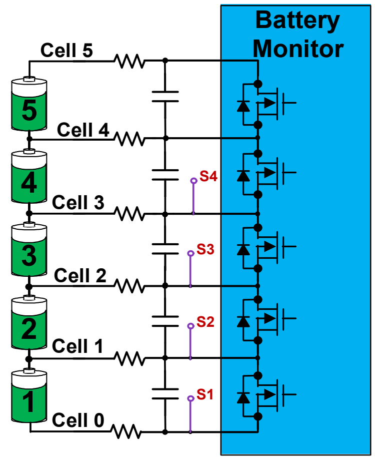


Figure 9: Battery Monitor Sn Circuitry (Bottom 4 Sn Signals)

The MP2642's ENABLE and MODE inputs have been designed to operate across a wide voltage range, ensuring compatibility with these Sn voltages. Furthermore, since the passive balancing outputs are at the proper common-mode voltage for controlling the corresponding MP2642 device, optoisolation is not required.

There are several ways to use Sn signals to control the MP2642, and each variation dictates the interface and the balancing algorithm. In most battery monitors, the passive balancing outputs are limited to operating the even channels and odd channels separately (e.g. adjacent passive balancers cannot be enabled simultaneously). This affects how to use Sn signals to control the balancers.

The sections below describe two basic battery monitor control methods and their associated algorithms.

Battery Monitor Mode Control

With battery monitor mode control, the Sn signals set the balancing mode for all of the MP2642 devices. Two MCU GPIO signals are required to enable the MP2642: one for all of the odd MP2642 devices, and one for all of the even MP2642 devices (see Figure 10).

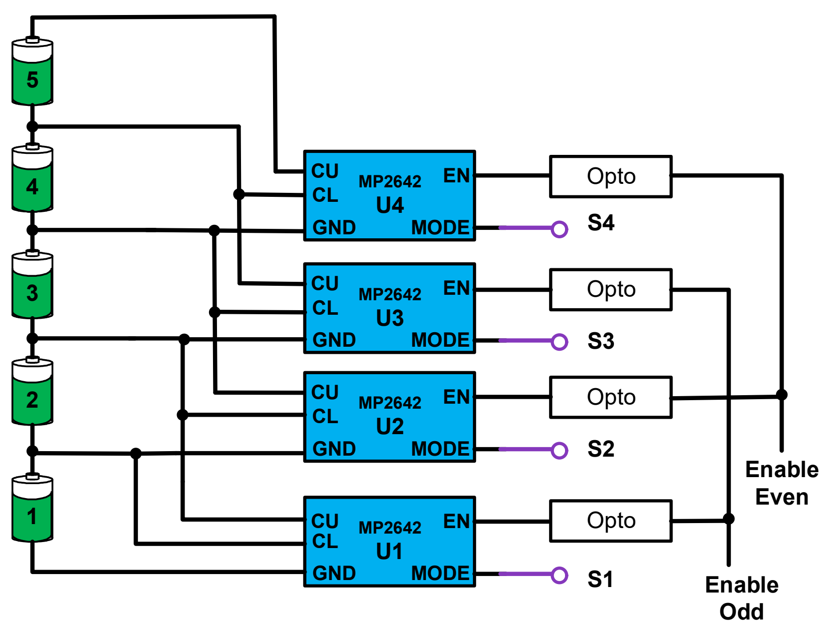


Figure 10: Controlling the MP2642 Using Battery Monitor Mode Control

The balancing algorithm is similar to previously described algorithms, with the addition of a two-step process to enable the odd balancers and even balancers separately:

1. Measure each cell and determine its imbalance status, such as a voltage or SOC imbalance.
2. If there are imbalanced cells (e.g. one or more cell(s) are high or low):
   A. Determine which balancers must operate in buck-balance mode or boost-balance mode.
   B. Set all individual odd MODE signals (boost-balance or buck-balance) via the battery monitor balancing outputs. The MCU sets these signals via commands to the battery monitor.
   C. Enable the odd balancers (e.g. U1 and U3) via the ENABLE signals controlled by an MCU GPIO.
   D. Disable balancing after a fixed period, such as 1s or 10s.
   E. Set all individual even MODE signals (boost-balance or buck-balance) via the battery monitor balancing outputs. The MCU sets these signals via commands to the battery monitor.
   F. Enable the even balancers (e.g. U2 and U4) via the ENABLE signals controlled by an MCU GPIO.
   G. Disable balancing after a fixed period, such as 1s or 10s.
3. Repeat until there are no imbalanced cells.

