

ISL6308AEVAL1Z

Three Phase Buck Converter with Integrated High Current 5V to 12V Drivers

AN1199
Rev 1.00
Jan 19, 2009

The progress in many parts of modern power systems, such as DDR/Chipset core voltage regulators, high current low voltage DC/DC converters, FPGA/ASIC DC/DC converters and many other general purpose applications, keeps challenging the power management IC makers to come up with innovative products and new solutions to meet the increase in power, reduction in size and increase in the DC/DC converter's efficiency targets. The interleaved multi-phase synchronous buck topology proves again to be the topology of choice for such high current, low voltage applications.

The ISL6308A is a space-saving, cost-effective solution for such applications. The ISL6308A is a three-phase PWM control IC with integrated high current MOSFET drivers. The integration of 5V to 12V high current MOSFET drivers into the controller IC marks a departure from the separate PWM controller and driver configuration of previous multi-phase product families. By reducing the number of external parts, this integration allows for a cost and space saving power management solution.

Output voltage can be programmed using the on-chip DAC or an external precision reference. A two bit code programs the DAC reference to one of 4 possible values (0.6V, 0.9V, 1.2V and 1.5V). A unity gain, differential amplifier is provided for remote voltage sensing, compensating for any potential difference between remote and local grounds. The output voltage can also be offset through the use of a single external resistor. An optional droop function is also implemented and can be disabled for applications having less stringent output voltage variation requirements or experiencing less severe step loads.

A unique feature of the ISL6308A is the combined use of both DCR and $r_{DS(ON)}$ current sensing. Load line voltage positioning and overcurrent protection are accomplished through continuous inductor DCR current sensing, while $r_{DS(ON)}$ current sensing is used for accurate channel-current balance. Using both methods of current sampling utilizes the best advantages of each technique.

Protection features of this controller IC include a set of sophisticated overvoltage and overcurrent protection. Overvoltage results in the converter turning the lower MOSFETs ON to clamp the rising output voltage and protect the load. An OVP output is also provided to drive an optional crowbar device. The overcurrent protection level is set through a single external resistor. Other protection features include protection against an open circuit on the remote sensing inputs. Combined, these features provide advanced protection for the output load.

The ISL6308AEVAL1Z evaluation board embodies a 85A to 90A regulator solution targeted at supplying power to the designated load. The physical board design is optimized for 3 phase operation and ships out configured to provide one of the following four output voltages (0.6V, 0.9V, 1.2V and 1.5V) depending on choice of the REF1, REF0 combination set by DIP switch U2, but can be easily modified to provide any output voltage values in the range of 0.6V to 2.3V by means of resistor divider composed of R_{90} and R_{81} .

For further details on the ISL6308A, consult the data sheet [1].

The Intersil multi-phase family controller and driver portfolio continues to expand with new selections to better fit our customer needs. Refer to our web site for updated information: www.intersil.com.

ISL6308AEVAL1Z Board Design

The evaluation kit consists of the ISL6308AEVAL1Z evaluation board, the ISL6308A datasheet, and this application note. The evaluation board is optimized for 3-phase operation without droop, the nominal output voltage is 1.5V (with DIP switch U2 set to 11 position) and the maximum output current is 90A.

The evaluation board provides convenient test points, a DIP switch for DAC (REF) voltage selection from four possible values (0.6V, 0.9V, 1.2V and 1.5V), footprint for a resistor divider for output voltage adjustment up to 2.3V, and an on-board transient load generator to facilitate the evaluation process. An on-board LED is present to indicate the status of the PGOOD signal. The board is configured for down conversion from 5V to 12V to the REF setting.

The printed circuit board is implemented in 6-layer, 2-ounce copper. Layout plots and part lists are provided at the end of this application note for this design.

Quick Start Evaluation

The ISL6308AEVAL1Z is designed for quick evaluation after following only a few simple steps. All that is required is two bench power supplies, Oscilloscope and Load. To begin evaluating the ISL6308AEVAL1Z, follow the steps below.

1. Before doing anything to the evaluation board, make sure that the "Enable" switch (S1) is in the Disable position and the "Transient Load Generator" switch (S2) is in the Load Off position.
2. Connect a 12V, 15A Lab power supply between J7 and J8. This power supply provides VIN and PVCC (with original board configuration).
3. Connect a 5V, 1A Lab power supply between J23 and GND. This power supply provides VCC bias (and PVCC bias if the board is configured for 5V PVCC).

4. Set the “REF Selection” DIP switch (U2) to 11 corresponding to DAC = REF = 1.5V. Figure 1 details the typical default configuration for U2 when the board is shipped. In this default setting, the evaluation board is set for a reference voltage of 1.5V.

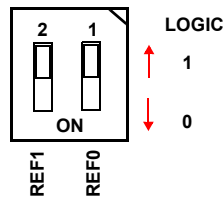


FIGURE 1. TYPICAL U2 DEFAULT SETTING 11 (1.5V)

5. Connect a load (either resistive or electronic) between VOUT terminal (J1, J2) and GND terminal (J3, J4).
6. Move the “Enable” switch (S1) to the Enable position releasing the IC ENLL pin to rise to begin regulation.

After Step 6, the ISL6308AEVAL1Z should be regulating the output voltage, at the “V_{OUT+}” and “V_{OUT-}” test points (P20, P21) and J5 to the REF voltage. The “PGOOD Indicator” LED (D1) should be green to indicate the regulator is operating correctly.

ISL6308AEVAL1Z Board Features

Input Power Connections

The ISL6308AEVAL1Z allows for the use of standard bench power supplies for powering up the board. Two female-banana jacks are provided for connection of bench power supplies. Connect the +5V terminal to P23, +12V terminal to J7, and the common ground to terminal J8. Voltage sequencing is not required when powering the evaluation board.

Once power is applied to the board, the PGOOD LED indicator will begin to illuminate red. With S1 in the Disable position, the ENLL pin of the ISL6308A is held low and the start-up sequence is inhibited.

Output Power Connections

The ISL6308AEVAL1Z output can be exercised using either resistive or electronic loads. Copper alloy terminal lugs provide connection points for loading. Tie the positive load connection to V_{OUT+} terminals J1 and J2, and the negative to ground, terminals J3 and J4. A shielded scope probe test point, J5, allows for inspection of the output voltage, VOUT.

REF and V_{OUT} Setup

The REF DIP switch would be preset to 11 (1.5V). Also 1.2V, 0.9V and 0.6V outputs can be selected using different codes on the DIP switch. If an output voltage different than the 4 possible REF values is desired, the output resistor divider composed of R₉₀ (initially 0Ω) and R₈₁ (initially open) can be used (refer to the section in the ISL6308A Data sheet entitled “Output Voltage Offset Programming” and “Adjusting the Output Voltage” on page 8 of this application note for

resistor value calculations). Note that the ISL6308A is usable for output voltages up to 2.3V when the REF voltage is set to 1.5V. See Table 1 for the maximum possible output voltage with different REF setting.

TABLE 1. MAXIMUM OUTPUT VOLTAGE WITH DIFFERENT REF SETTING WITH THE USE OF A RESISTOR DIVIDER ON VSEN

| REF1 | REF0 | REF = DAC | VOUT MAX |
|------|------|-----------|----------|
| 0 | 0 | 0.6V | 1.4V |
| 0 | 1 | 0.9V | 1.7V |
| 1 | 0 | 1.2V | 2V |
| 1 | 1 | 1.5V | 2.3V |

PVCC Power Options

One unique feature of the ISL6308A is the variable gate drive bias for the integrated drivers. The gate drive voltage for the internal drivers can be any voltage from +5V to +12V by simply connecting the desired voltage to the PVCC pin of the controller. To accommodate the flexibility of the drivers, the ISL6308AEVAL1Z has been designed to support a multitude of options for the PVCC voltage.

Switching between the different PVCC voltages available on the evaluation board is as simple as populating and depopulating certain resistors. The evaluation board has three on-board voltages available: +5V, +12V, and +8V (from an on-board linear regulator). Refer to Table 2 for what resistors to populate for each voltage option.

TABLE 2. GATE DRIVE VOLTAGE OPTIONS AND RESISTOR SETTINGS

| UGATE VOLTAGE | LGATE VOLTAGE | R48 | R68 | R71 | R72 |
|---------------|---------------|------|------|------|------|
| 12.0V | 12.0V | OPEN | OPEN | OPEN | 0Ω |
| 8.0V | 8.0V | OPEN | OPEN | 0Ω | OPEN |
| 5.0V | 5.0V | 0Ω | OPEN | OPEN | OPEN |
| 12.0V | 5.0V | 0Ω | 0Ω | OPEN | OPEN |

Enabling the Controller

In order to enable the controller, the board must be powered, a REF (DAC) code must be set, and the PVCC and VCC voltages must be set. If these steps have been properly followed, the regulator is enabled by toggling the “ENABLE” switch (S1) to the Enable position, which allows the voltage on the ENLL pin of the ISL6308A to rise above the ENLL threshold of 0.66V and the controller will begin its digital soft-start sequence. The output voltage ramps up to the programmed setting, at which time the PGOOD indicator will switch from red to green.

On-Board Load Transient Generator

Most bench-top electronic loads are not capable of producing the current slew rates required to emulate most

To create an output voltage change proportional to the total current in all the active channels (droop), the ISL6308A uses an inductor DCR sensing R-C network. This network, shown in Figure 4, is designed not only to precisely control the load line of the regulator, but also to thermally compensate for any changes in DCR that may skew the load line as a result of increases in temperature.

