

ISL8272MEVAL1Z

Evaluation Board User Guide

UG003

Rev 0.00

September 17, 2014

Description

The ISL8272M is a 50A step-down DC/DC power supply module with an integrated digital PWM controller, dual-phase synchronous power switches, inductors and passives. Only input output capacitors and minimal passives are needed to finish the design. 50A of continuous output current can be delivered without a need of airflow or heatsink. The ISL8272M uses ChargeMode™ control (ASCR) architecture, which responds to a transient load within a single switching cycle.

The ISL8272MEVAL1Z evaluation board is a 4.7in x 4.8in 6-layer FR4 board with 2oz. copper in all layers. This evaluation board comes with placeholders for pin-strap resistor population to adjust output voltage, switching frequency, soft-start/stop timing and input UVLO threshold, ASCR gain and residual parameters and device PMBus™ address. More configurations, such as sequencing, Digital-DC™ (DDC) bus configuration and fault limits can be easily programmed or changed via PMBus compliant serial bus interface.

ZLUSBEVAL3Z (USB to PMBus adapter) is provided with this evaluation kit, which connects the evaluation board to a PC to activate the PMBus communication interface. The PMBus command set is accessed by using the PowerNavigator™ evaluation software from a PC running Microsoft Windows.

References

[ISL8272M](#) datasheet

Key Features

- V_{IN} range of 4.5V to 14V, V_{OUT} adjustable from 0.6V to 5V
- Programmable V_{OUT} , margining, input and output UVP/OVP, I_{OUT} limit, OTP/UTP, soft-start/stop, sequencing, and external synchronization
- Monitor: V_{IN} , V_{OUT} , I_{OUT} , temperature, duty cycle, switching frequency and faults
- ChargeMode™ control tunable with PMBus
- Mechanical switch for enable and power-good LED indicator

Specifications

This board has been configured for the following operating conditions by default:

- $V_{IN} = 5V$ to 12V
- $V_{OUT} = 1.2V$
- $I_{MAX} = 50A$
- $f_{SW} = 421kHz$
- Peak efficiency: >90.5% at 70% load
- Output ripple: <10mV_{p-p}
- ASCR gain = 200, ASCR residual = 90
- On/off delay = 5ms; On/off ramp time = 5ms

Ordering Information

PART NUMBER	DESCRIPTION
ISL8272MEVAL1Z	ISL8272M Kit (Evaluation Board, ZLUSBEVAL3Z Adapter, USB Cable)

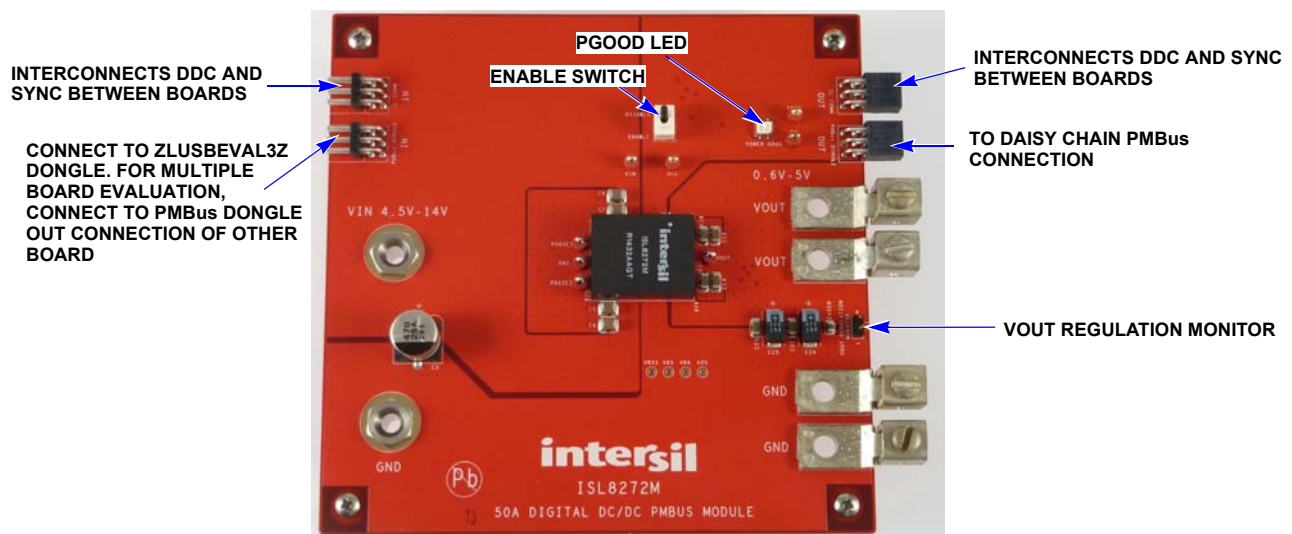


FIGURE 1. TOP SIDE

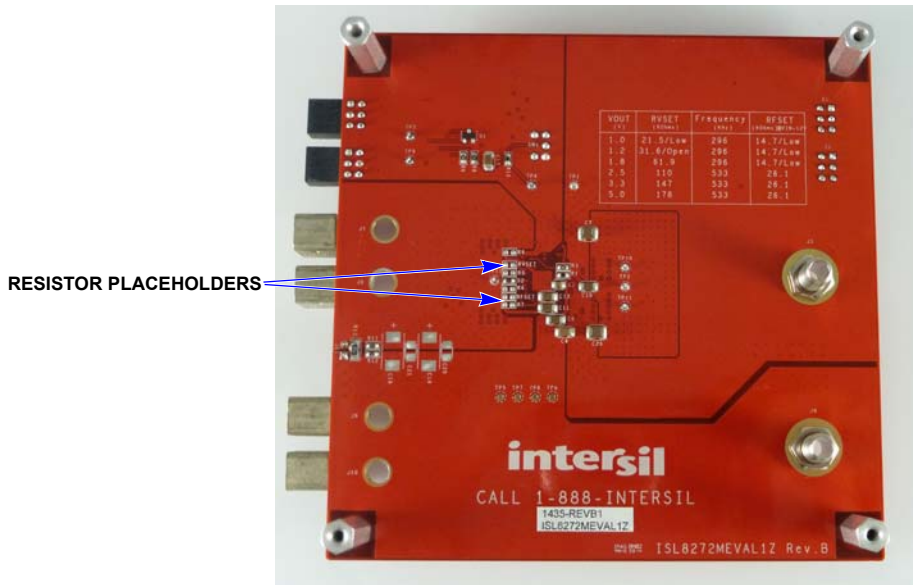


FIGURE 2. BOTTOM SIDE

Recommended Equipment

- DC power supply with minimum 15V/25A sourcing capacity
- Electronic load capable of sinking current up to 50A
- Digital multimeters (DMMs)
- Oscilloscope with higher than 100MHz bandwidth

Functional Description

The ISL8272MEVAL1Z provides all circuitry required to evaluate the features of the ISL8272M. A majority of the features of the ISL8272M, such as compensation-free ChargeMode™ control, soft-start delay and ramp times, supply sequencing, and voltage margining are available on this evaluation board. For sequencing evaluation, the board can be connected to any Intersil digital module evaluation board that supports the DDC bus.

Figures 1 and 2 show the board images of the ISL8272MEVAL1Z evaluation board.

Quick Start Guide

Pin-Strap Option

ISL8272MEVAL1Z can be configured in pin-strap mode with standard 1% 0603 resistors. PMBus interface is not required to evaluate ISL8272M in pin-strap mode. Output voltage (V_{OUT}), switching frequency (f_{SW}), soft-start/stop delay and ramp time, input undervoltage protection (UVLO) threshold, ASCR gain and residual, and device PMBus address can be changed by populating recommended resistors at placeholders provided in the evaluation board. By default, the evaluation board operates in pin-strap mode and regulates at $V_{OUT} = 1.2V$, $f_{SW} = 421kHz$, soft-start/stop delay time = 5ms, soft-start/stop ramp time = -5ms, UVLO = 4.5V, ASCR gain = 200, ASCR residual = 90 and PMBus address = 28h. Follow these steps to evaluate ISL8272M in pin-strap mode.