MPS provides an option for the EVL2642-R-00A that eliminates the isolation for direct Sn MODE connections, and is preconfigured for battery monitor mode control. Contact MPS for more details.

Battery Monitor Enable Control

With battery monitor enable control, the Sn signals set the enable signal for all of the MP2642 devices. One MCU GPIO signal is required to set the mode for all the devices (see Figure 10).

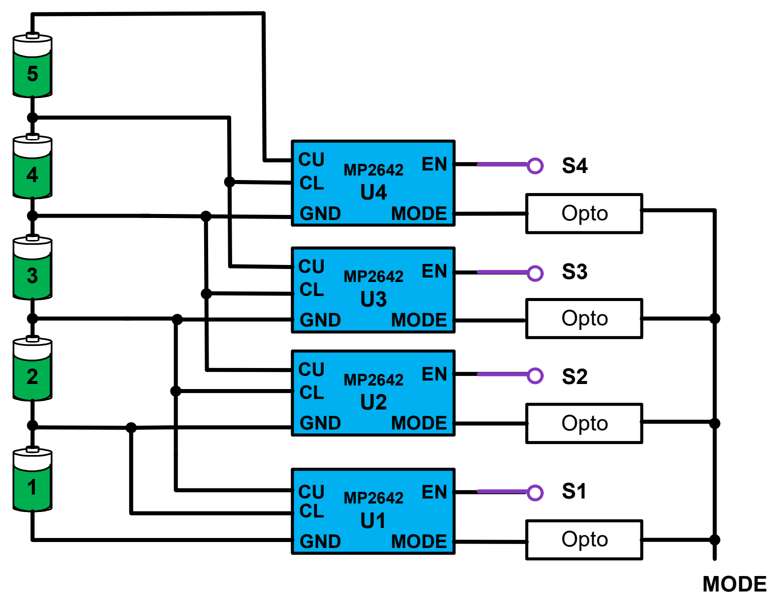


Figure 11: Controlling the MP2642 Using Battery Monitor Enable Control

This balancing algorithm builds on the previous algorithms and includes additional steps to account for both buck-balance and boost-balance operation, as required by the single MODE control signal:

1. Measure each cell and determine its imbalance status, such as a voltage or SOC imbalance.
2. If there are imbalanced cells (e.g. one or more cell(s) are high or low):
   A. Determine which balancers must operate in buck-balance mode or boost-balance mode.

B. Set MODE to buck-balance mode via the MCU GPIO.
C. Enable all individual odd balancers that must operate buck-balance mode via the Sn signals. The MCU sets the enable signal via commands to the battery monitor.
D. Disable balancing after a fixed period, such as 1s or 10s.
E. Enable all individual even balancers that must operate in buck-balance mode via the Sn signals. The MCU sets the enable signals via commands to the battery monitor.
F. Disable balancing after a fixed period, such as 1s or 10s.
G. Set MODE to boost-balance mode via the MCU GPIO.
H. Enable all individual odd balancers that must operate in boost-balance mode via the Sn signals. The MCU sets the enable signals via commands to the battery monitor.
I. Disable balancing after a fixed period, such as 1s or 10s.
J. Enable all individual even balancers that must operate in boost-balance mode via the Sn signals. The MCU sets the enable signals via commands to the battery monitor.
K. Disable balancing after a fixed period, such as 1s or 10s.

