# AN-2093 LMZ23610/8/6 and LMZ22010/8/6 Current Sharing Evaluation Board

## 1 Introduction

The LMZ23610/8/6 and LMZ22010/8/6 SIMPLE SWITCHER® power modules are easy-to-use DC-DC solution capable of driving up to a 10, 8 or 6 ampere load. They are available in an innovative package that enhances thermal performance and allows for hand or machine soldering. The LMZ23610/8/6 can accept an input voltage rail between 6V and 36V and the LMZ22010/8/6 can accept an input voltage rail between 6V and 20V.

The current sharing evaluation board is designed so that four modules can be easily connected to supply up to a 40 amp load. More can be connected as long as care is taken to not exceed the current capabilities of the banana plug connectors and the 5-amp per pin rating of the edge board connector.

The current sharing evaluation board is highly configurable. The output voltage can be changed to 5V, 3.3V, 2.5V or 1.2V with a jumper change. The external soft-start capacitor facilitates a controlled and adjustable startup rise time of the output. The board temperature can be measured with the onboard resistor. The UVLO can be adjusted by adding one resistor. To simplify the synchronization of the modules an onboard 555 timer provides an adjustable frequency clock from 350 to 600 kHz.

The LMZ23610 and LMZ22010 family is a reliable and robust solution with the following features: loss-less cycle-by-cycle valley current limit to protect for over current or short-circuit fault, thermal shutdown, input under-voltage lockout, and will start up into a pre-biased output.

## 2 Board Specifications

- $V_{IN}$ = 6V to 36V (LMZ23610/8/6)
- $V_{IN}$ = 6V to 20V (LMZ22010/8/6)
- $V_{OUT}$ = 1.2V, 2.5V, 3.3V or 5V (minimum input voltage of 7V required for 5V output)
- $I_{OUT}$ = 0 to 10, 8, or 6 Amps
- $\theta_{JA}$ = 8.8 °C / W, $\theta_{JC}$ = 1.0 °C/W
- Designed on four layers; Inner are 2 oz copper; Outer are 2 oz copper.
- Measures 3.54" x 3.54" (90 mm x 90 mm) and is 62 mils (1.57 mm) thick of FR4 laminate material

For additional circuit considerations, including additional output voltage options, refer to the *Applications* section of the *LMZ23610 10A SIMPLE SWITCHER® Power Module with 36V Maximum Input Voltage and Current Sharing* (SNVS707) or *LMZ22010 10A SIMPLE SWITCHER® Power Module with 20V Maximum Input Voltage and Current Sharing* (SNVS687) data sheets. For negative output voltage connections see *AN-2027 Inverting Application for the LMZ14203 SIMPLE SWITCHER® Power Module* (SNVA425).

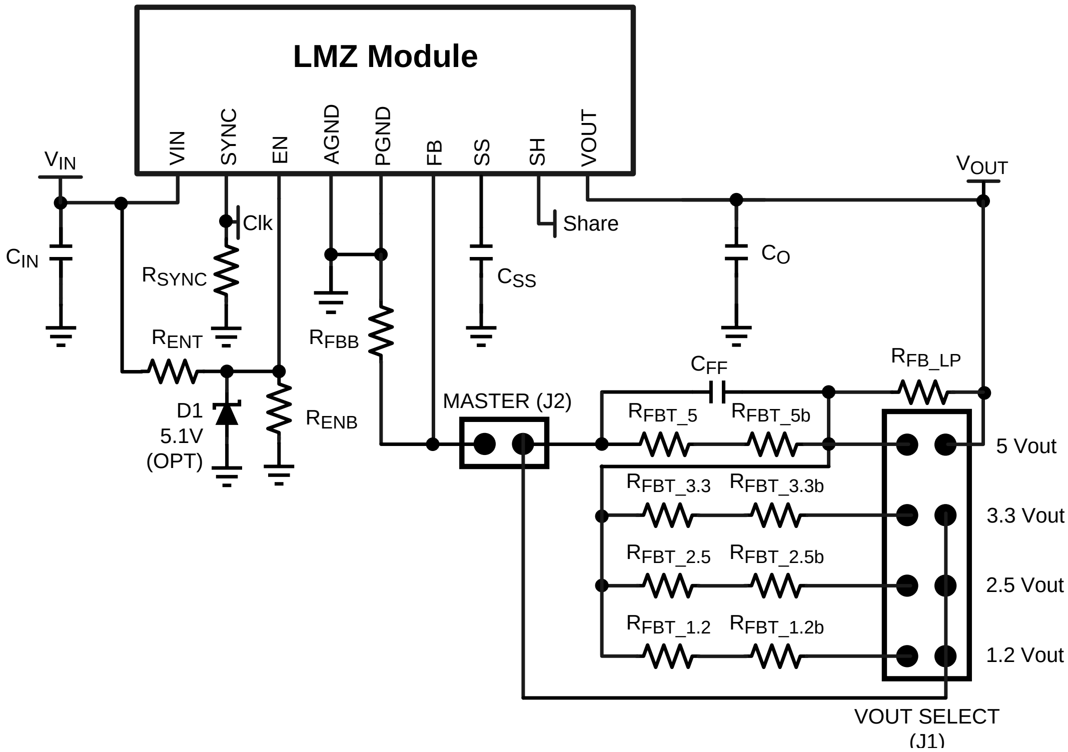



**Figure 1. Simplified Schematic**

## 3 Test Connections

The board should be connected to a power supply and load as shown below in Figure 2. The EN post is connected to the UVLO circuit on the back of the board. There is a resistive divider implemented on the board, with the bottom resistor unpopulated, that can be used to establish a precision UVLO level of the board. A common user change to this circuit is to adjust the value of RENT and RENB to adjust the operating UVLO to that of the target application. Refer to the respective data sheet for calculation. Note that if in the end application the EN pin voltage does not exceed 5.5V at maximum Vin, then the enable clamp zener D1 can be omitted. Pull EN low to shutdown the module and clock circuitry.