1. Set ENABLE switch to "DISABLE".
2. Connect Load to VOUT lug connectors (J7-J8 and J9-J10).

3. Connect power supply to VIN connectors (J5 and J6). Make sure power supply is not enabled when making connection.
4. Turn power supply on.
5. Set ENABLE switch to "ENABLE".
6. Measure 1.2V VOUT at probe point labeled "VOUT REGULATION MONITOR" (J11).
7. Observe switching frequency of 421kHz at probe points labeled "PHASE1" (TP10) and "PHASE2" (TP11).
8. To measure the module efficiency, connect the multimeter voltage probes at probe points labeled "VIN" (TP1), "GND" (TP2) and "VOUT" (TP12).
9. To change VOUT, disconnect board from the setup and populate a 1% standard 0603 resistor at RVSET placeholder location on bottom layer. Refer to the "Output Voltage Resistor Settings" table in the [ISL8272M](#) datasheet for recommended values. By default, VOUT_MAX is set to 110% of VOUT set by pin-strap resistor.
10. To change switching frequency, disconnect board from the setup and populate a 1% standard 0603 resistor at RFSET placeholder location on bottom layer. Refer to the "Switching Frequency Resistor Settings" table in the [ISL8272M](#) datasheet for recommended values.
11. To change soft-start/stop delay and ramp time, disconnect board from the setup and populate a 1% standard 0603 resistor at R6 placeholder location on bottom layer. Refer to the "Soft Start/Stop Resistor Settings" table in the [ISL8272M](#) datasheet for recommended values.
12. To change UVLO, disconnect board from the setup and populate a 1% standard 0603 resistor at R6 placeholder location on bottom layer. Refer to the "UVLO Resistor Settings" table in the [ISL8272M](#) datasheet for recommended values. Notice that the UVLO programming shares the same pin with soft-start/stop programming.
13. To change ASCR gain and residual, disconnect board from the setup and populate a 1% standard 0603 resistor at R7 placeholder location on bottom layer. Refer to the "ASCR

Resistor Settings” table and the design guide matrix in the [ISL8272M](#) datasheet for recommended values.

PMBus Option

ISL8272MEVAL1Z can be evaluated for all features using the provided ZLUSBEVAL3Z dongle and PowerNavigator™ evaluation software. Follow these steps to evaluate ISL8272M with PMBus option.

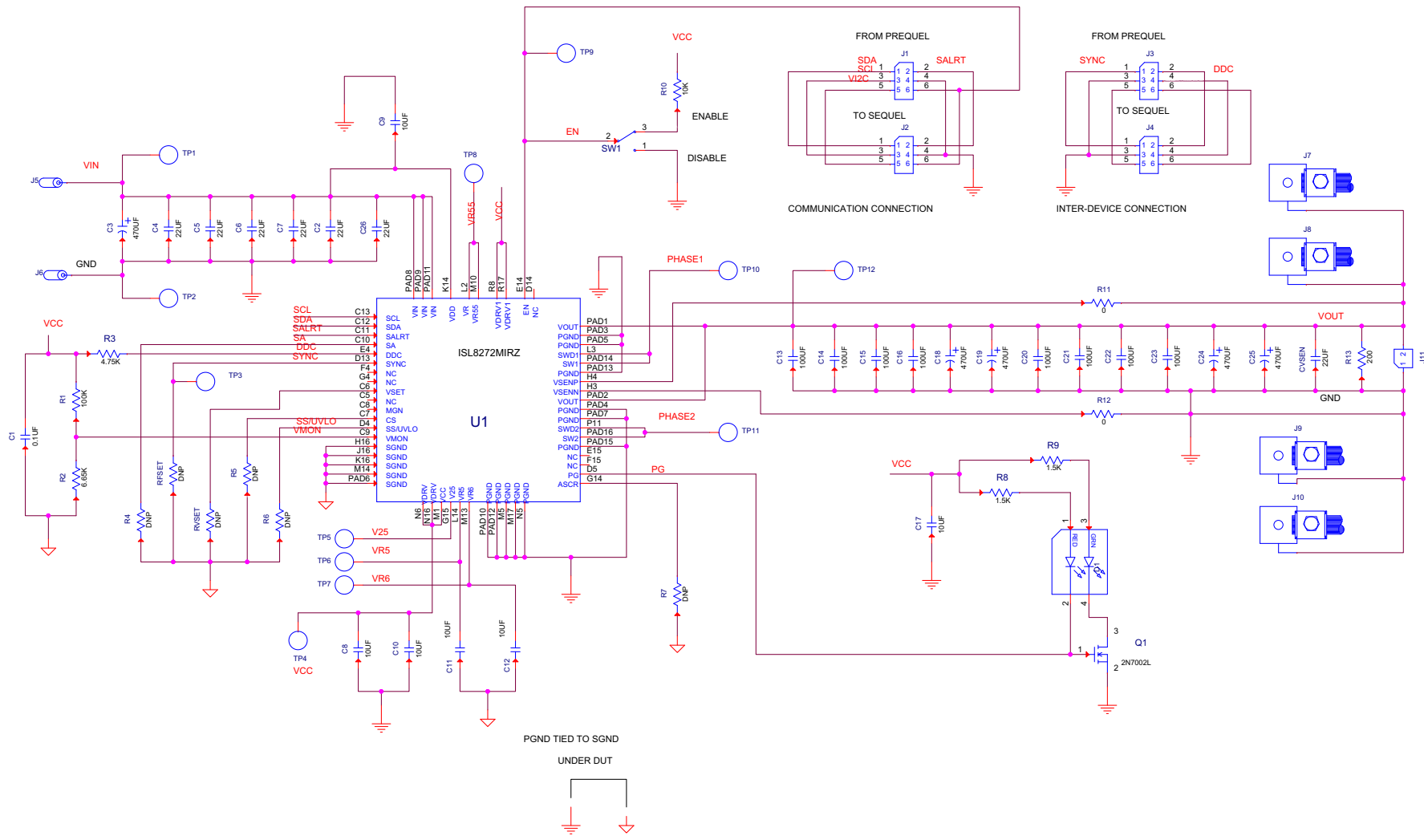
1. Install PowerNavigator™ software from the following Intersil website: www.intersil.com/powernavigator
2. Set ENABLE switch to “DISABLE”.
3. Connect Load to VOUT lug connectors (J7-J8 and J9-J10).
4. Connect power supply to VIN connectors (J5 and J6). Make sure power supply is not enabled when making connection.
5. Turn power supply on.
6. Connect ZLUSBEVAL3Z dongle (USB to PMBus™ adapter) to ISL8272MEVAL1Z board to the 6-pin male connector labeled as “PMBus DONGLE IN”.
7. Connect supplied USB cable from computer USB to ZLUSBEVAL3Z dongle.
8. Launch PowerNavigator™ software.
9. It is optional to load a predefined set-up from a configuration file using the PowerNavigator™ software. The ISL8272M device on the board operates in pin-strap mode from factory default, but the user may modify the operating parameters through the evaluation software or by loading a predefined set-up from a configuration file. A sample “[Configuration File](#)” on page 6 is provided and can be copied to a notepad editor to make desired changes. The default pin-strap configurations will be overwritten if a user-defined configuration file is loaded.
10. Set ENABLE switch to “ENABLE”. Alternatively, the PMBus ON_OFF_CONFIG and OPERATION commands may be used from the PowerNavigator™ software to allow PMBus Enable.
11. Monitor and configure the ISL8272MEVAL1Z board using the PMBus commands in the evaluation software. To store the configuration changes, disable the module and use the command STORE_USER_ALL. To restore factory default settings, disable the module and use the command RESTORE_FACTORY and STORE_USER_ALL.
12. PowerNavigator™ tutorial videos are available at Intersil website. www.intersil.com/powernavigator
13. For sequencing via Digital-DC Bus (DDC) or to evaluate multiple Intersil digital power products using a single ZLUSBEVAL3Z dongle, ISL8272M can be daisy chained with other digital power evaluation boards. PMBus address can be changed by placing a 1% standard 0603 resistor at the R4 placeholder location on the bottom layer. Refer to the “SMBus Address Resistor Selection” table in the [ISL8272M](#) datasheet for recommended values.