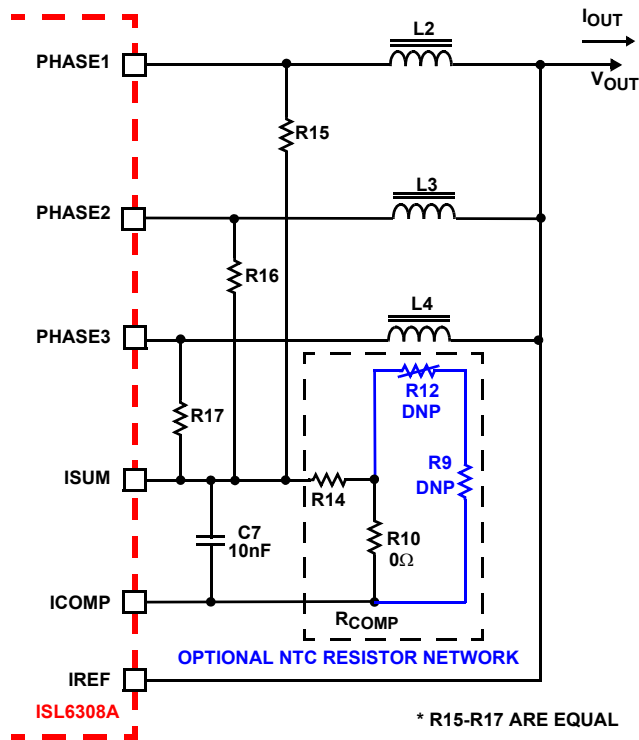


FIGURE 4. DCR SENSING CONFIGURATION WITH OPTIONAL FOOTPRINTS FOR NTC LOAD-LINE COMPENSATION

This sensing technique works off the principle that if the R-C time constant of $C7 \cdot R_{COMP}$ ($R_{COMP} = R_{14}$) is equal to the L/DCR time constant of the inductor, the load line impedance will be equal to $R_{COMP} \cdot DCR / R_{15}$ (R_{15} , R_{16} and R_{17} are equal).

If the load line impedance needs to be changed, all that is required is adjusting the values of R_{15} through R_{17} , as explained in the section entitled “Load Line Regulation Component Selection (DCR Current Sensing)” of the ISL6308A datasheet. If the Inductor is changed though, the resistance of time constant matching network will need to be changed. The NTC resistor network must first be adjusted so that the new L/DCR time constant is precisely matched. Refer to section entitled “Load Line Regulation Component Selection (DCR Current Sensing)” of the ISL6308A datasheet to design the entire R-C sense network.

An Optional NTC resistor network consisting of 3 resistors (R_9 , R_{10} , and R_{14}) and a single NTC thermistor (R_{12}), which is placed close the output inductors. This network is designed to compensate for any change in DCR that occurs

due to temperature when the Droop option is used and a tight load-line regulation is required, and keep the time constant of the R-C network equal to that of the inductor L/DCR time constant.

Overcurrent Protection Level

The ISL6308A utilizes a single resistor to set the maximum current level for the IC’s overcurrent protection circuitry. Please refer to section titled “Overcurrent Protection” of the ISL6308A datasheet, and adjust resistor R_{11} accordingly to set the desired overcurrent trip level.

Output Voltage Offset

The ISL6308A allows a designer to accurately offset the output voltage both negatively and positively. All that is required is a single resistor between the OFS and VCC pins, or the OFS pin and GND. The ISL6308AEVAL1Z has both of these resistor options available on the board. To positively offset the output voltage, populate resistor R_5 . To negatively offset the output voltage, populate resistor R_7 . Please refer to section entitled “Output Voltage Setting” of the ISL6308A datasheet to accurately calculate these resistor values.

Switching Frequency

The switching frequency of the ISL6308AEVAL1Z board is set to an optimal value of 325kHz giving the best efficiency and performance for the given design with $R_{13} = 75k\Omega$. However, the switching frequency can be adjusted anywhere from 80kHz to 1.5MHz per phase. In practice, many factors affect the choice of switching frequency among which are efficiency, and gate drive losses (which depend on the MOSFET choice and Gate Driver Voltage). Since the ISL6308A has integrated MOSFET drivers, the driver losses must be taken into account when the switching frequency is chosen. To change the switching frequency, refer to section entitled “Switching Frequency” of the ISL6308A datasheet and adjust the value of frequency set resistor, R_{13} , accordingly.

MOSFET Gate Drive Voltage (PVCC)

The gate drive bias voltage of the integrated drivers in the ISL6308A can be any voltage between +5V and +12V. This bias voltage is set by connecting the desired voltage to the PVCC pins of the IC. Please refer to the “PVCC Power Options” on page 2 to set the desired gate drive voltage.

Number of Active Phases

The ISL6308A has the option of 1-, 2- or 3-phase operation. The ISL6308AEVAL1Z is designed to change the number of active phases by simply populating or depopulating few resistors, R_{62} through R_{65} . Refer to Table 4 for which resistors to populate for 1-, 2- or 3-phase operation.

TABLE 4. SETTINGS FOR NUMBER OF ACTIVE PHASES

| # OF ACTIVE PHASES | R62 | R63 | R64 | R65 |
|--------------------|------|------|------|------|
| 3 | 0Ω | 0Ω | OPEN | OPEN |
| 2 | OPEN | 0Ω | 0Ω | OPEN |
| 1 | OPEN | OPEN | 0Ω | 0Ω |

ISL6308A Performance

Soft-Start Interval

The typical start-up waveforms for the ISL6308AEVAL1Z are shown in Figure 5. The waveforms represented in this image show the soft-start sequence of the regulator with the DAC set to 1.50V. Before the soft-start interval begins, VCC and PVCC are above POR and the DAC inputs are set to logic 11. With these two conditions met, throwing the ENABLE switch into the Enable position causes the voltage on the ENLL pin to rise above the ISL6308A’s enable threshold, beginning the soft-start sequence. For a delay time of 0.85ms, V_{OUT} does not move due to the manner in which soft-start is implemented within the controller. After this delay (which is approximately equal to 240 switching cycles), V_{OUT} begins to ramp linearly toward the DAC voltage. With the converter running at 325kHz, this ramp takes approximately 5.2ms, during which time the input current, ICC12, also ramps slowly due to the controlled building of the output voltage.

Once V_{OUT} reaches the DAC set point, the internal pull-down on the PGOOD pin is released. This allows a resistor from PGOOD to VCC to pull PGOOD high and the PGOOD LED indicator changes from red to green.

Special consideration is given to start-up into a pre-charged output (where the output is not 0V at the time the SS cycle is initiated). Under such circumstances, the ISL6308A keeps off both sets of output MOSFETs until the internal ramp starts to exceed the output voltage sensed at the FB pin. This special scenario is detailed in Figure 6. The circuit is enabled at time t0. As the internal ramp exceeds the magnitude of the output voltage at time t1, the MOSFETs

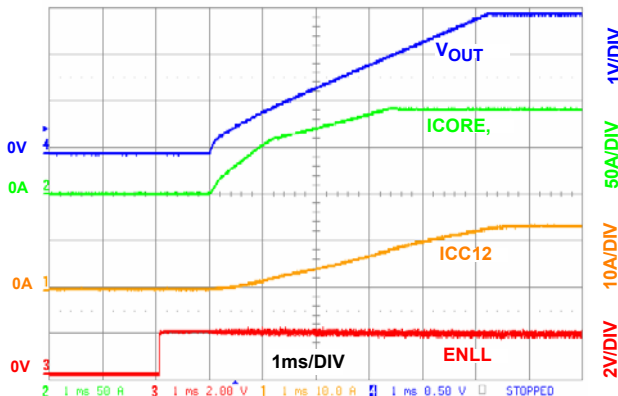


FIGURE 5. SOFT-START INTERVAL WAVEFORMS

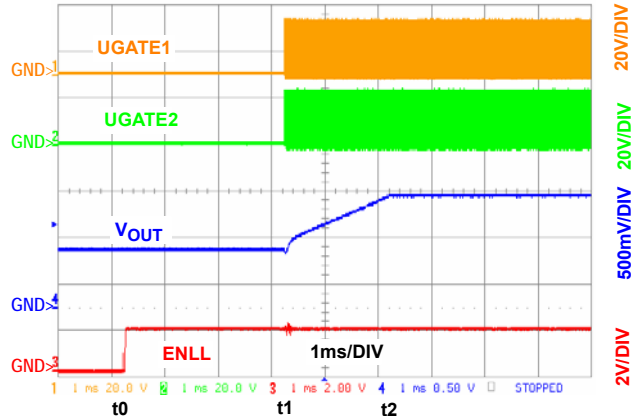


FIGURE 6. ISL6308AEVAL1Z START-UP INTO A PARTIALLY CHARGED OUTPUT (V_{DAC} = 1.2V)

drivers are enabled and the output voltage ramps up in a seamless fashion from the pre-existent level to the DAC-set level, reached at time t2.

A second scenario can be encountered with a pre-charged output: output being pre-charged above the DAC-set point, as shown in Figure 7. In this situation, the ISL6308A behaves in a way similar to that of Figure 6, keeping the MOSFETs off until the end of the SS ramp. However, once the end of the ramp has been reached, at time t1, the output drivers are enabled for operation, and the output is quickly drained down to set-point level. An OV condition during start-up will take precedence over this normal start-up behavior, but will allow reversal back to normal behavior as soon as the condition is removed or brought under control.