3. Repeat until there are no imbalanced cells.

MPS provides an option for the EVL2642-R-00A that eliminates the isolation for direct Sn ENABLE connections, and is preconfigured for battery monitor enable control. Contact MPS for more details.

EVALUATION BOARD SCHEMATIC

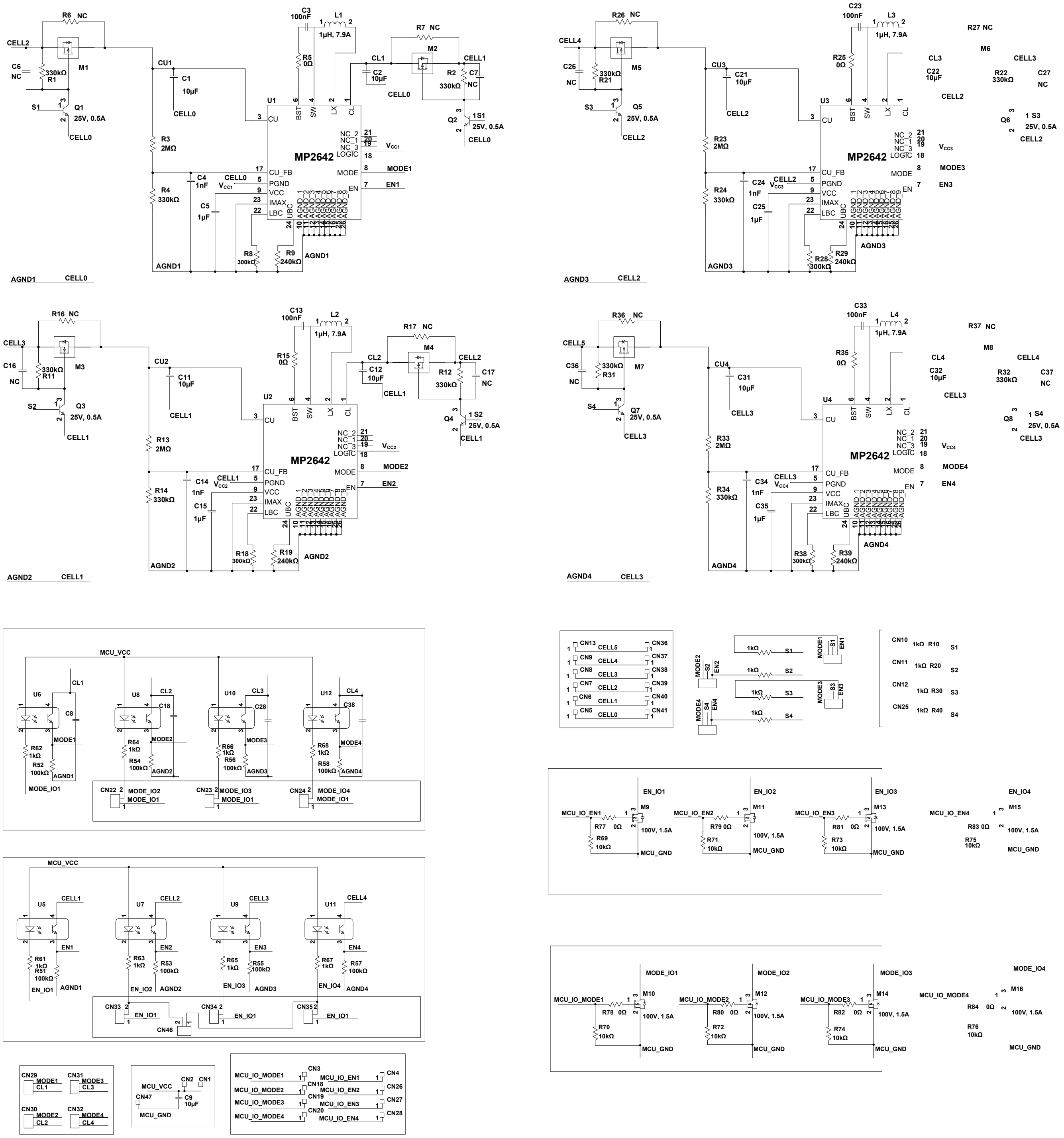


Figure 12: EVL2642-R-00A Evaluation Board Schematic

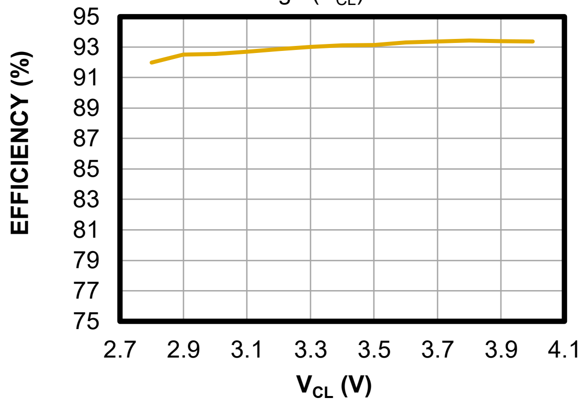
EVL2642-R-00A BILL OF MATERIALS

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer PN
8	C1, C2, C11, C12, C21, C22, C31, C32	10µF	Capacitor, 16V, X5R	0805	Murata	GRM21BR61C106 KE15L
4	C3, C13, C23, C33	100nF	Capacitor, 50V, X7R	0603	Murata	GRM188R71H104 KA93D
4	C4, C14, C24, C34	1nF	Capacitor, 50V, X7R	0402	Murata	GCM155R71H102 KA37D
4	C5, C15, C25, C35	1µF	Capacitor, 25V, X5R	0402	Murata	GRM155R61E105 KA12D
12	C6, C7, C8, C16, C17, C18, C6, C27, C28, C36, C37, C38	NC				
1	C9	10µF	Capacitor, 25V, X5R	0603	TDK	C1608X5R1E106 MT000E
8	R1, R2, R11, R12, R21, R22, R31, R32	330kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-07330KL
4	R4, R14, R24, R34	330kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-07330KL
4	R3, R13, R23, R33	2MΩ	Film resistor, 1%	0402	Yageo	RC0402FR-072ML