Thermal Considerations and Current Derating

Board layout is very critical in order to make the module operate safely and deliver maximum allowable power. To work in the high temperature environments and carry large currents, the board layout needs to be carefully designed to maximize thermal performance. To achieve this, select enough trace width, copper weight and the proper connectors.

The ISL8272MEVAL1Z evaluation board is designed for running 50A at room temperature without additional cooling systems needed. However, if the output voltage is increased or the board is operated at elevated temperatures, then the available current is derated. Refer to the derated current curves in the [ISL8272M](#) datasheet to determine the maximum output current the evaluation board can supply. θ_{JA} is measured by inserting a thermocouple inside the module to measure peak junction temperature.

ISL8272MEVAL1Z Schematic



PGND TIED TO SGND
UNDER DUT

Bill of Materials

REFERENCE DESIGNATORS	QTY	MANUFACTURER	MANUFACTURER PART	DESCRIPTION
C1	1	PANASONIC	ECJ-2VB1E104K	CAP, SMD, 0805, 0.1 μ F, 25V, 10%, X7R, ROHS
CVSEN	1	TDK	C2012X5R0J226M	CAP, SMD, 0805, 22 μ F, 6.3V, 20%, X5R, ROHS
C8, C10-C12, C17	5	VENKEL	C1206X7R100-106KNE	CAP, SMD, 1206, 10 μ F, 10V, 10%, X7R, ROHS
C9	1	VENKEL	C1206X7R250-106KNE	CAP, SMD, 1206, 10 μ F, 25V, 10%, X7R, ROHS
C13, C14, C15, C16, C22, C23	6	MURATA	GRM31CR60J107ME39L	CAP, SMD, 1206, 100 μ F, 6.3V, 20%, X5R, ROHS
C20, C21	0			CAP, SMD, 1206, DNP-PLACEHOLDER, ROHS
C2, C4, C5, C6, C7, C26	6	MURATA	GRM32ER71C226KE18L	CAP, SMD, 1210, 22 μ F, 16V, 10%, X7R, ROHS
C24, C25	2	SANYO	6TPE470MI	CAP-POSCAP, LOW ESR, SMD, D4, 470 μ F, 6.3V, 20%, 18m Ω , ROHS
C3	1	PANASONIC	EEE-1EA471P	CAP, SMD, 10mm, 470 μ F, 25V, 20%, ALUM.ELEC., 380mA, ROHS
J5, J6	2	JOHNSON COMPONENTS	108-0740-001	CONN-JACK, BANANA-SS-SDRLESS, VERTICAL, ROHS
TP1-TP4, TP9-TP12	8	KEYSTONE	5005	CONN-COMPACT TEST PT, VERTICAL, RED, ROHS
J11	1	BERG/FCI	69190-202HLF	CONN-HEADER, 1X2, RETENTIVE, 2.54mm, 0.230 x 0.120, ROHS
J2, J4	2	SAMTEC	SSQ-103-02-T-D-RA	CONN-SOCKET STRIP, TH, 2x3, 2.54mm, TIN, R/A, ROHS
J1, J3	2	SAMTEC	TSW-103-08-T-D-RA	CONN-HEADER, 2x3, BRKAWY, 2.54mm, TIN, R/A, ROHS
D1	1	LUMEX	SSL-LXA3025IGC-TR	LED, SMD, 3x2.5mm, 4P, RED/GREEN, 12/20MCD, 2V
U1	1	INTERSIL	ISL8272MAIRZ	IC-50A DIGITAL DC/DC MODULE, 42P, HDA, ROHS
Q1	1	ON SEMICONDUCTOR	2N7002LT1G	TRANSISTOR-MOS, N-CHANNEL, SMD, SOT23, 60V, 115mA, ROHS
R4, R5, R6, R7, RFSET, RVSET	0			RESISTOR, SMD, 0603, 0.1%, MF, DNP-PLACEHOLDER
R11, R12	2	VENKEL	CR0603-10W-000T	RES, SMD, 0603, 0 Ω , 1/10W, TF, ROHS
R10	1	KOA	RK73H1JT1002F	RES, SMD, 0603, 10k, 1/10W, 1%, TF, ROHS
R1	1	VENKEL	CR0603-10W-1003FT	RES, SMD, 0603, 100k, 1/10W, 1%, TF, ROHS
R8, R9	2	VENKEL	CR0603-10W-1501FT	RES, SMD, 0603, 1.5k, 1/10W, 1%, TF, ROHS
R3	1	VENKEL	CR0603-10W-4751FT	RES, SMD, 0603, 4.75k, 1/10W, 1%, TF, ROHS
R2	1	YAGEO	RC0603FR-076K65L	RES, SMD, 0603, 6.65k, 1/10W, 1%, TF, ROHS
R13	1	PANASONIC	ERJ-8ENF2000V	RES, SMD, 1206, 200 Ω , 1/4W, 1%, TF, ROHS
SW1	1	C&K COMPONENTS	GT13MCBE	SWITCH-TOGGLE, THRU-HOLE, 5PIN, SPDT, 3POS, ON-OFF-ON, ROHS
J7, J8, J9, J10	4	BERG/FCI	KPA8CTP	HDWARE, MTG, CABLE TERMINAL, 6-14AWG, LUG&SCREW, ROHS
C18, C19	0			DO NOT POPULATE
TP5, TP6, TP7, TP8	0			DO NOT POPULATE

Configuration File

Sample Configuration File for ISL8272M Module. Copy and paste (from RESTORE_FACTORY TO ### End User Store) to a notepad and save it as Confile_file_name.txt. The # symbol is used for a comment line. Following settings are already loaded to ISL8272M module as factory defaults.

```

RESTORE_FACTORY           # reset device to the factory setting
STORE_USER_ALL           # Clears user memory space
# VOUT Related
VOUT_COMMAND             0x2666           # 1.2 V
VOUT_MAX                 0x2a3c           # 1.32 V
VOUT_MARGIN_HIGH        0x2851           # 1.26 V
VOUT_MARGIN_LOW         0x247a           # 1.14 V
VOUT_OV_FAULT_LIMIT     0x2c28           # 1.38 V
VOUT_OV_FAULT_RESPONSE  0x80           # Disable and no retry
VOUT_OV_WARN_LIMIT      0x2a3c           # 1.32 V
VOUT_UV_WARN_LIMIT      0x228f           # 1.08 V
VOUT_UV_FAULT_LIMIT     0x20a3           # 1.02 V
VOUT_UV_FAULT_RESPONSE  0x80           # Disable and no retry
POWER_GOOD_ON           0x228f           # 1.08 V
VOUT_TRANSITION_RATE    0xba00           # 1 mV/us
VOUT_DROOP              0x0000           # 0 mV/A
VOUT_CAL_OFFSET         0x0000           # 0 mV/A
# IOUT Related
IOUT_CAL_GAIN           0xb370           # 0.86 mV/A
IOUT_CAL_OFFSET         0x0000           # 0 A
IOUT_OC_FAULT_LIMIT     0xe3c0           # 60 A
IOUT_UC_FAULT_LIMIT     0xe440           # -60A
MFR_IOUT_OC_FAULT_RESPONSE 0x80           # Disable and no retry
MFR_IOUT_UC_FAULT_RESPONSE 0x80           # Disable and no retry
ISENSE_CONFIG           0x05           # 256ns Blanking time, Mid-Range
# Other Faults
OT_FAULT_LIMIT          0xebe8           # 125 °C
OT_FAULT_RESPONSE      0x80           # Disable and no retry
OT_WARN_LIMIT          0xeb70           # 110 °C
UT_WARN_LIMIT          0xdc40           # -30 °C
UT_FAULT_LIMIT        0xe530           # -45 °C
UT_FAULT_RESPONSE      0x80           # Disable and no retry
VIN_OV_FAULT_LIMIT     0xd380           # 14 V
VIN_OV_FAULT_RESPONSE  0x80           # Disable and no retry
VIN_OV_WARN_LIMIT     0xd353           # 13.3 V
VIN_UV_WARN_LIMIT     0xca5d           # 4.73 V
VIN_UV_FAULT_LIMIT     0xca40           # 4.5 V
VIN_UV_FAULT_RESPONSE  0x80           # Disable and no retry
#Enable, Timing and Sequence Related
ON_OFF_CONFIG          0x16           # Pin Enable, Soft Off
TON_DELAY              0xca80           # 5 ms
TON_RISE               0xca80           # 5 ms
TOFF_DELAY             0xca80           # 5 ms
TOFF_FALL             0xca80           # 5 ms
POWER_GOOD_DELAY      0xca00           # 4 ms
FREQUENCY_SWITCH      0x0215           # 533 kHz
SYNC_CONFIG           0x00           # Use Pin-strap for FSW setting
SEQUENCE              0x0000           # Sequence Disabled
# Manufacturer Related
MFR_ID                Intersil Corp       # Example Only
MFR_MODEL             ISL8272MEVAL1Z     # Example Only
MFR_REVISION          Rev-1              # Example Only
MFR_LOCATION          Milpitas, CA       # Example Only
MFR_DATE              09/05/2014        # Example Only
MFR_SERIAL            1234               # Example Only
USER_DATA_00         Module              # Example Only
# Advance Settings
USER_CONFIG           0x80           # ASCR on for Start, Open Drain PG
DDC_CONFIG           0x0a01           # DDC rail ID = 10, 2-phase
DDC_GROUP            0x00000000        # All Broadcast disabled
# Loop Compensation
ASCR_CONFIG          0x15a0100         # ASCR gain = 256, Residual = 90
STORE_USER_ALL       # Store all above settings to NVRAM
### End User Store