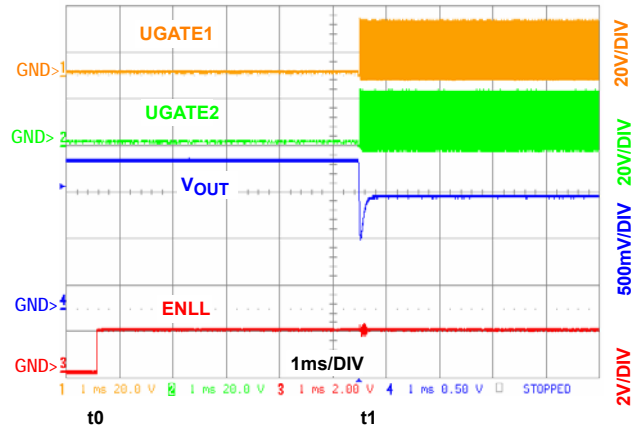


FIGURE 7. ISL6308AEVAL1Z START-UP INTO AN OVERCHARGED OUTPUT (V_{DAC} = 1.2V)

Transient Response

The ISL6308AEVAL1Z is designed without droop for a maximum output load current of 90A. The Load step is approximately 30A and the output voltage variation during the transient is kept below 100mV peak-to-peak. This load step has a maximum slew rate of approximately 50A/μs on both the rising and falling edges. The on-board load transient generator is designed to provide the specified load step, different load steps and current slew rates can be accommodated with the on-Board Transient Load Generator.

The rising edge transient response of the ISL6308AEVAL1Z, is shown in Figure 8. In order to obtain the load current waveform shown, the bench-top load is turned off, while the on-board transient generator is pulsing a 30A step for 550μs. When the load step occurs, the output capacitors provide the initial output current, causing V_{OUT} to drop suddenly due to the ESR and ESL voltage drops in the capacitors. The controller immediately responds to this drop by increasing the PWM duty cycles to as much as 66%. The duty cycles then decrease to stabilize V_{OUT} . At the end of the 550μs load pulse, the load current returns to 0A. The transient response to this falling edge of the load is shown in Figure 9. When the falling load step occurs, the output capacitors must absorb the inductor current which can not fall at the same rate of the load step. This causes V_{OUT} to rise suddenly due to the ESR and ESL voltage drops in the capacitors. The controller immediately responds to this rise by decreasing the PWM duty cycles to zero, and then increasing them accordingly to regulate V_{CORE} to the programmed 1.5V level.

Figure 10 shows both the rising and falling edges.

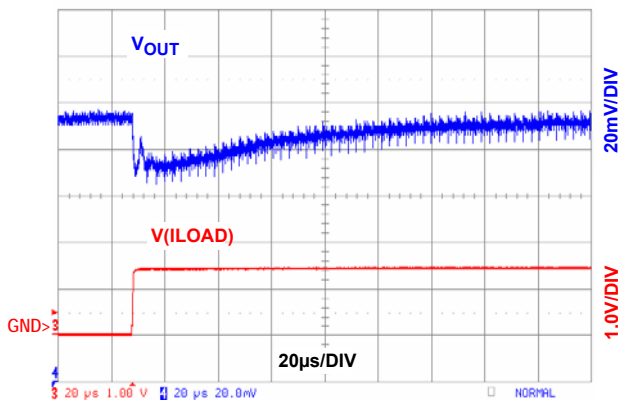


FIGURE 8. ISL6308AEVAL1Z RISING EDGE TRANSIENT LOAD RESPONSE

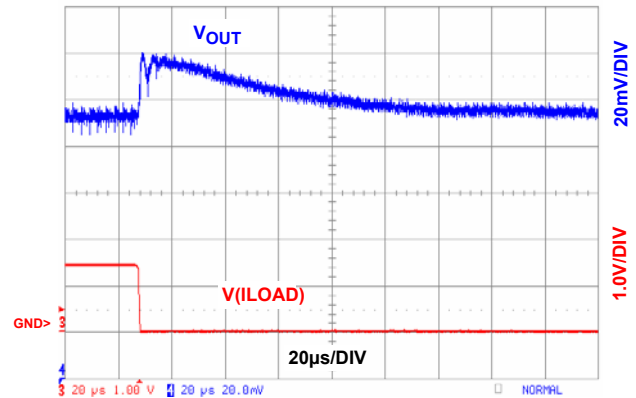


FIGURE 9. ISL6308AEVAL1Z FALLING EDGE TRANSIENT RESPONSE

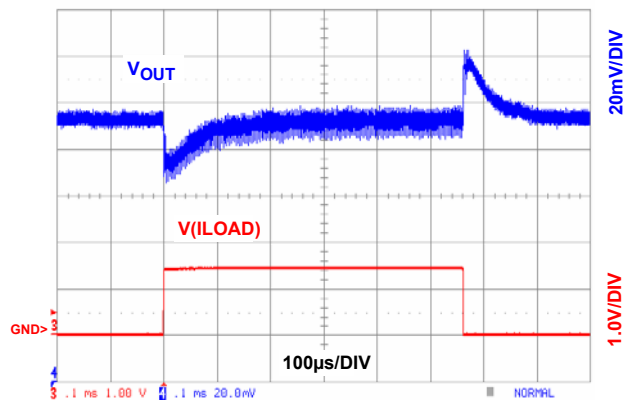


FIGURE 10. ISL6308AEVAL1Z TRANSIENT RESPONSE

Overcurrent Protection

The ISL6308A is designed to stop all regulation and protect the sensitive load if an overcurrent event occurs. This is done by continuously monitoring the total output current and comparing it to an overcurrent trip level set by the OCSET resistor, R_{11} . If the output current ever exceeds the trip level, as shown in Figure 11 (at time t_1), the ISL6308A immediately turns the upper and lower MOSFETs off, causing V_{OUT} to fall to 0V. The controller holds the UGATE and LGATE signals in this state for a period of 4096 switching cycles, which at 325kHz is 13.65ms. The controller then re-initializes the soft-start cycle (at time t_2). If the load that caused the overcurrent trip remains, another overcurrent trip will occur before the soft-start cycle completes. The controller will continue to try to cycle soft-start indefinitely until the load current is reduced, or the controller is disabled. This operation is shown in Figure 11.

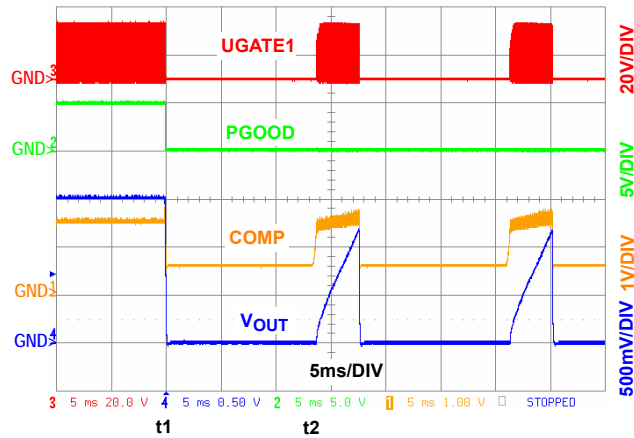


FIGURE 11. ISL6308AEVAL1Z OVERCURRENT PROTECTION

Pre-POR Overvoltage Protection

Prior to PVCC and VCC exceeding their POR levels, the ISL6308A is designed to protect the load from any overvoltage events that may occur (such an overvoltage may occur if for example one of the upper MOSFETs was shorted at assembly due to manufacturing defects). This is accomplished by means of an internal 10kΩ resistor tied from PHASE to LGATE, which turns on the lower MOSFET to control the output voltage until the input power supply current limits itself and cuts off. In Figure 12, an artificial pre-POR overvoltage event has been created by shorting the positive 12V input plane to the PHASE plane. This same 12V input is connected to PVCC pins of the ISL6308A. Figure 12 illustrates how the controller protects the load from a high output voltage spike, when the 12V input turns on, by tying LGATE to PHASE.

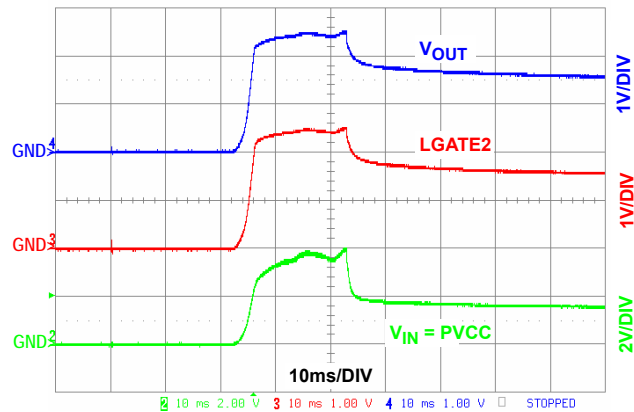


FIGURE 12. ISL6308AEVAL1Z PRE-POR OUTPUT OVERVOLTAGE PROTECTION (START-UP WITH SHORTED UPPER FET)

Overvoltage Protection

To protect from an overvoltage event during normal operation, the ISL6308A continually monitors the output voltage. If the output voltage exceeds a specific limit (set internally), the controller commands the LGATE signals high, turning on the lower MOSFETs to keep the output voltage below a level that might cause damage to the load. As shown in the overvoltage event in Figure 12, turning on the lower MOSFETs not only keeps the output voltage from rising, it also sinks a large amount of current, causing the input voltage to the power stage to drop. If this causes the input power supply voltage to fall below the POR level of the ISL6308A, as seen at the end of the waveform in Figure 13, the controller responds by using the pre-POR overvoltage protection explained in the previous section. This allows the ISL6308A to always keep the output load safe from high voltage spikes during an entire overvoltage event.