The SYNC post is connected to the output of a 555 timer on the back of the board and is fed to the SYNC pin of the device. This clock is provided to simplify the testing of the current sharing features of the device and is not required for stand alone operation. The frequency of the clock can be adjusted from 350kHz to 600kHz using the potentiometer labeled R_freq_adj. Jumper J3 (SLAVE) can be used to disable the 555 timer and allow the use of external clocks from 314 to 600 kHz.

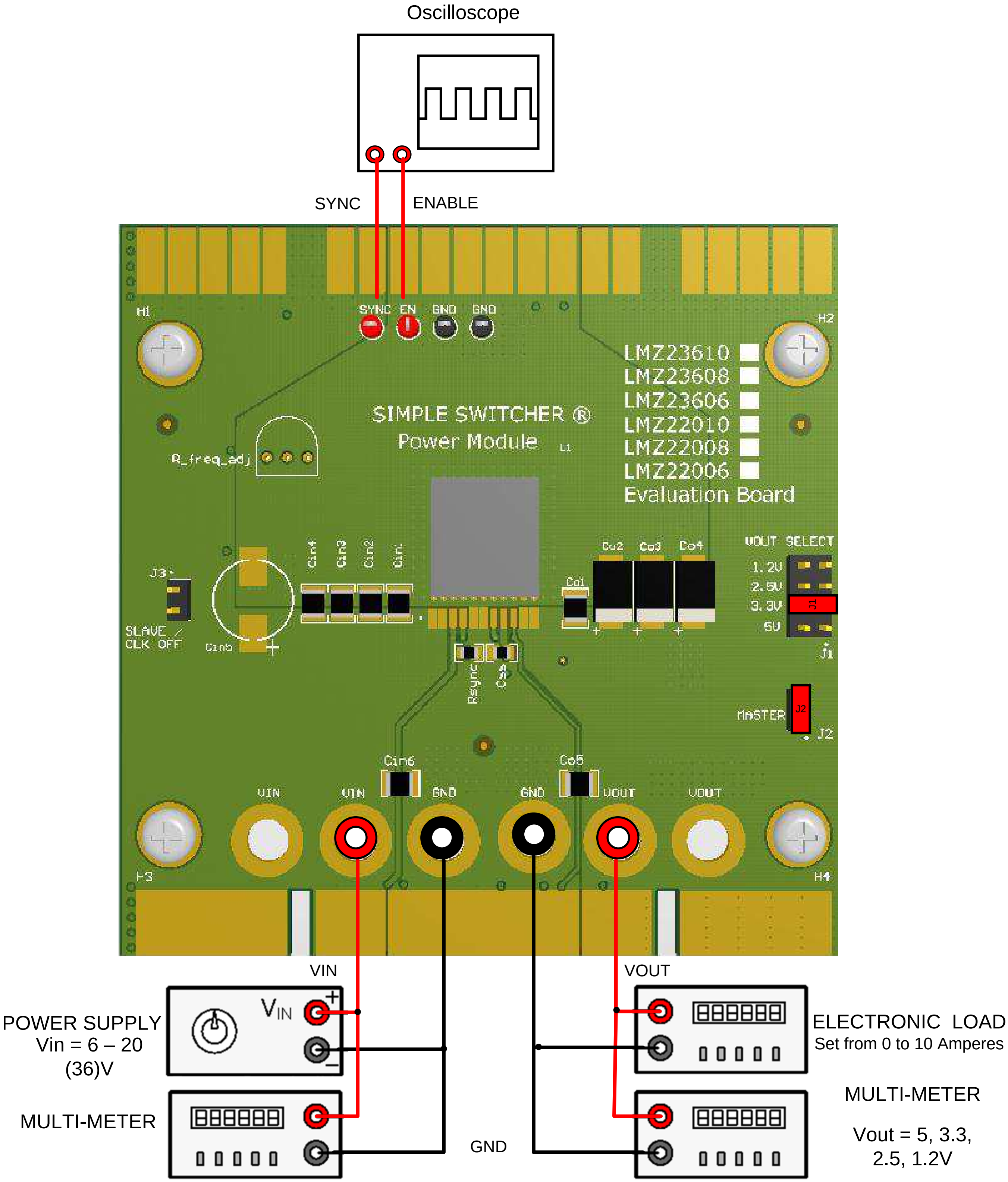



**Figure 2. Board Connection Diagram**

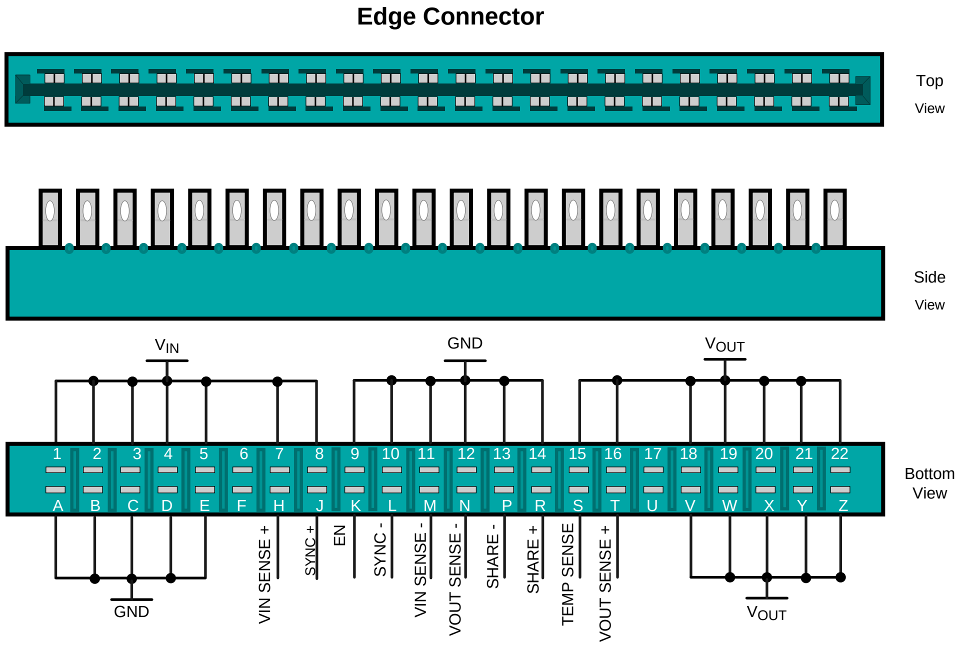



**Figure 3. Edge Connector Diagram**

The evaluation board is also compatible with the 44-pin edge connector shown in Figure 3. Table 1 explains the functionality of the pins.

**Table 1. Functionality of the Pins**

| Pin | Name | Description |
|---|---|---|
| 1, 2, 3, 4, 5, 7, 8 | VIN | Input supply — Nominal operating range is from 6V to 20V for the LMZLMZ22010/8/6 and from 6V to 36V for the LMZLMZ23610/8/6. |
| 9, 10, 11, 12, 13, 14, A, B, C, D, E | GND | Power Ground — Electrical path for the power circuits within the module. |
| 15, 16, 18, 19, 20, 21, 22, V, W, X, Y, Z | VOUT | Output Voltage — Regulated 5, 3.3, 2.5 or 1.2V. |
| H | VIN SENSE + | Positive Kelvin Sense of Input voltage — Tied to VIN pin of the LMZ module. |
| M | VIN SENSE - | Negative Kelvin Sense of Input voltage — Tied to PGND (EP) of the LMZ module. |
| T | VOUT SENSE + | Positive Kelvin Sense of Output voltage — Tied to Vout banana jack. |
| N | VOUT SENSE - | Negative Kelvin Sense of Output voltage — Tied to AGND of the LMZ module. |