```

Layout

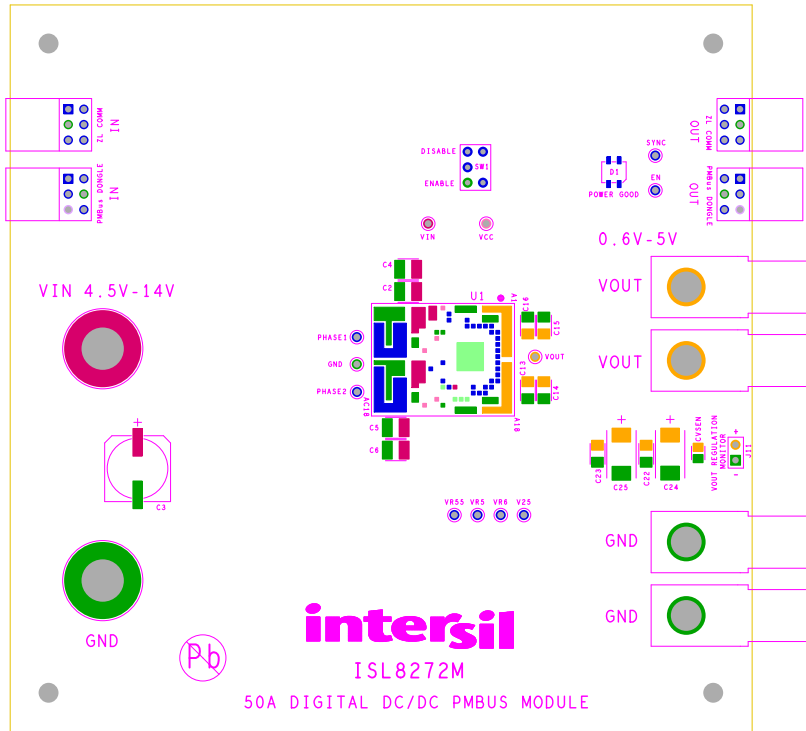


FIGURE 3. SILKSCREEN TOP

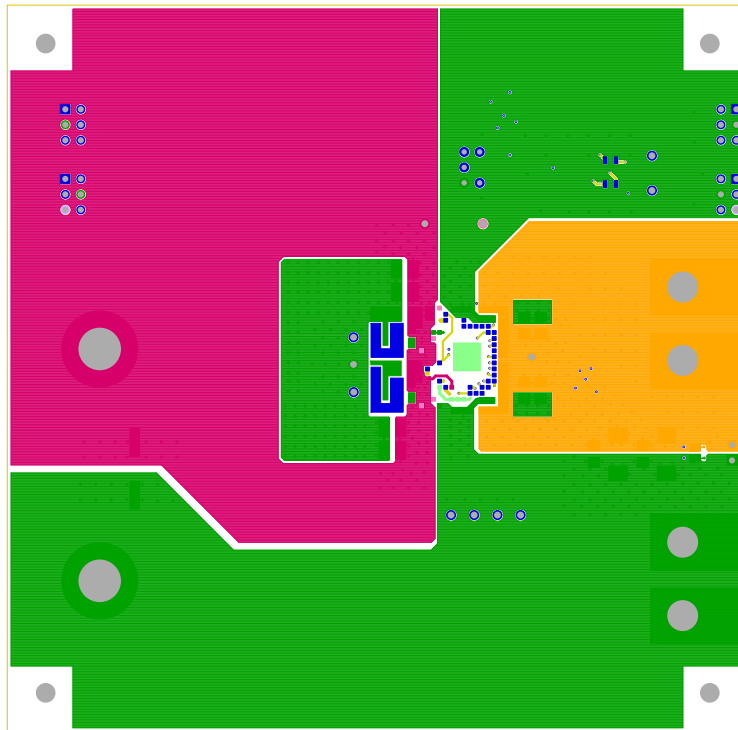


FIGURE 4. TOP LAYER COMPONENT SIDE

Layout (Continued)