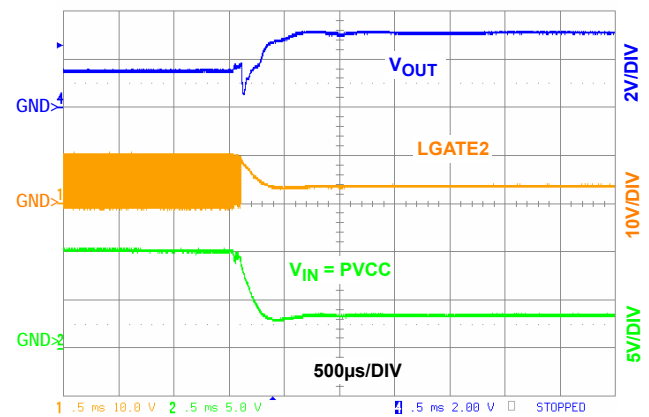


FIGURE 13. ISL6308AEVAL1Z PRE-POR OVERVOLTAGE PROTECTION

Efficiency

The efficiency of the ISL6308AEVAL1Z board, loaded from 0A to 90A, at both PVCC = 5V and 12V are plotted in Figure 14 for $V_{OUT} = 1.5V$. Measurements were performed at room temperature and taken at thermal equilibrium with an air flow of 200LFM. The efficiency peaks just below 89% at 50A for the PVCC = 12V case and then levels off steadily to approximately 86.5% at 90A, while for the PVCC = 5V, efficiency peaks at around 90% at 25A and then falls down to approximately 85% at 90A.

The efficiency for $V_{OUT} = 1.8V$ is plotted in Figure 15. The efficiency peaks around 90% at 50A for the PVCC = 12V case and then levels off steadily to approximately 88% at 90A, while for the PVCC = 5V, efficiency peaks at around 91% at 30A and then falls down to approximately 87% at 90A. The use of stronger air flow could improve the efficiency across the load range and keeps the components cooler leading to better reliability and longer component lives.

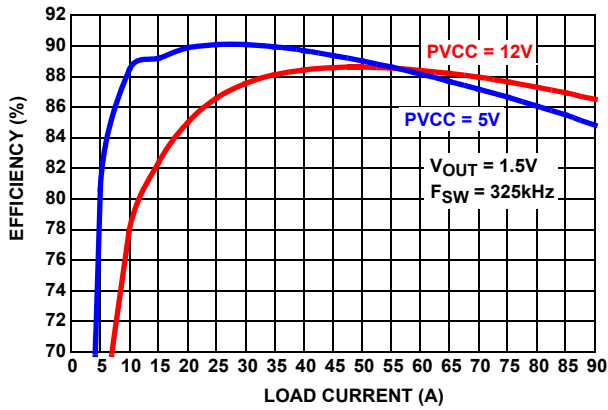


FIGURE 14. EFFICIENCY vs LOAD CURRENT

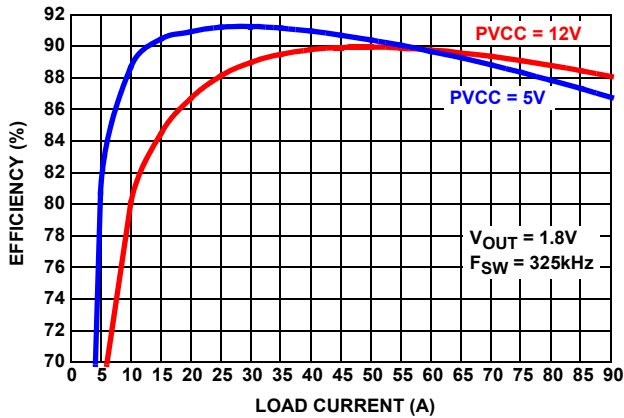


FIGURE 15. EFFICIENCY vs LOAD CURRENT

Modifications

Adjusting the Output Voltage

The output voltage can be adjusted by changing the 2-bit inputs (REF1, REF0) of internal DAC (externally connected with a resistor to REF). Please consult the data sheet for the available voltage ranges and the required settings.

The offset pin (OFS) allows for small-range (less than 100mV), positive or negative, offsetting of the output voltage. The board is shipped with R₉₀ equal to 0Ω and R₈₂ is not populated to provide an output voltage equal to the internal DAC setting. Should an output voltage setting outside the normal range provided via the internal DAC be required, a separate resistor divider connected from the load output terminals to VSEN pin as shown in Figure 16 is needed.

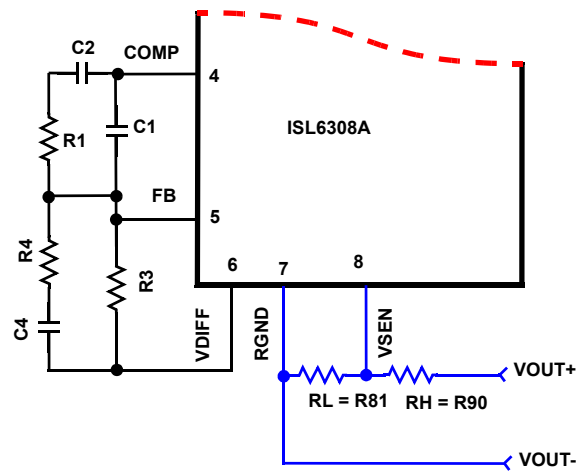


FIGURE 16. ADJUSTING VOUT OUTSIDE THE REF (DAC) RANGE

Use the following relationships in Equations 1 through 4 to calculate the value of the resistors based on the known parameters.

$$R_L + R_H \leq 500\Omega \tag{EQ. 1}$$

Choose $R_L = 300\Omega$

Choose a value of VREF that meets the following condition:

$$V_{REF} \geq V_{OUT} - 0.8V \tag{EQ. 2}$$

Choose a value for R_L (for example 300Ω):

Calculate the value of the resistor R_H:

$$R_H = \frac{R_L \cdot (V_{OUT} - REF)}{REF} \tag{EQ. 3}$$

Example:

$$V_{OUT} = 2.1V$$

$$V_{REF} \geq 2.1V - 0.8V \geq 1.3V$$

$$V_{REF} = 1.5V$$

$$R_L = 300\Omega$$

$$R_H = \frac{300\Omega \cdot (2.1V - 1.5V)}{1.5V} = 120\Omega \tag{EQ. 4}$$

Down-Converting From a Different Input Voltage

The ISL6308AEVAL1Z is powered from bench supplies, the input labelled '+12V' can be adjusted down as desired. If experimenting with a lower voltage, be mindful of a few aspects:

- The duty cycle of the controller is limited to 66%; the circuit will not be capable of properly regulating the output voltage should the input be reduced to a level low enough to induce duty cycle saturation.
- As the evaluation board (as shipped) was not optimized for high duty cycle operation, closely monitor the board temperatures and increase the output current only as allowed by the board thermal behavior.
- The reduced input voltage will decrease the amount of loop gain the modulator provides in the feedback loop, as a result, expect a more sluggish transient response when operating the board at reduced down-conversion voltage.
- The Evaluation Board (as shipped) has the +12V connected as the input to be down-converted and provides gate drive bias (PVCC). Since PVCC can assume any value between +5 and +12V, the Input can be reduced only to 5V. If a lower input voltage is desired, the PVCC voltage should be provided by a separate supply whose value does not drop below +5V. The VCC bias supply can be used in this case (consult the section entitled "PVCC Power Options" on page 2 for more details on how this can be accomplished).