4	R5, R15, R25, R35	0Ω	Film resistor, 1%	0402	Yageo	RC0402FR-070RL
8	R6, R7, R16, R17, R26, R27, R36, R37	NC				
4	R8, R18, R28, R38	300kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-07300KL
4	R9, R19, R29, R39	240kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-07240KL
12	R10, R20, R30, R40, R61, R62, R63, R64, R65, R66, R67, R68	1kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-071KL
8	R51, R52, R53, R54, R55, R56, R57, R58	100kΩ	Film resistor, 1%	0402	Yageo	RC0402FR-07100KL
8	R69, R70, R71, R72, R73, R74, R75, R76	10kΩ	Film resistor, 1%	0402	Yageo	AF0402FR-0710KL
8	R77, R78, R79, R80, R81, R82, R83, R84	0Ω	Film resistor, 1%	0402	Yageo	RC0402FR-070RL
8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	0.5A	S8050 transistor	SOT-23	MDD	S8050
8	M1, M2, M3, M4, M5, M6, M7, M8	-12V	P-channel MOSFET, 12mΩ	DFN2020 M-6	Nexperia	PMPB09R5VP
8	M9, M10, M11, M12, M13, M14, M15, M16	30V	N-channel MOSFET, 32mΩ	SOT-23	Analog Power	AM2336N-T1-PF
8	U5, U6, U7, U8, U9, U10, U11, U12	1-channel	1-channel photocoupler	SOP-4	Everlight	EL357N(C)(TA)-G
4	L1, L2, L3, L4	1µH	Inductor, 10.1mΩ, 7.9A	SMD	MPS	MPL-AL4020-1R0
4	U1, U2, U3, U4	MP2642	1A active balancer for 5-cell batteries	QFN-26 (4mmx 4mm)	MPS	MP2642GR