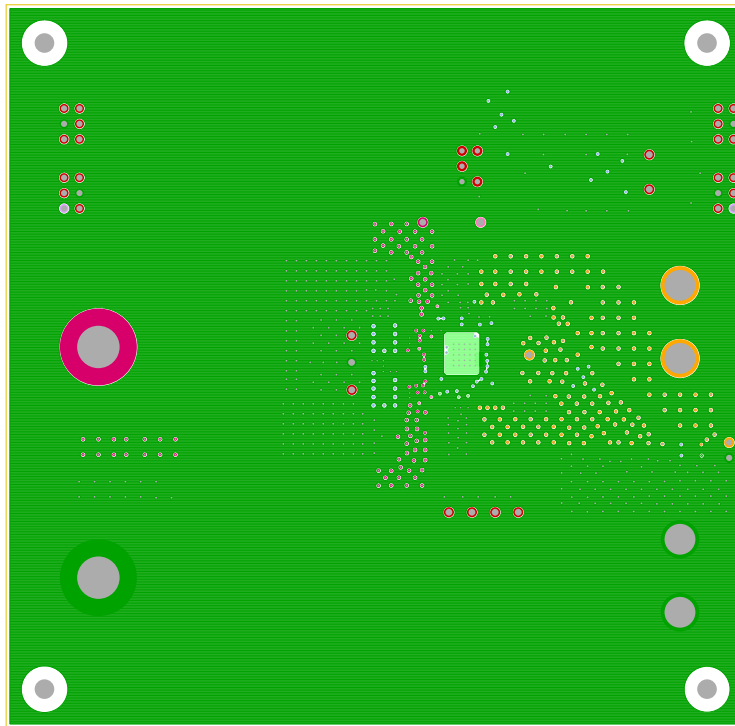


FIGURE 5. LAYER 2

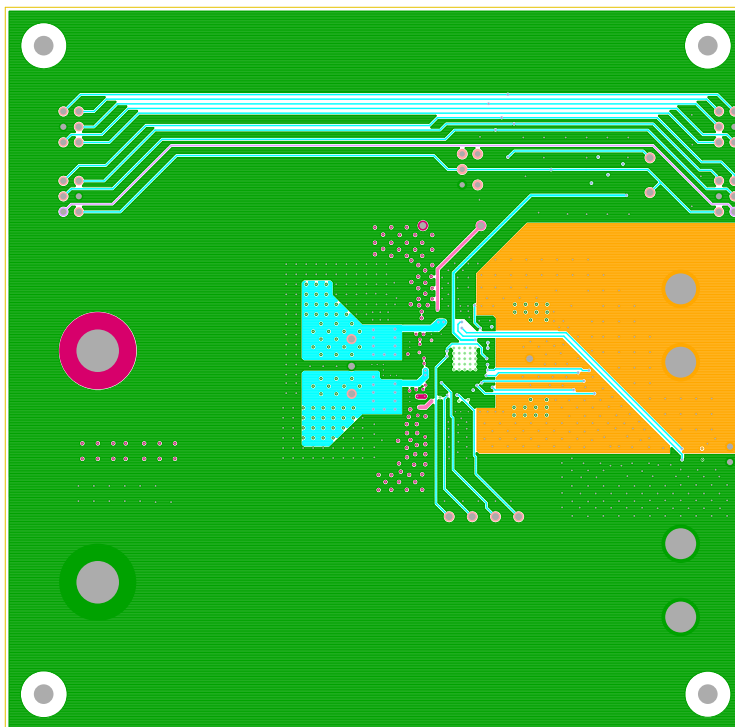


FIGURE 6. LAYER 3

Layout (Continued)

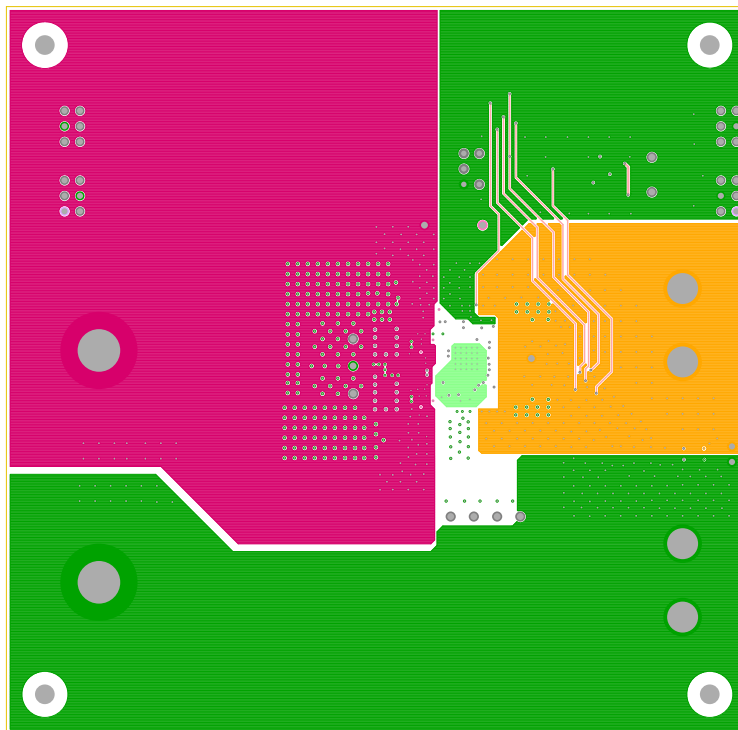


FIGURE 7. LAYER 4

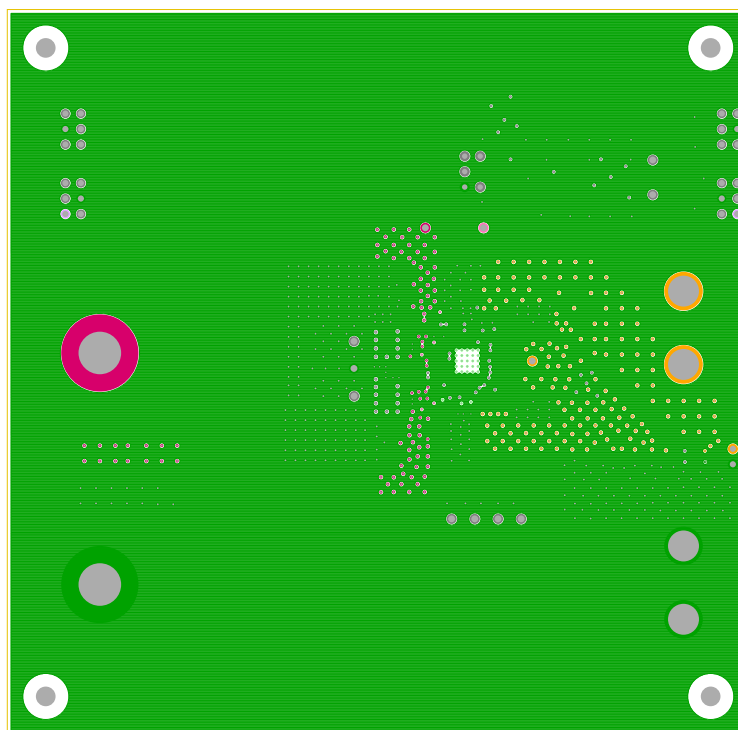


FIGURE 8. LAYER 5

Layout (Continued)

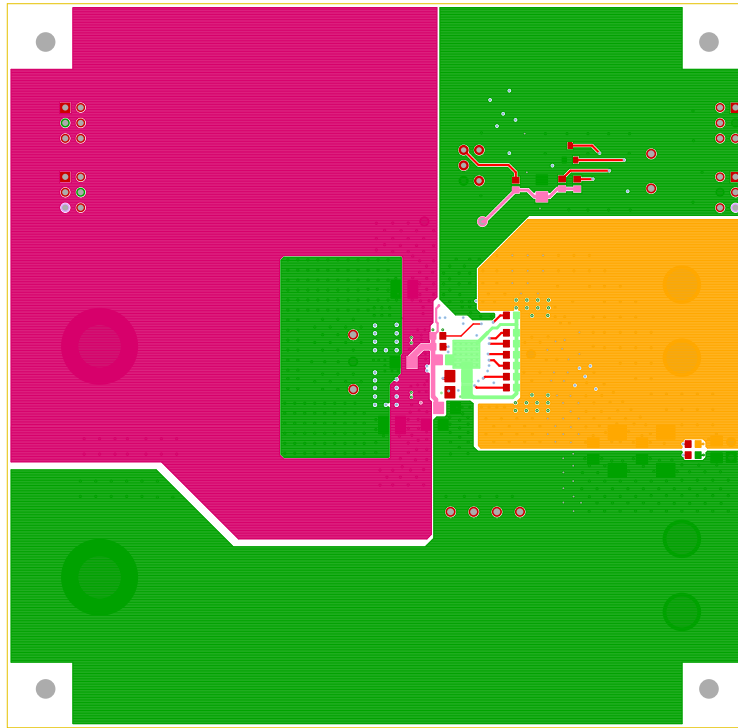


FIGURE 9. BOTTOM LAYER SOLDER SIDE

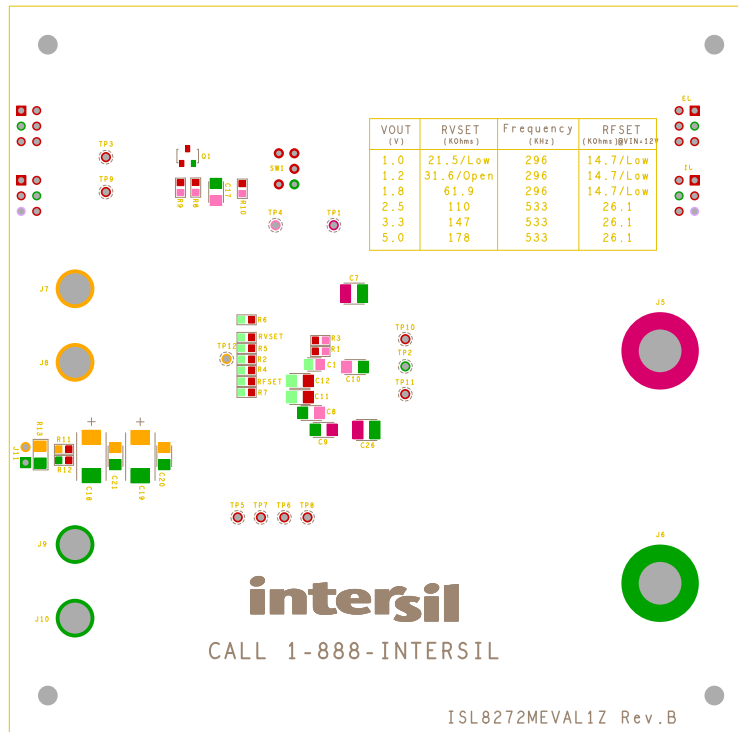


FIGURE 10. SILKSCREEN BOTTOM

Typical Performance Data The following data was acquired using a ISL8272MEVAL1Z evaluation board.