Summary

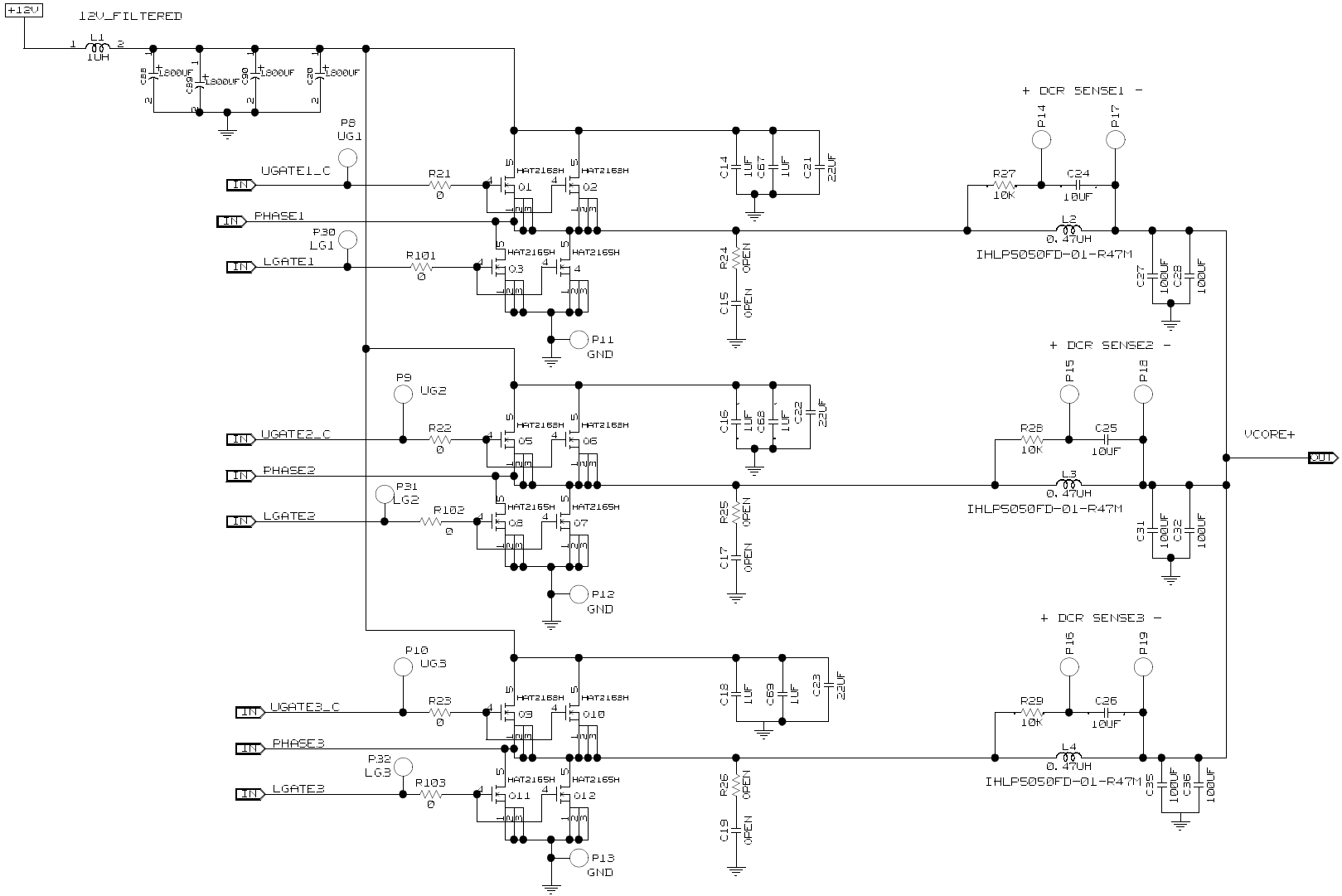
The ISL6308AEVAL1Z evaluation board showcases a highly integrated approach to providing control in a wide variety of applications. The sophisticated feature set and high-current MOSFET drivers of the ISL6308A yield a highly efficient power conversion solution with a reduced number of external components in a compact footprint. The following pages provide a board schematic, bill of materials and layout drawings to support implementation of this solution.

References

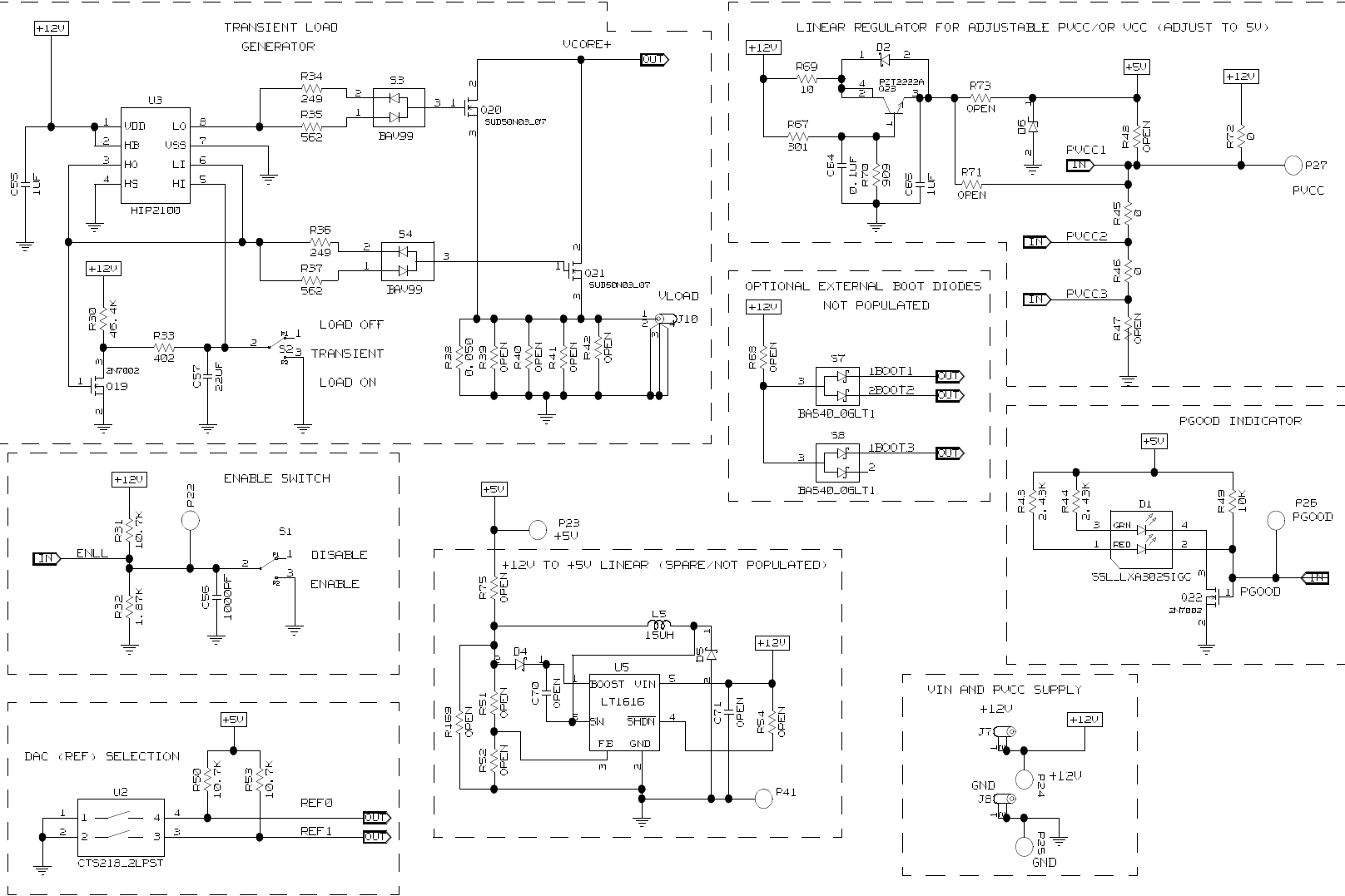
Intersil documents are available on the web at www.intersil.com.

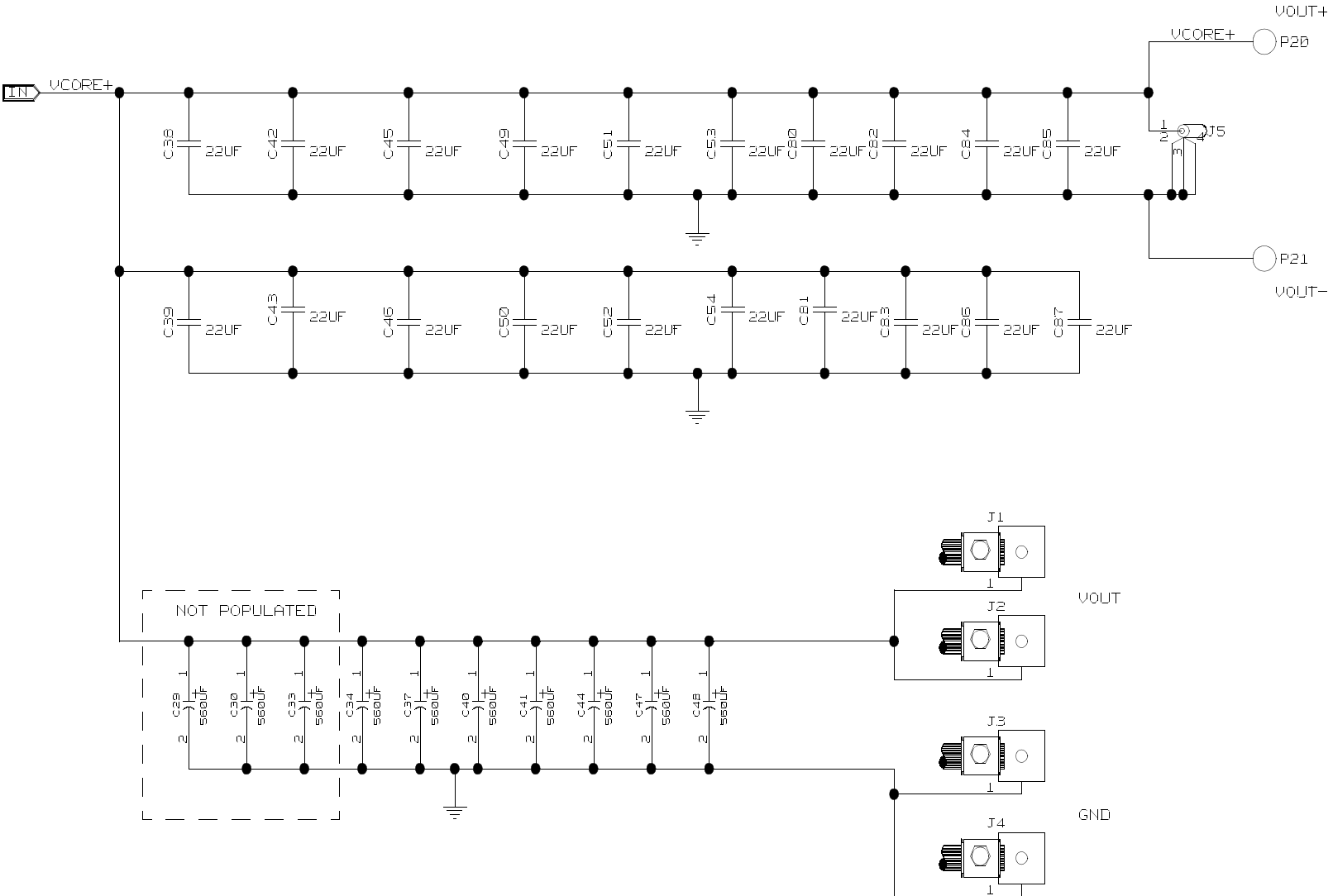
- [1] ISL6308A Data Sheet, Intersil Corporation, File No. FN6669.