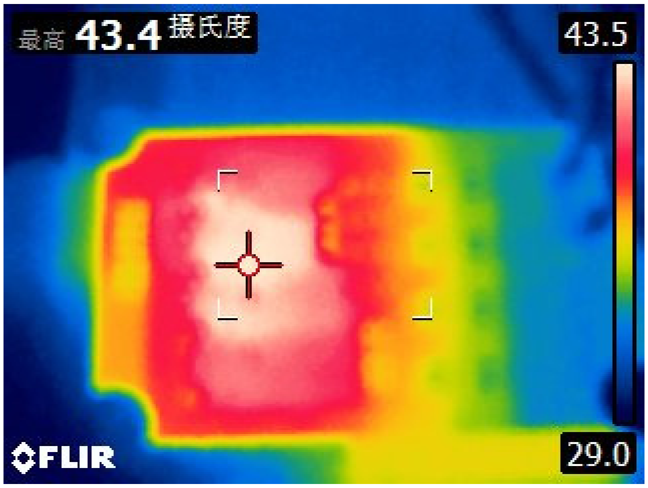
EVB TEST RESULTS

Performance curves and waveforms are tested on the evaluation board. V_{CL} = 3.6V, V_{CU} = 3.6V, L = 1µH, T_A = 25°C, unless otherwise noted.

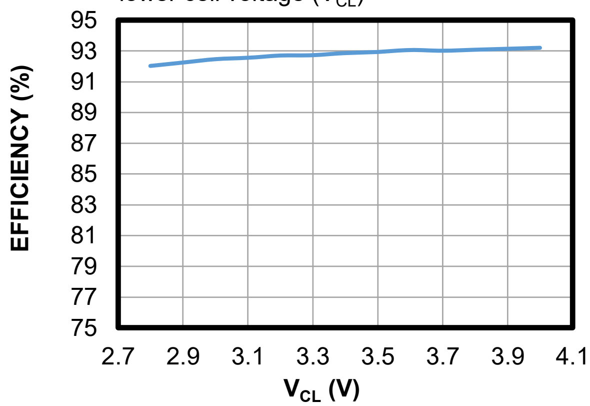
Buck Balance Efficiency Curve
The upper cell voltage is 0.2V above the lower cell voltage (V_{CL})



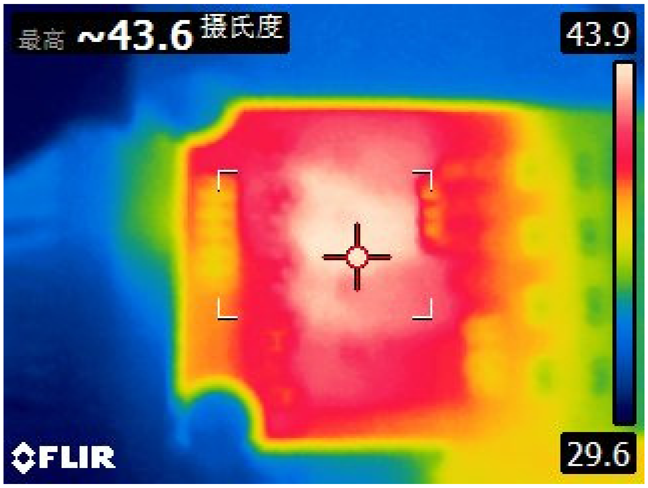
Thermal Performance
Buck-balance mode, no forced airflow, T_A = 25°C



Boost Balance Efficiency Curve
The upper cell voltage is 0.2V below the lower cell voltage (V_{CL})