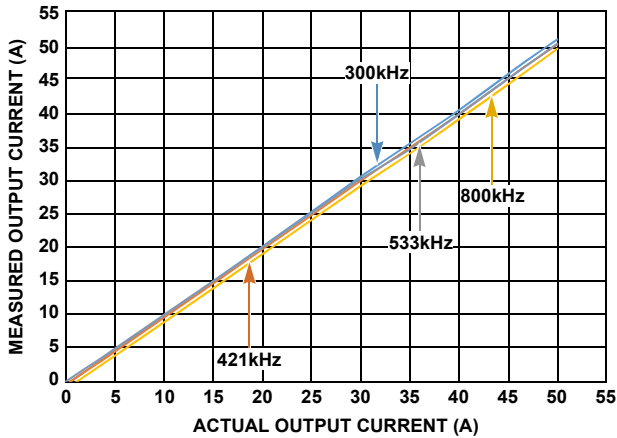


FIGURE 11. OUTPUT CURRENT MEASUREMENT ACCURACY AT $V_{IN} = 12V$, $V_{OUT} = 1V$, $T_A = +25^\circ C$ FOR VARIOUS SWITCHING FREQUENCIES

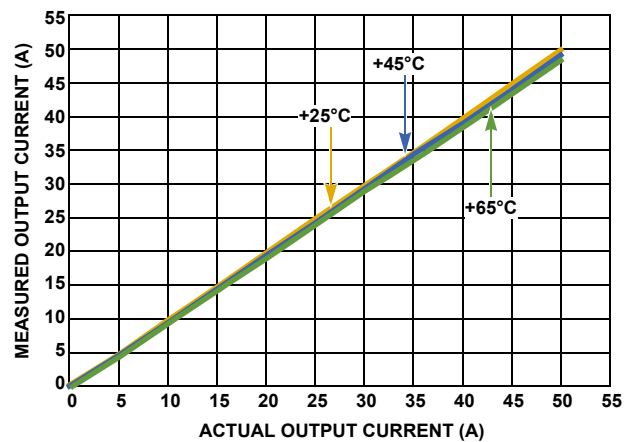


FIGURE 12. OUTPUT CURRENT MEASUREMENT ACCURACY AT $V_{IN} = 12V$, $V_{OUT} = 1V$, $f_{SW} = 533kHz$ FOR VARIOUS AMBIENT TEMPERATURES

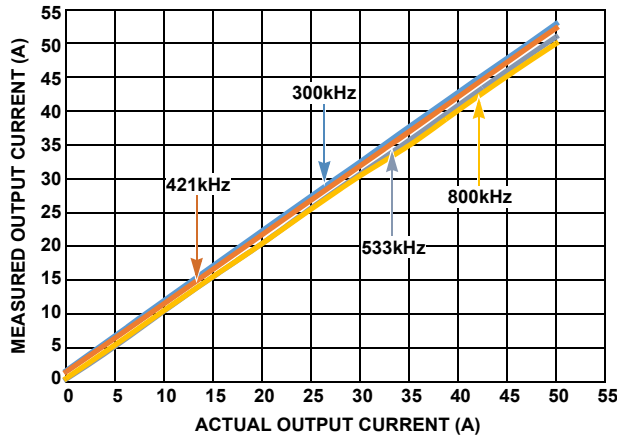


FIGURE 13. OUTPUT CURRENT MEASUREMENT ACCURACY AT $V_{IN} = 12V$, $V_{OUT} = 3.3V$, $T_A = +25^\circ C$ FOR VARIOUS SWITCHING FREQUENCIES

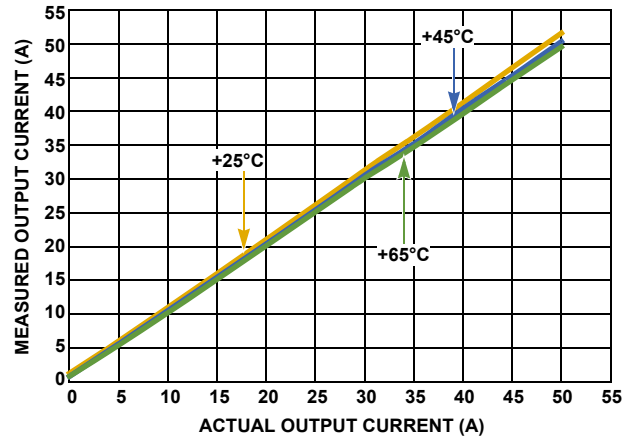


FIGURE 14. OUTPUT CURRENT MEASUREMENT ACCURACY AT $V_{IN} = 12V$, $V_{OUT} = 3.3V$, $f_{SW} = 533kHz$ FOR VARIOUS AMBIENT TEMPERATURES