ISL6308AEVAL1Z Schematic



ISL6308AEVAL1Z Schematic





ISL6308AEVAL1Z Schematic

Bill of Materials for ISL6308AEVAL1Z

| REFERENCE DESIGNATOR | PART NUMBER | DESCRIPTION | CASE/ FOOTPRINT | MANUF. OR VENDOR | QTY |
|--|-------------------|---|-----------------|------------------------------|-----|
| PCB | ISL6308AEVAL1Z | | | | 1 |
| C1 | 100pF | CAPACITOR, SMD, 0805, 100pF, 50V, 5%, NPO | 0805 | PANASONIC VENKEL | 1 |
| C2 | 33000pF | CAPACITOR, SMD, 0603, 33000pF, 25V, 10%, X7R | 0603 | PANASONIC VENKEL | 1 |
| C3, C15, C17, C19, C70, C71, C91, C92 | DNP | | | | 0 |
| C4 | 0.027μF | CAPACITOR, SMD, 0603, 0.027μF, 50V, 10%, X7R | 0603 | Any | 1 |
| C5 | 0.022μF | CAPACITOR, SMD, 805, 0.022μF, 50V, 10%, X7R | 0805 | PANASONIC VENKEL | 1 |
| C6, C11-C13 | 1.0μF | CAPACITOR, SMD, 0805, 1.0μF, 25V, 10%, X5R | 0805 | AVX VENKEL | 4 |
| C7 | 0.01μF | CAPACITOR, SMD, 0805, 0.01μF, 50V, 10%, X7R | 0805 | KEMET, AVX PANASONIC, VENKEL | 1 |
| C8-C10, C64 | 0.1μF, | CAPACITOR, SMD, 0805, 0.1μF, 50V, 10%, X7R | 0805 | MURATA, KEMET VENKEL | 4 |
| C14, C16, C18, C55, C67, C68, C69. | 1μF | CAPACITOR, SMD, 1206, 1μF, 16V, 10%, X7R | 1206 | PANASONIC VENKEL | 7 |
| C20, C88-C90 | 16MBZ1800M10X23 | CAP, RADIAL, 10x23, 1800μF, 16V, 20%, ALUM.ELEC | 10x23 | RUBYCON PANASONIC | 4 |
| C21-C23 | 22μF | CAPACITOR, SMD, 1210, 22μF, 16V, 20%, X5R | 1210 | TDK MURATA | 2 |
| C24-C26 | 10μF | CAPACITOR, SMD, 1206, 10μF, 10V, 10%, X7R | 1206 | VENKEL Any | 3 |
| C27, C28, C31, C32, C35, C36 | 100μF | CAPACITOR, SMD, 1210, 100μF, 6.3V, 20%, X5R | 1210 | TDK, PANASONIC AVX | 6 |
| C29, C30, C33 (DNP) | 4SEPC560M | Capacitor, TH, 8x13mm, 560μF, 4V, 20%, 7mΩ | 8mmx13mm | SANYO | 0 |
| C34, C37, C40, C41, C44, C47, C48 | 4SEPC560M | Capacitor, TH, 8x13mm, 560μF, 4V, 20%, 7mΩ | 8mmx13mm | SANYO | 7 |
| C38, C39, C42, C43, C45, C46, C49-C54, C80-C87 | 22μF | CAPACITOR, SMD, 1206, 22μF, 6.3V, 20%, X5R | 1206 | Any | 20 |
| C56 | 1000pF | Ceramic Capacitor, X7R, 0603, 50V, 10%, 1000pF | 0603 | MURATA, PANASONIC VENKEL | 1 |
| C57 | C3225X5R1A226M | Ceramic Capacitor, X5R, 10V, 22μF | 1210 | TDK | 1 |
| C58 | 3300pF | CAPACITOR, SMD, 0603, 3300pF, 50V, 10%, X7R | 0603 | VENKEL BC COMPONENTS | 1 |
| C65 | 1μF | CAPACITOR, SMD, 0805, 1μF, 16V, 10%, X7R | 0805 | VENKEL KEMET | 1 |
| D1 | SSL-LXA3025IGC-TR | LED, SMD, 3x2.5mm, 4P, RED/GREEN, 12/20MCD, 2V | | LUMEX | 1 |
| D2 | MBR0540T1G-T | DIODE-RECTIFIER, SMD, SOD-123, 2P, 40V, 0.5A | | ON SEMICONDUCTOR | 1 |
| D3 (DNP) | LT1009CLPE3 | IC-2.5V ADJ. SHUNT REGULATOR, TH, 3P, TO-92 | TO-92 | TI | 0 |

Bill of Materials for ISL6308AEVAL1Z (Continued)

| REFERENCE DESIGNATOR | PART NUMBER | DESCRIPTION | CASE/ FOOTPRINT | MANUF. OR VENDOR | QTY |
|--|-----------------------------|--|-----------------|-----------------------|-----|
| D4, D5 (DNP) | MBR0540T1G-T | DIODE-RECTIFIER, SMD, SOD-123, 2P, 40V, 0.5A | | ON SEMICONDUCTOR | 0 |
| D6 (DNP) | ZMM5231B-7-T | DIODE-ZENER, SMD, MINI-MELF, 2 PIN, 5.1V, 500mW | | | 0 |
| J1-J4 | KPA8CTP | MTG HDWR, CBL.TERMINAL-LUG & SCREW, 6-14AWG | | BERG/FCI | 4 |
| J5, J10 | 131-4353-00 | CONN-GEN, SCOPE PROBE TEST PT | | Tektronix | 2 |
| J7 | 571-0500 | CONN-PLUG, BANA-INSUL-SDRLESS, RED, 4.23mm, RA | | MOUSER | 1 |
| J8 | 571-0100 | CONN-PLUG, BANA-INSUL-SDRLESS, BLK, 4.23mm | | MOUSER | 1 |
| L1 | T50-8/90-8T-16AWG-1 μ H | CORE, RADIAL, TH, 1.0 μ H, T50-8/90, 8TURNS, 16AWG | | Any | 1 |
| L2-L4 | IHLP5050FDERR47M01 | COIL-PWR INDUCTOR, SMD, 13mm, 0.47 μ H, 20%, 55A, SHIELDED | | VISHAY | 3 |
| L5 (DNP) | 1008PS-153KLB | COIL RF INDUC, SMD, 2.74mm, 15 μ H, 10%, 0.6A | | COILCRAFT | 0 |
| P1-P5, P7-P10, P14-P20, P22, P26, P28-P32, P42 | 5002 | CONN-GEN, MINI TEST POINT, VERTICAL, WHITE | | MOUSER | 24 |
| P6, P11-P13, P21, P23-P25, P27, P41 | 1514-2 | CONN-GEN, TERMINAL POST, TH, 0.09 | | KEYSTONE | 10 |
| P40 (DNP) | 1514-2 | CONN-GEN, TERMINAL POST, TH, 0.09 | | KEYSTONE | 0 |
| Q1, Q2, Q5, Q6, Q9, Q10 | HAT2168H | MOSFET, 30V, 8.8m Ω | LFAK | Renesas | 6 |
| Q3, Q4, Q7, Q8, Q11, Q12 | HAT2165H | MOSFET, 30V, 3.4m Ω | LFAK | Renesas | 6 |
| Q19, Q22 | 2N7002-7-F-T | TRANSISTOR, N-CHANNEL, 3LD, SOT-23, 60V, 115mA | | Any | 2 |
| Q20, Q21 | SUD50N03-07-E3 | TRANSIST-MOS, N-CHANNEL, SMD, TO-252, 30V, 20A | DPAK | VISHAY | 2 |
| Q23 | CZT3019LEADFREE | TRANSISTOR, NPN, 4P, SOT-223, 120V, 1A | | Central Semiconductor | 1 |
| R1 | 1.13k Ω | Resistor, 1.13k Ω , 1/16W, 1% | 0603 | Any | 1 |
| R3 | 1k Ω | Resistor, 1k Ω , 1/16W, 1% | 0603 | Any | 1 |
| R4 | 51.1 Ω | Resistor, 51.1 Ω , 1/16W, 1% | 0603 | Any | 1 |
| R5, R7, R9, R12, R24-R26, R39-R42, R47, R48, R51, R52, R54-R57, R64-R66, R68, R71, R73, R75, R81R83-R85, R92, R169 | DNP | | | | 0 |
| R6 | 20 Ω | Resistor, 20 Ω , 1/16W, 5% | 0603 | Any | 1 |
| R8, R21-R23, R101-R103 | 0 Ω | Resistor, 0 Ω , 1/10W, 5% | 0805 | Any | 7 |