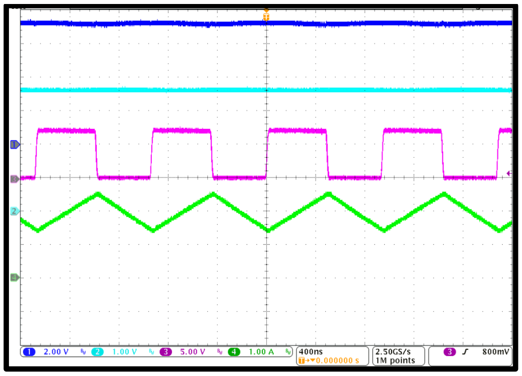
Thermal Performance
Boost-balance mode, no forced airflow, T_A = 25°C



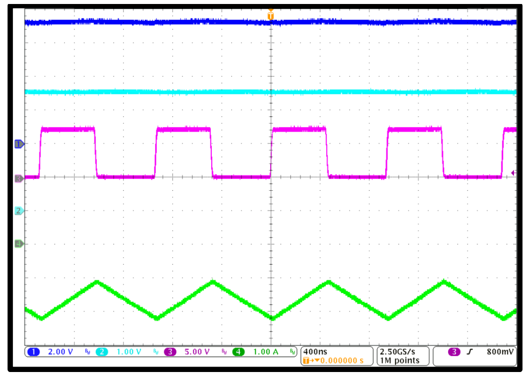
EVB TEST RESULTS *(continued)*

Performance curves and waveforms are tested on the evaluation board. V_{CL} = 3.6V, V_{CU} = 3.6V, L = 1µH, T_A = 25°C, unless otherwise noted.

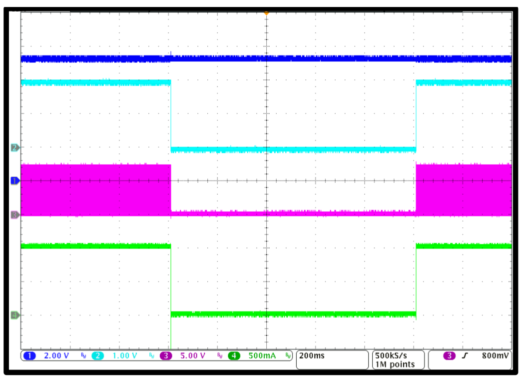
Buck-Balance Steady State



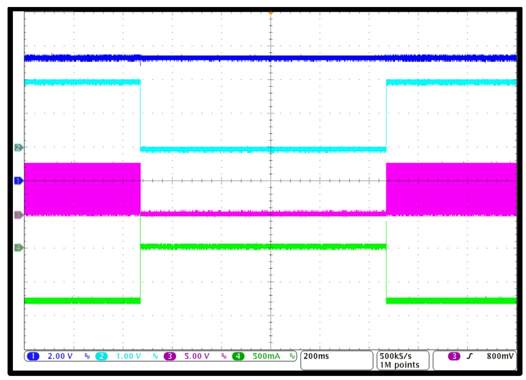
Boost-Balance Steady State



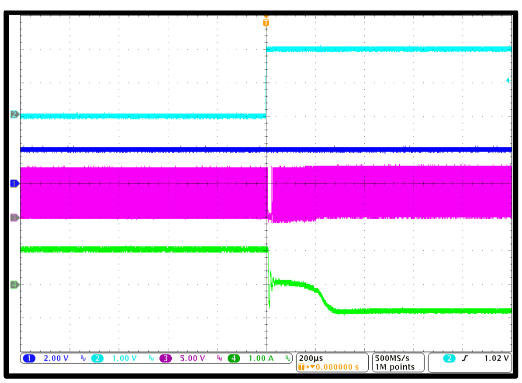
Buck-Balance Mode Enabled/Disabled via EN



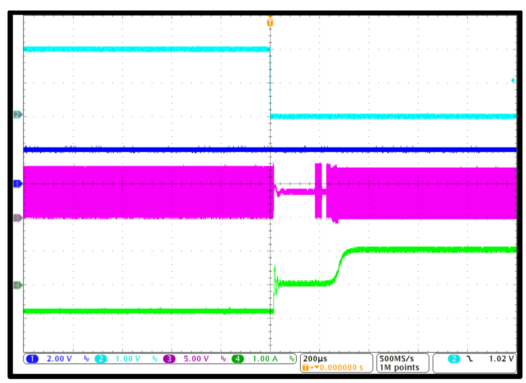
Boost-Balance Mode Enabled/Disabled via EN