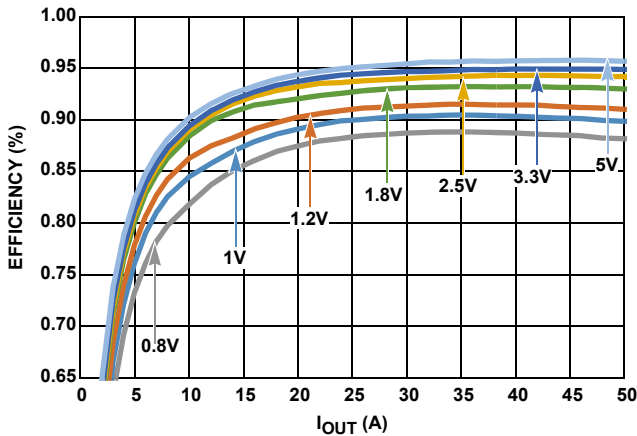


FIGURE 15. EFFICIENCY vs OUTPUT CURRENT AT $V_{IN} = 12V$, $f_{SW} = 300kHz$ FOR VARIOUS OUTPUT VOLTAGES

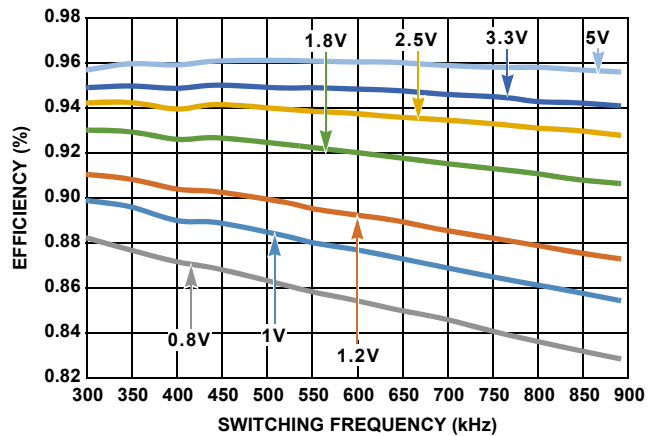
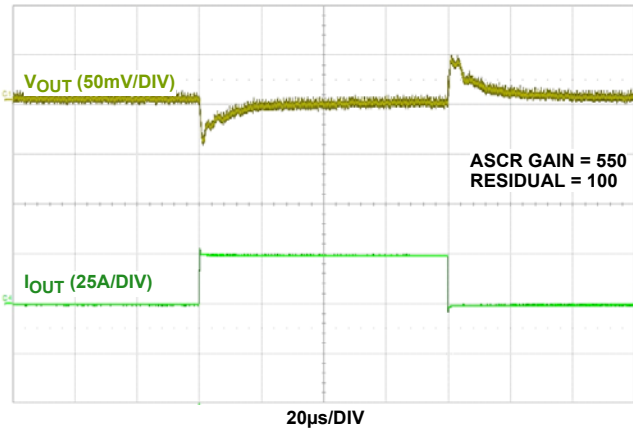
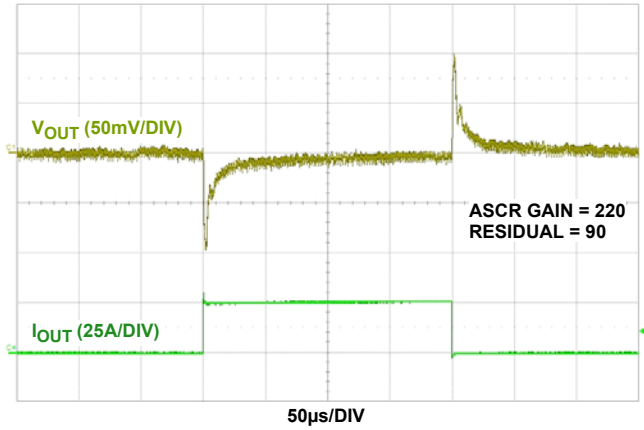


FIGURE 16. EFFICIENCY vs SWITCHING FREQUENCY AT $V_{IN} = 12V$, $I_{OUT} = 50A$ FOR VARIOUS OUTPUT VOLTAGES

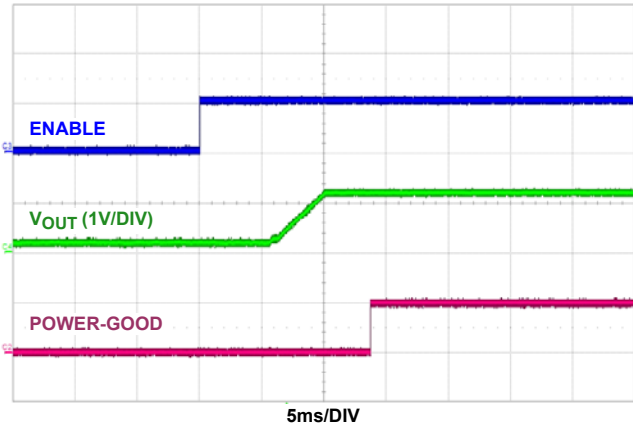
Typical Performance Data The following data was acquired using a ISL8272MEVAL1Z evaluation board. (Continued)



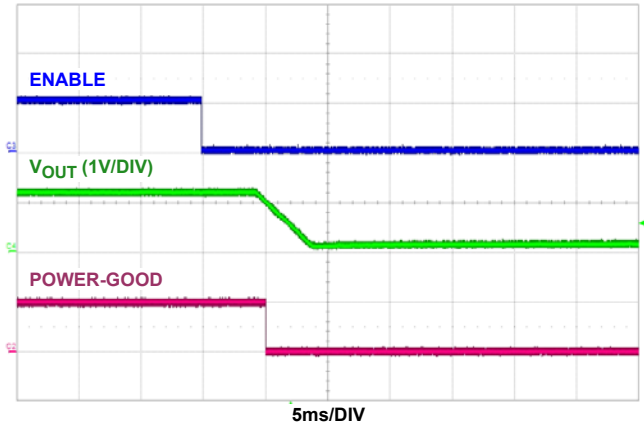
**FIGURE 17. LOAD TRANSIENT RESPONSE AT $V_{IN} = 12V$, $V_{OUT} = 1V$, $I_{OUT} = 0A$ TO $25A$ ($>100A/\mu s$), $f_{SW} = 533kHz$.
 $C_{OUT} = 8 \times 100\mu F$ CERAMIC + $4 \times 470\mu F$ POSCAP**



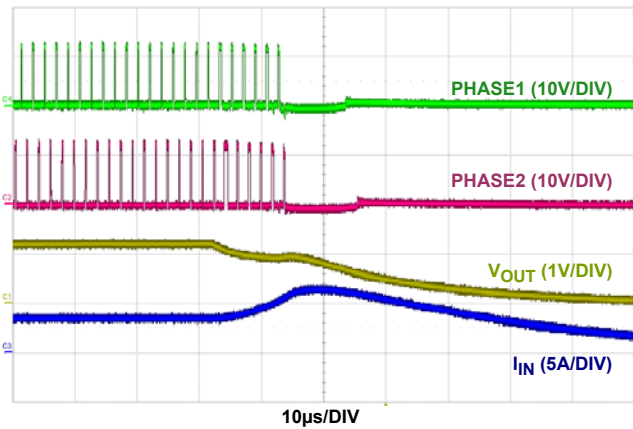
**FIGURE 18. LOAD TRANSIENT RESPONSE AT $V_{IN} = 12V$, $V_{OUT} = 3.3V$, $I_{OUT} = 0A$ TO $25A$ ($>100A/\mu s$), $f_{SW} = 533kHz$.
 $C_{OUT} = 4 \times 100\mu F$ CERAMIC + $2 \times 470\mu F$ POSCAP**



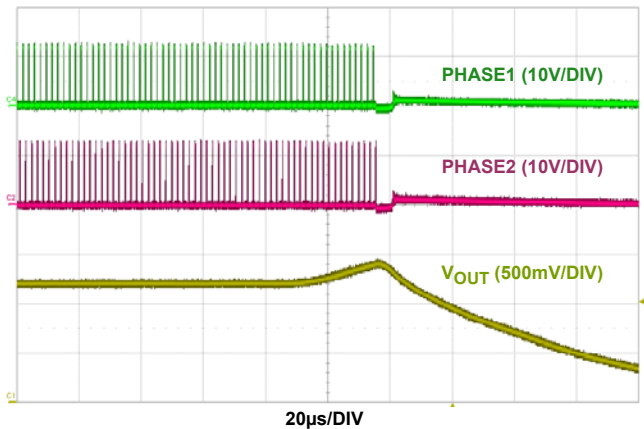
**FIGURE 19. SOFT-START AT $V_{IN} = 12V$, $V_{OUT} = 1.2V$,
 $TON_DELAY = 5ms$, $TON_RISE = 5ms$,
 $POWER_GOOD_DELAY = 4ms$**



**FIGURE 20. SOFT-STOP AT $V_{IN} = 12V$, $V_{OUT} = 1.2V$,
 $TOFF_DELAY = 5ms$, $TOFF_FALL = 5ms$**



**FIGURE 21. OUTPUT SHORT CIRCUIT PROTECTION AT $V_{IN} = 12V$,
 $V_{OUT} = 1.2V$, $f_{SW} = 533kHz$**



**FIGURE 22. OUTPUT OVERVOLTAGE PROTECTION AT $V_{IN} = 12V$,
 $V_{OUT} = 1.2V$, $f_{SW} = 533kHz$,
 $V_{OUT_OV_FAULT_LIMIT} = 1.38V$**

Typical Performance Data The following data was acquired using a ISL8272MEVAL1Z evaluation board. (Continued)