| J | SYNC + | Synchronization Positive Input — This is the positive probe point for viewing the clock generated by the 555 timer and is connected to the SYNC pin of the LMZ module. If the 555 timer is shutdown using J3 then an external clock can be used. The external clock must provide a CMOS logic level square wave whose frequency is between 314 kHz and 600 kHz. |
| L | SYNC - | Synchronization Negative Input — Tied to AGND of the LMZ module. |
| R | SHARE + | Share Positive Input — Connect this pin to the share pin of other LMZ modules to share the load between the devices. |
| P | SHARE - | Share Negative Input — Tied to AGND of the LMZ module. |
| K | EN | Enable — Input to the precision enable comparator of the LMZ Module. Also tied to a pull-up resistor to enable the 5v bias supply and the 555 timer. |
| S | TEMP SENSE | Connected to top of the Rts temperature sensing resistor. Temperature measurements can be made by measuring the temperature dependant resistance between TEMP SENSE and VIN SENSE -. Convert the resistance to temperature with the following equation: Temperature (C) ≅ 2.6245 x Resistance (Ω) - 262.7 |

## 4 Adjusting the Output Voltage

The output voltage of the evaluation board is adjusted to either 5V, 3.3V, 2.5V, or 1.2V by moving jumper J1. For other voltage options see the data sheet for adjusting the feedback resistors.

## 5 Current Sharing

Current sharing is easy to evaluate. The next steps should be implemented only while the power to the device is off.

Select which board will be the master. This is usually the board closer to the load. Connect the master board as described above in Test Connections. Insert the slave board into the socket on the master. If there is no socket, connect a 44-pin board-edge extender to the top of the master board and solder the pins. The board-edge connector will connect Vin, Gnd, Vout, Enable, Sync and the Share pin between the boards to split the current demand between multiple boards.