Bill of Materials for ISL6308AEVAL1Z (Continued)

| REFERENCE DESIGNATOR | PART NUMBER | DESCRIPTION | CASE/ FOOTPRINT | MANUF. OR VENDOR | QTY |
|---|----------------------------|--|-----------------|------------------|-----|
| R10, R45, R46, R62, R63, R74, R86, R90, R91, R93, R104-R106 | 0Ω | Shorting resistor | 0603 | Any | 13 |
| R11, R32 | 1.87kΩ | Resistor, 1.87kΩ, 1/16W, 1% | 0603 | Any | 2 |
| R13 | 75kΩ | Resistor, 75kΩ, 1/16W, 1% | 0603 | Any | 1 |
| R14 | 47kΩ | Resistor, 47kΩ, 1/16W, 1% | 0603 | Any | 1 |
| R15-R17 | 36kΩ | Resistor, 36kΩ, 1/16W, 1% | 0603 | Any | 3 |
| R18-R20 | 806Ω | Resistor, 806Ω, 1/16W, 1% | 0603 | Any | 3 |
| R27-R29, R49 | 10kΩ | Resistor, 10kΩ, 1/16W, 1% | 0603 | Any | 4 |
| R30 | 46.4kΩ | Resistor, 46.6kΩ, 1/16W, 1% | 0603 | Any | 1 |
| R31, R50, R53 | 10.7kΩ | Resistor, 10.7kΩ, 1/16W, 1% | 0603 | Any | 3 |
| R33 | 402Ω | Resistor, 402Ω, 1/16W, 1% | 0603 | Any | 1 |
| R34, R36 | 249Ω | Resistor, 249Ω, 1/16W, 1% | 0603 | Any | 2 |
| R35, R37 | 562Ω | Resistor, 562Ω, 1/16W, 1% | 0603 | Any | 2 |
| R38 | 0.05Ω | Resistor, 0.05Ω, 1W, 5% | 2512 | Any | 1 |
| R43, R44 | 2.43kΩ | Resistor, 2.43kΩ, 1/16W, 1% | 0603 | Any | 1 |
| R67 | 301Ω | Resistor, 301Ω, 1/10W, 1% | 0805 | Any | 1 |
| R69 | 10Ω | Resistor, 10Ω, 1/10W, 1% | 0805 | Any | 1 |
| R70 | 909Ω | Resistor, 909Ω, 1/10W, 1% | 0603 | Any | 1 |
| R72 | 0Ω | Resistor, 0Ω, 1W, 5% | 2512 | Any | 1 |
| R82 | 2.4kΩ | Resistor, SMD, 0, 1/16W,5% | 0603 | Any | 1 |
| R94- R96 | 10Ω | Resistor, 10Ω, 1/16W, 5% | 0603 | Any | 3 |
| R100 | 4.99kΩ | Resistor, 4.99kΩ, 1/16W, 1% | 0603 | Any | 1 |
| S1, S2 | GT11MSCBE-T | SWITCH-TOGGLE, SMD, ULTRAMINI, 1P, SPST MINI | | C&K | 2 |
| S3, S4 | BAV99LT1G-T | DIODE-SWITCHING, SMD, SOT23, 70V, 0.2A | | ZETEX INC | 2 |
| S7, S8 | BAS40-06LT1G-T | DIODE-SCHOTTKY BARRIER, SMD, SOT-23, 3P, 40V | | ON SEMICONDUCTOR | 1 |
| U1 | ISL6308AIRZ or ISL6308ACRZ | IC-3 PHASE PWM CONTROLLER, 40P, QFN, 6X6, PbFREE | | Intersil | 1 |
| U2 | 218-2LPST | SWITCH, SMD, 2P, SLIDE, 150M HALF-PITCHGOLD | | CTS | 1 |
| U3 | HIP2100IBZ | IC-HI FREQ BRIDGE DRIVER, 8P, SOIC, 100V | | Intersil | 1 |
| U5 (DNP) | LT1616ES6#TRMPBF | IC-SWITCHING REGULATOR, 6P, SOT23, 0.6A | SOT23 | Linear Tech | 0 |

NOTES:

1. DNP means do not populate
2. PCB board and all parts are RoHS (Pb-free)

ISL6308AEVAL1Z Layout

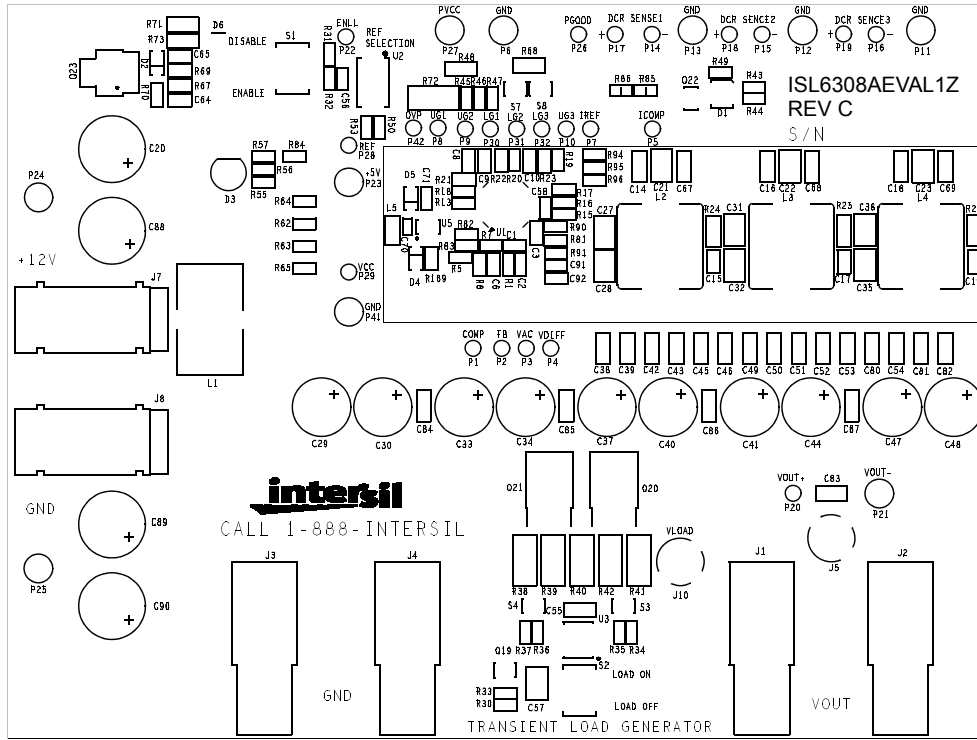


FIGURE 17. TOP SILK SCREEN

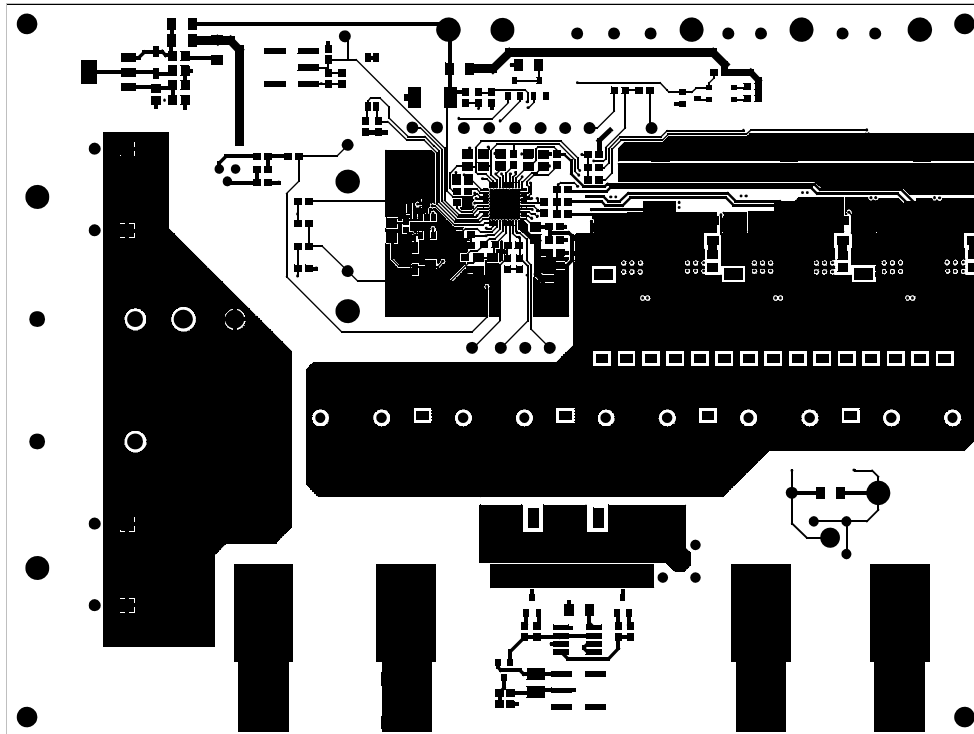


FIGURE 18. TOP LAYER (1st)

ISL6308AEVAL1Z Layout (Continued)