Buck-Balance to Boost-Balance via MODE



Boost-Balance to Buck-Balance via MODE



PCB LAYOUT

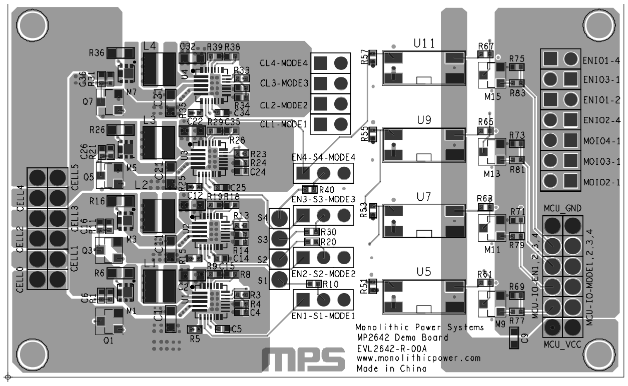


Figure 13: Top Layer

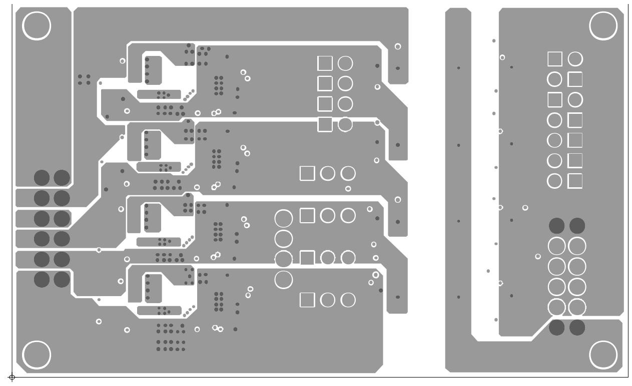


Figure 14: Mid-Layer 1

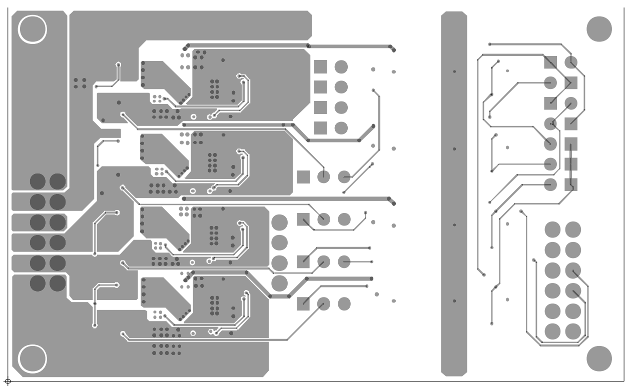


Figure 15: Mid-Layer 2

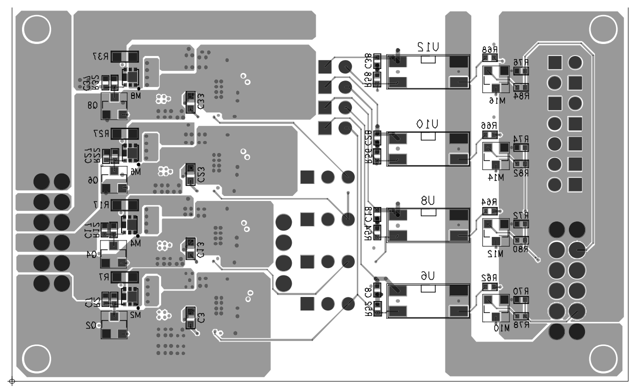


Figure 16: Bottom Layer

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	12/5/2024	Initial Release	-