On the slave board(s) remove the jumper J1 (MASTER) and move it to jumper J2 (SLAVE). This disconnects the FB pin of the slave converter(s) (J1) and disables the clock that is provided on the slave board (J2). The slave module's switching frequency will now be controlled by the clock on the master board. Turning the R_freq_adj pot counter clockwise lowers the clock frequency and turning the pot clockwise increases the frequency. By placing an additional jumper on J3 (SLAVE) of the master board, the 555 timer is disabled on both boards. With the clock disabled you can observe the parts performance when the devices are not synchronized, or you can supply an external clock through the SYNC post. J3 must be in place (555 disabled) on all boards to use an external clock on sync. The Sync pin of the slave can also be disconnected from the master board by removing the RSHORT resistor. This allows the user to provide a multiphase clock of their choosing to the boards.

The advantage to running the clocks out of phase is to reduce the current stress on the input and output capacitors. For two modules the clocks should be run 180 degrees out of phase, for three modules the clocks should be run 120 degrees out of phase an so on. Although local input bypass capacitors are still required, the bulk capacitance required for a given ripple voltage can be greatly reduced.

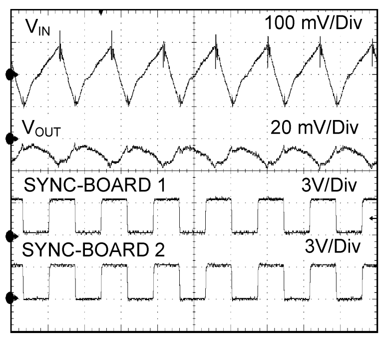



**Figure 4. Output Voltage Ripple with Two Boards Synchronized to 350Khz**

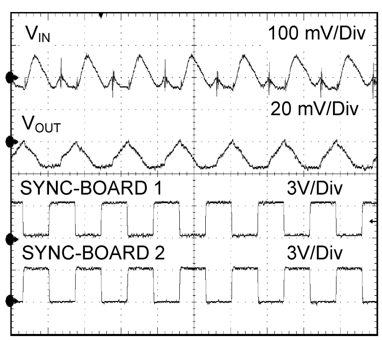



**Figure 5. Output Voltage Ripple with Two Boards Synchronized with 180° Phase Shift**

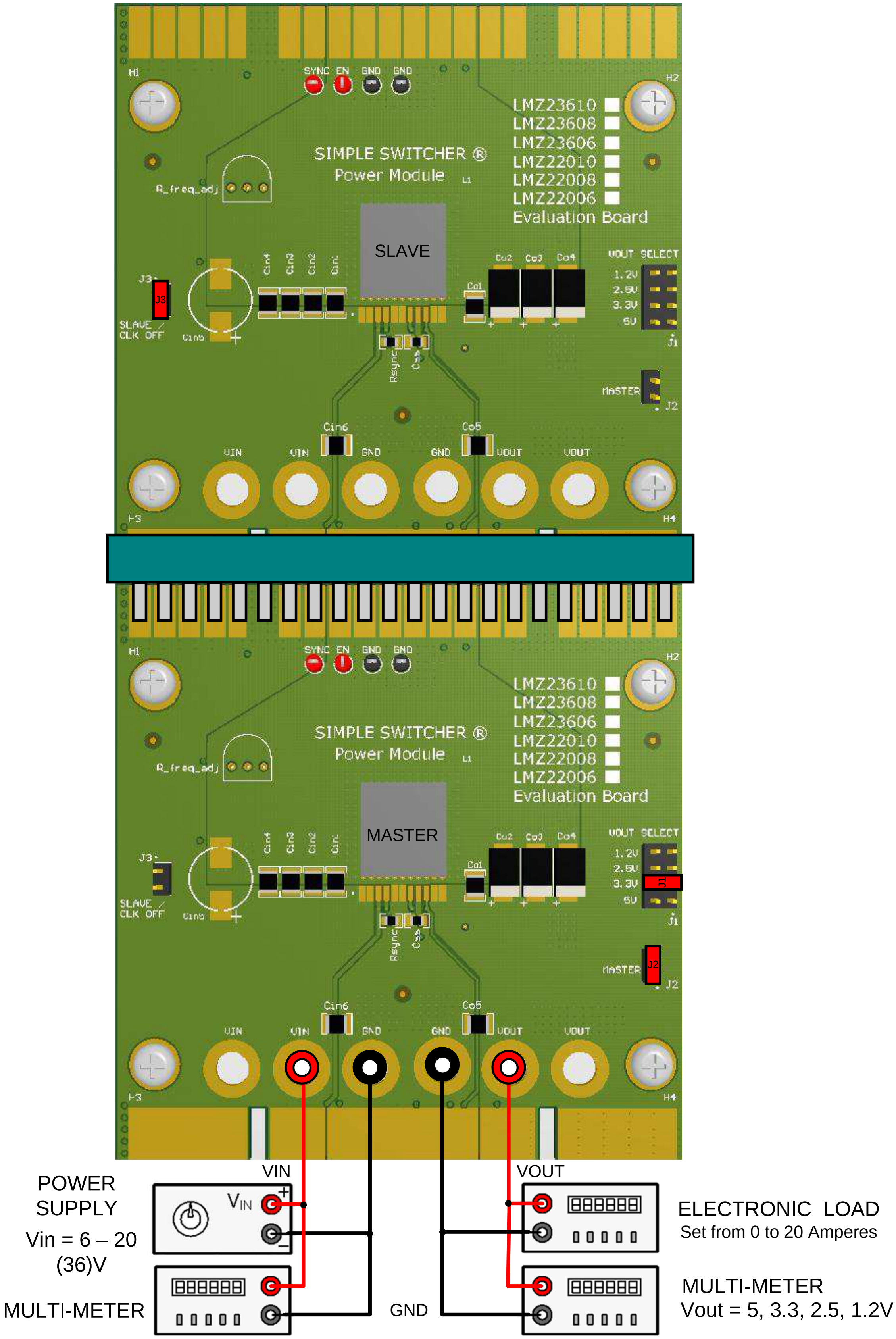



**Figure 6. Master Slave Connection**

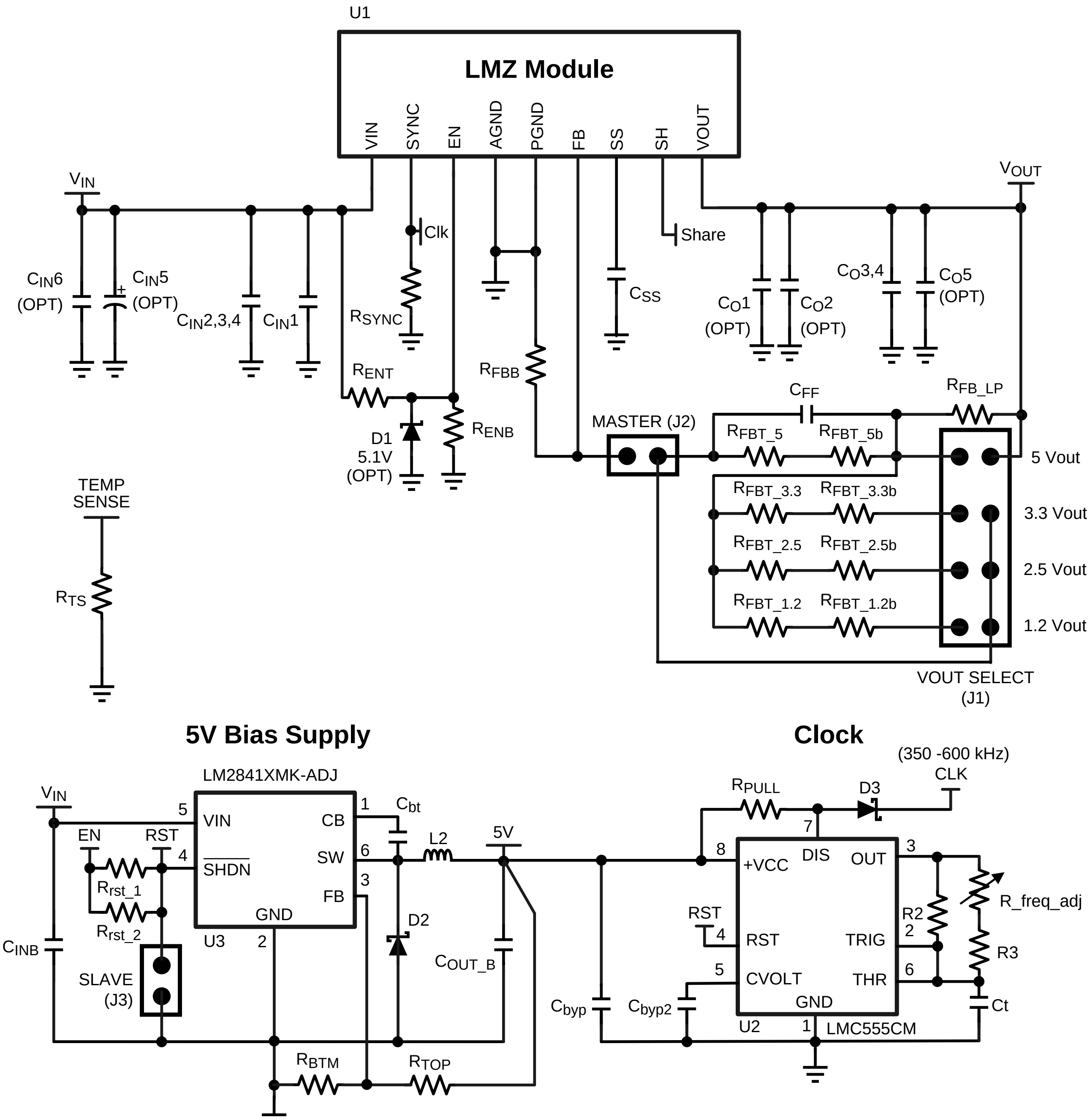



**Figure 7. Evaluation Board Schematic**

## 6 Bill of Materials

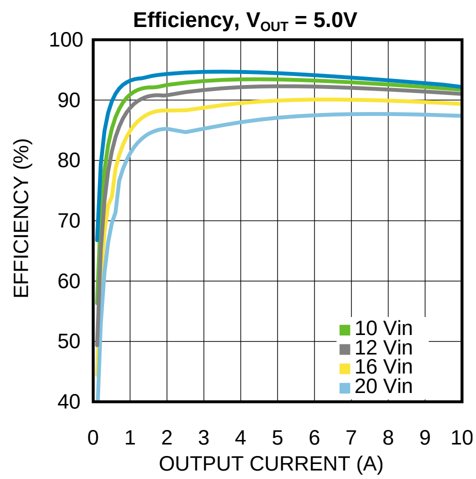
**Table 2. Current Sharing Evaluation Board Bill of Materials, $V_{IN}$ = 6V to 36V (20V), $V_{OUT}$ = 1.2 / 3.3V / 5V, $I_{OUT\ (MAX)}$ = 10/08/06A**