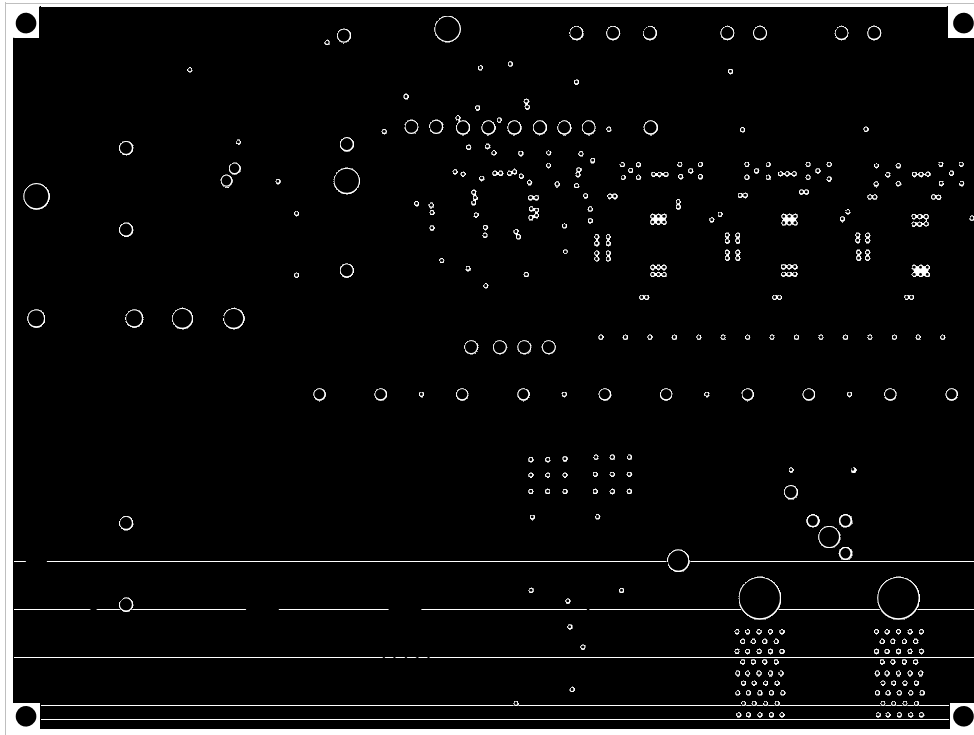


FIGURE 19. GROUND LAYER (2ND)

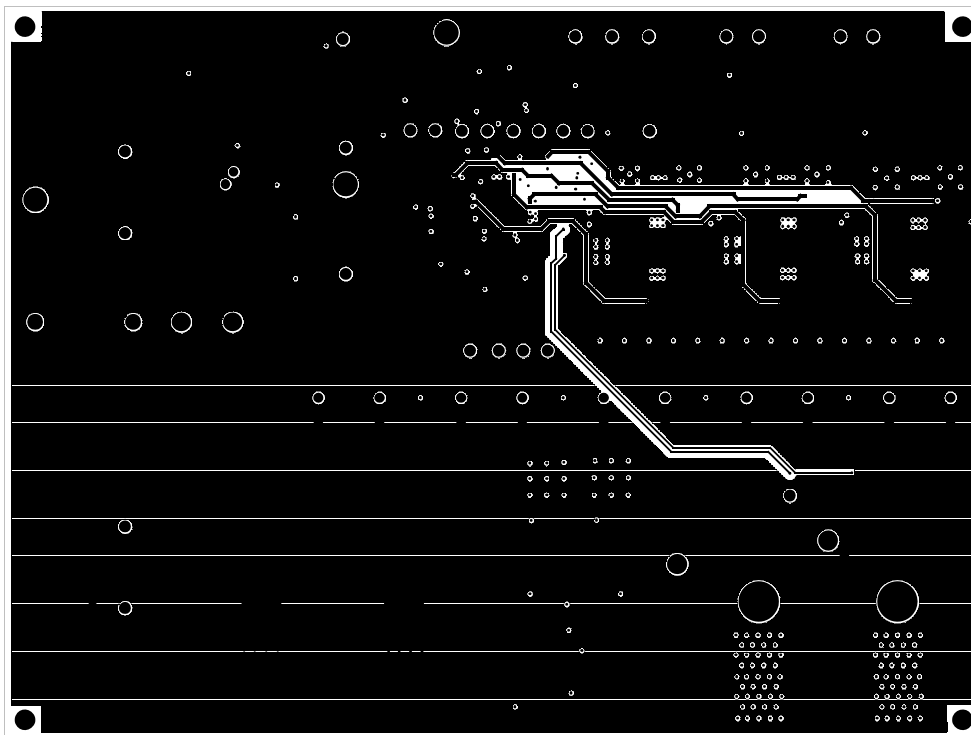


FIGURE 20. GND/SIGNAL LAYER (3RD)

ISL6308AEVAL1Z Layout (Continued)

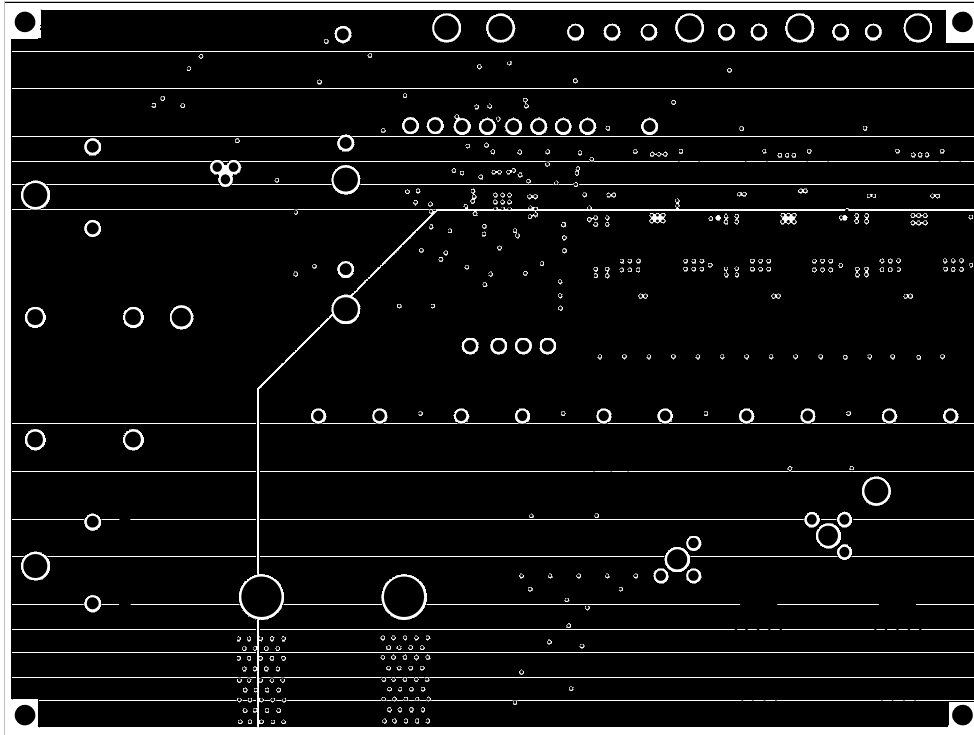


FIGURE 21. POWER LAYER (4TH)

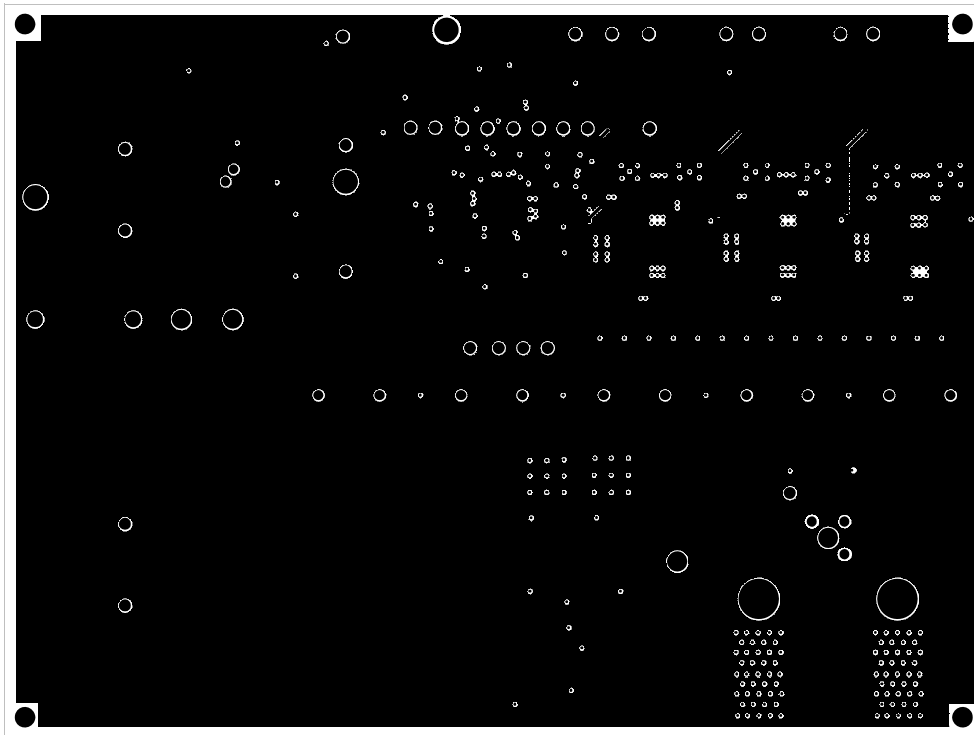


FIGURE 22. GND LAYER (5TH)

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