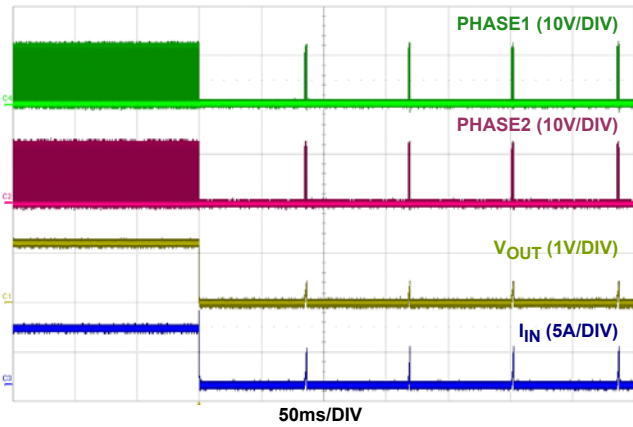


FIGURE 23. OUTPUT SHORT CIRCUIT PROTECTION WITH CONTINUOUS RETRY ENABLED (HICCUP MODE), $V_{IN} = 12V$, $V_{OUT} = 1.2V$

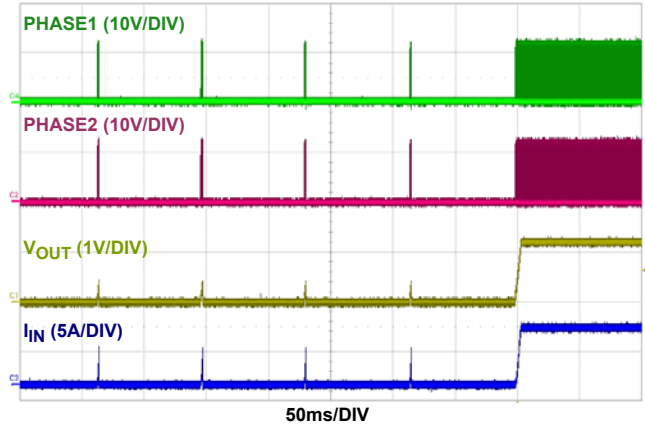


FIGURE 24. OUTPUT SHORT CIRCUIT RECOVERY FROM CONTINUOUS RETRY (HICCUP MODE). $V_{IN} = 12V$, $V_{OUT} = 1.2V$

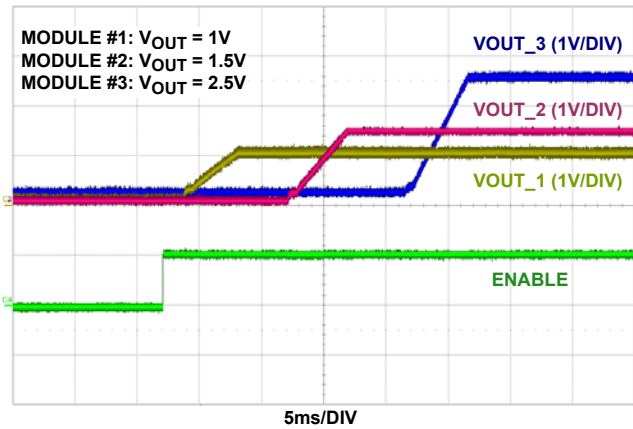


FIGURE 25. SOFT-START WITH OUTPUT SEQUENCING AT $V_{IN} = 12V$, THREE ISL8272MEVAL1Z BOARDS ARE CONNECTED IN DAISY CHAIN

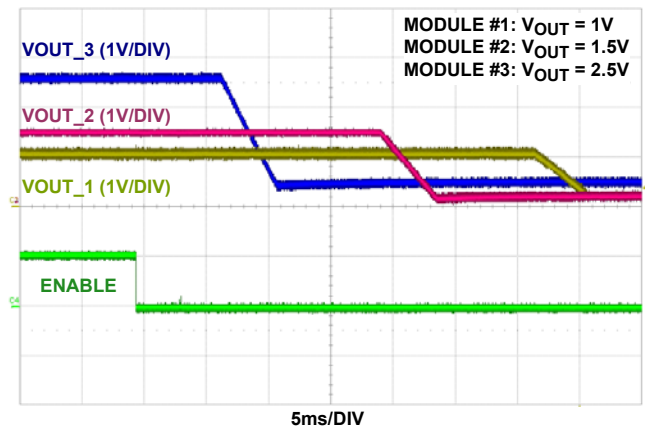


FIGURE 26. SOFT-STOP WITH OUTPUT SEQUENCING AT $V_{IN} = 12V$, THREE ISL8272MEVAL1Z BOARDS ARE CONNECTED IN DAISY CHAIN

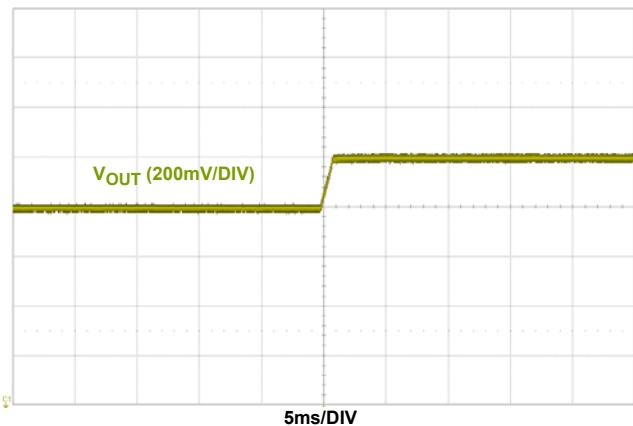


FIGURE 27. DYNAMIC VOLTAGE SCALING WITH V_{OUT} CHANGE FROM 1.1V TO 1.3V, $V_{IN} = 12V$, $V_{OUT_TRANSITION_RATE} = 1mV/\mu s$

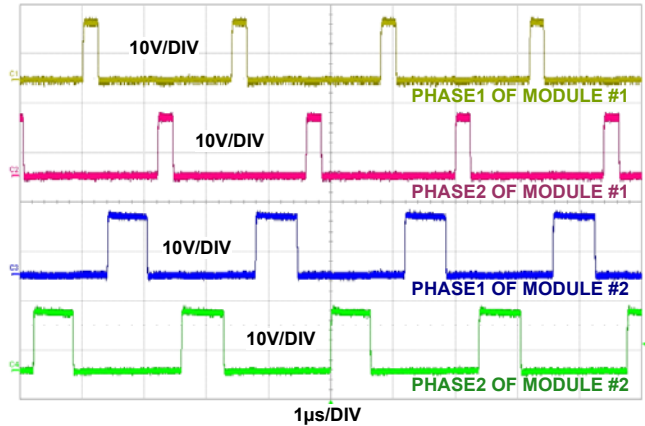


FIGURE 28. PHASE SPREADING/INTERLEAVING, TWO ISL8272MEVAL1Z BOARDS ARE CONNECTED IN DAISY CHAIN, MODULE #1 RAIL POSITION: 0; MODULE #2 RAIL POSITION:4. $V_{IN} = 12V$, $V_{OUT_1} = 1.2V$, $V_{OUT_2} = 3.3V$, $f_{SW} = 421kHz$

Typical Performance Data

The following data was acquired using a ISL8272MEVAL1Z evaluation board. (Continued)

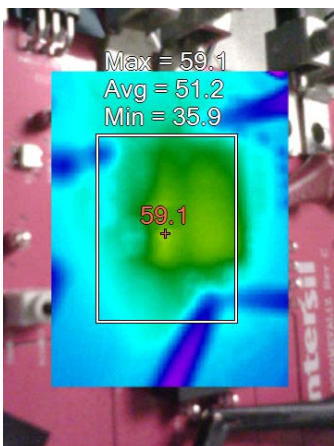


FIGURE 29. THERMAL IMAGE AT $V_{IN} = 12V$, $V_{OUT} = 1V$, $I_{OUT} = 50A$, $f_{SW} = 300kHz$, $T_A = +25^\circ C$, NO AIRFLOW

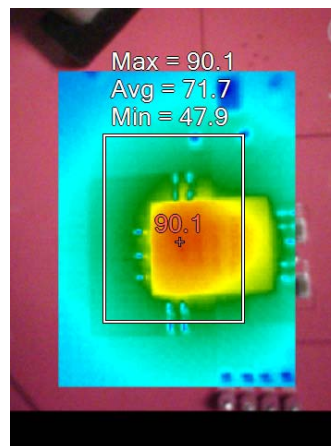


FIGURE 30. THERMAL IMAGE AT $V_{IN} = 14V$, $V_{OUT} = 5V$, $I_{OUT} = 50A$, $f_{SW} = 533kHz$, $T_A = +25^\circ C$, NO AIRFLOW

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338