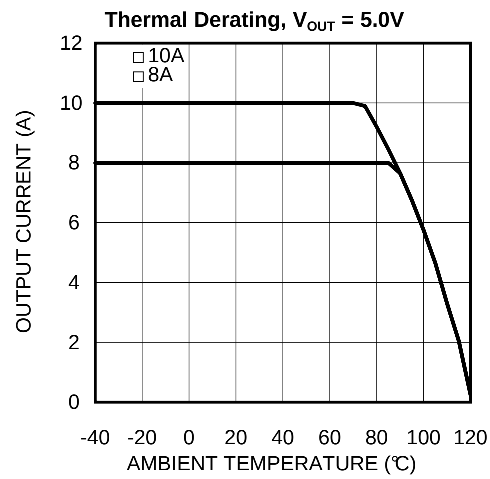
| Designator | Description | Case Size | Manufacturer | Manufacturer P/N | Quantity |
|---|---|---|---|---|---|
| U1 | SIMPLE SWITCHER® | TO-PMOD-11 | Texas Instruments | LMZ23610/08/06 or LMZ22010/08/06 | 1 |
| U2 | Timer, 8-pin Narrow SOIC, Pb-Free | TSSOP-8 | Texas Instruments | LMC555CM/NOPB | 1 |
| U3 | 300 mA/600 mA up to 42V Input Step-Down DC/DC Regulator | SOT23 | Texas Instruments | LM2841XMK-ADJL/NOPB | 1 |
| Cin1<br>Cin6<br>Co1<br>Co5 | 0.047uF, X7R, 50V | 0805 | Kemet | C0805C473K5RACTU | 4 |
| Cin_b<br>Cin2<br>Cin3<br>Cin4 | 10 µF, X7S, 50V | 1210 | TDK | C3225X7S1H106M | 4 |
| Cin5 | 150 µF, Aluminum Electrolytic, 50V | G | Panasonic | EEE-FK1H151P | 1 |
| Co2<br>Cout_b | 47uF, X5R, 10V | 1210 | Murata | GRM32ER61A476KE20L | 2 |
| Co3<br>Co4 | 330µF, 6.3V, 0.015 ohm, | 2917 | Kemet | T520D337M006ATE015 | 2 |
| Cff | 4700 pF, X7R, 50V | 0805 | Kemet | C0805C472K5RACTU | 1 |
| Css<br>Cbt | 0.15uF, X7R, 10V | 0603 | Murata | GRM188R71A154KA01D | 2 |
| Cbyp, Cbyp2 | 0.1uF, X7R, 50V | 0805 | TDK | C2012X7R1H104K | 2 |
| Ct | 470pF, C0G/NP0, 50V | 0805 | AVX | 08055A471FAT2A | 1 |
| D1 | 4.7V, 500mW | SOD-123 | Vishay | MMSZ4688-V-GS08 | 1 |
| D2 | Diode, Schottky, 40V, 1A | SMA | Diodes Inc. | B140-13-F | 1 |
| D3 | Diode, Schottky, 20V, 1A | SOD_123FL | ON Semiconductor | MBR120LSFT1G | 1 |
| Rent<br>Rrst2<br>Rsync | 1.0k ohm, 5%, 0.125W | 0805 | Vishay-Dale | CRCW08051K00JNEA | 1 |
| Renb | Not Populated | 0805 | | | 0 |
| Rtop | 5.62k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08055K62FKEA | 1 |
| Rbtm | 1.02k ohm, 1%, 0.125W, | 0805 | Vishay-Dale | CRCW08051K02FKEA | 1 |
| Rfbb | 1.07k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08051K07FKEA | 1 |
| Rfbt_1.2 | 576 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW0805576RFKEA | 1 |
| Rfbt_1.2b | 9.53 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08059R53FKEA | 1 |
| Rfbt_2.5 | 3.74k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08053K74FKEA | 1 |
| Rfbt_2.5b | 84.5 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW080584R5FKEA | 1 |
| Rfbt_3.3 | 8.06k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08058K06FKEA | 1 |
| Rfbt_3.3b | 169 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW0805169RFKEA | 1 |
| Rfbt_5 | 5.6k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08055K60FKEA | 1 |
| Rfbt_5b | 73.2 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW080573R2FKEA | 1 |
| RFB_LP | 20 Ω | 0805 | Vishay-Dale | CRCW080520R0FKEA | 1 |

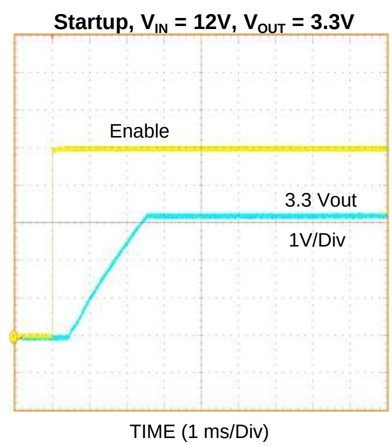
**Table 2. Current Sharing Evaluation Board Bill of Materials, $V_{IN}$ = 6V to 36V (20V), $V_{OUT}$ = 1.2 / 3.3V / 5V, $I_{OUT\ (MAX)}$ = 10/08/06A (continued)**

| Designator | Description | Case Size | Manufacturer | Manufacturer P/N | Quantity |
|---|---|---|---|---|---|
| Rpull | 200 ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW0805200RFKEA | 1 |
| Rshrt | 0 ohm, 5%, 0.125W | 0805 | Vishay-Dale | CRCW08050000Z0EA | 1 |
| Rts | 100 ohm,Temp Sense Resistor | 0805 | Vishay | PTS08051B100RP 100 | 1 |
| R_freq_adj | ADJ, 100K ohm, 0.5W | Round - 0.350" Dia x 0.150" H | Bourn | 3352T-1-104LF | 1 |
| R2<br>R3 | 3.48k ohm, 1%, 0.125W | 0805 | Vishay-Dale | CRCW08053K48FKEA | 2 |
| L2 | Inductor, Shielded Drum Core, Ferrite, 22uH, 0.7A, 0.155 ohm | SMD | Wurth Elektronik | 744043220 | 1 |
| SYNC<br>EN | Test Point, TH, Miniature, Red | | Keystone Electronics | 5000 | 2 |
| GND<br>GND | Test Point, TH, Miniature, Black | | Keystone Electronics | 5001 | 2 |
| GND<br>GND<br>VIN<br>VOUT | Banana Jack Connector | | Keystone Electronics | 575-8 | 6 |
| J1 | Header, 4x2, Gold plated, 230 mil above insulator | TH, 100mil | Samtec Inc. | TSW-104-07-G-D | 1 |
| J2<br>J3 | Header, 2x1, Gold plated, 230 mil above insulator | TH, 100mil | Samtec Inc. | TSW-102-07-G-S | 2 |
| SH-1<br>SH-2<br>SH-3 | Shunt, 100mil, Gold plated, Black | | Amp | 382811-6 | 3 |
| H1<br>H2<br>H3<br>H4 | Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead | | B and FFastener Supply | NY PMS 440 0025 PH | 4 |
| H5<br>H6<br>H7<br>H8 | Standoff, Hex, 0.5"L #4-40 Nylon | | Keystone | 1902C | 4 |
| J4 | 44-Pin Edge Connector | | EDAC | 305-044-555-201 | 1 |
| Rrst1 | Not Populated | | | | 0 |

# 7 Performance Characteristics



# 8 PCB Layout Diagrams

Gerber and CAD files can be downloaded from the associated product folder.

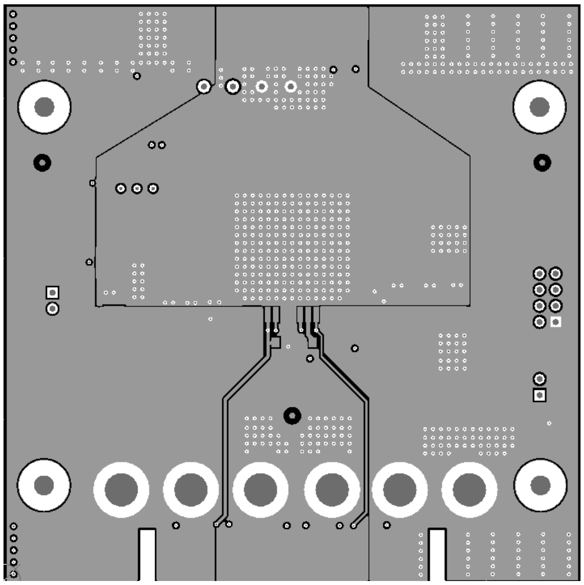


**Figure 8. Top Layer**

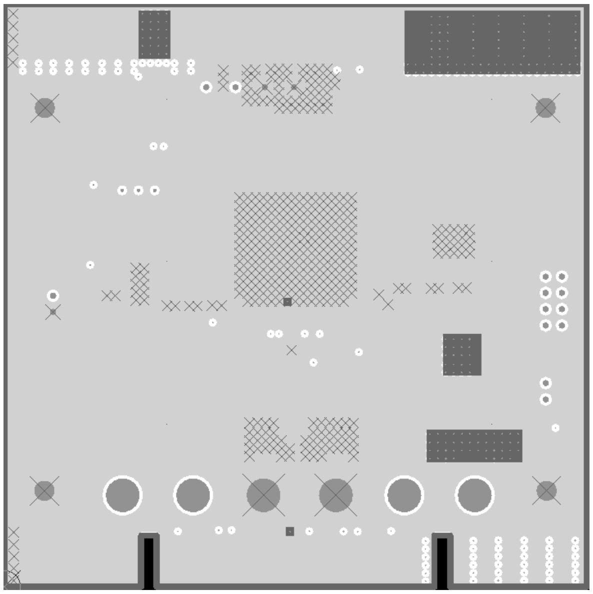


**Figure 9. Internal Layer I (Ground) Heat Sinking Layer**

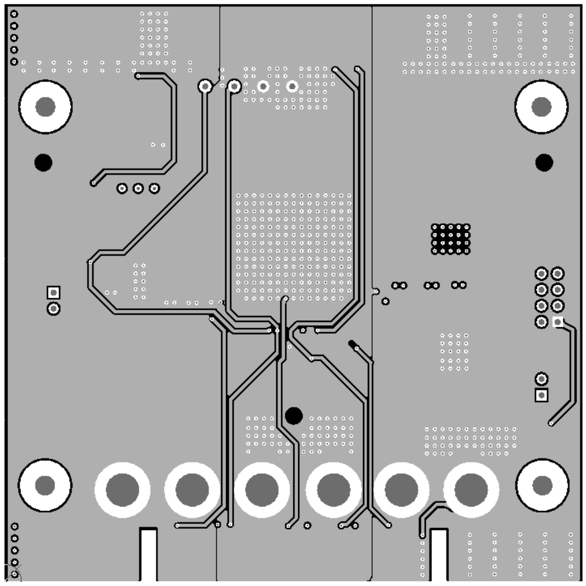


**Figure 10. Internal Layer II (Routing) Heat Sinking Layer**

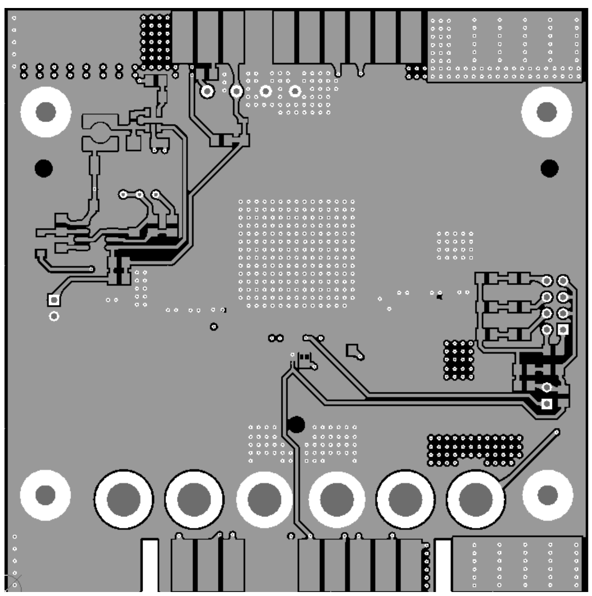


**Figure 11. Bottom Layer (Ground and Routing) Heat Sinking Layer**

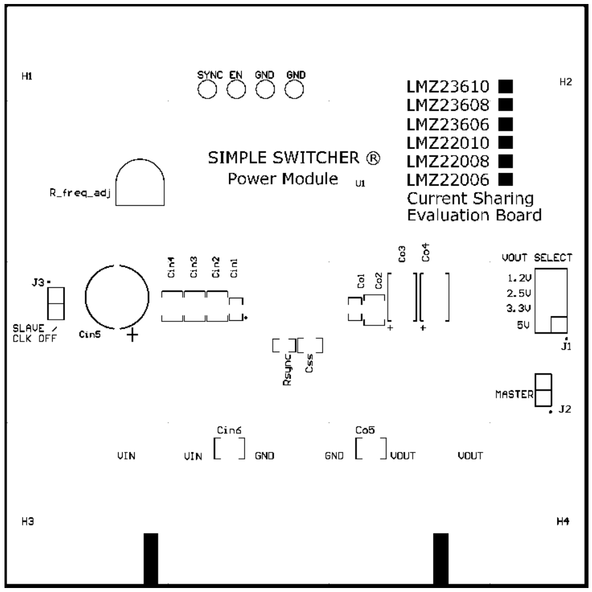



**Figure 12. Top Silkscreen**

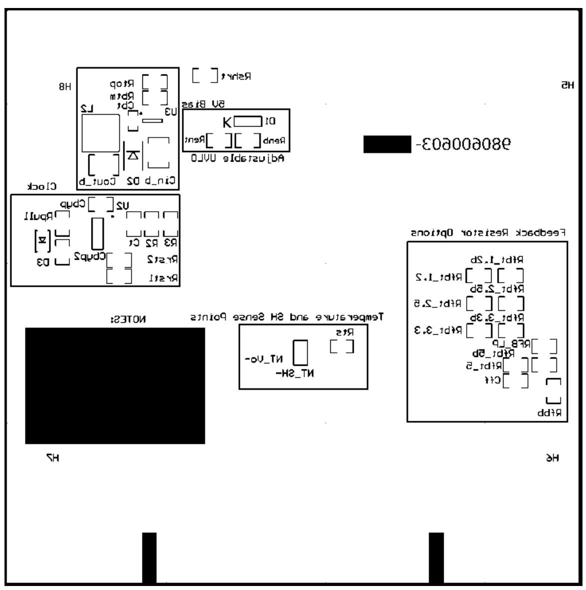


**Figure 13. Bottom Silkscreen**