LMZ23610/8/6 and LMZ22010/8/6 Current Sharing Evaluation Board

National Semiconductor
Application Note 2093
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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.

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
- θ_{JA} = 8.8 °C / W, θ_{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 section of the LMZ23610/8/6 or LMZ22010/8/6 data sheets. For negative output voltage connections see AN-2027.

Simplified Schematic

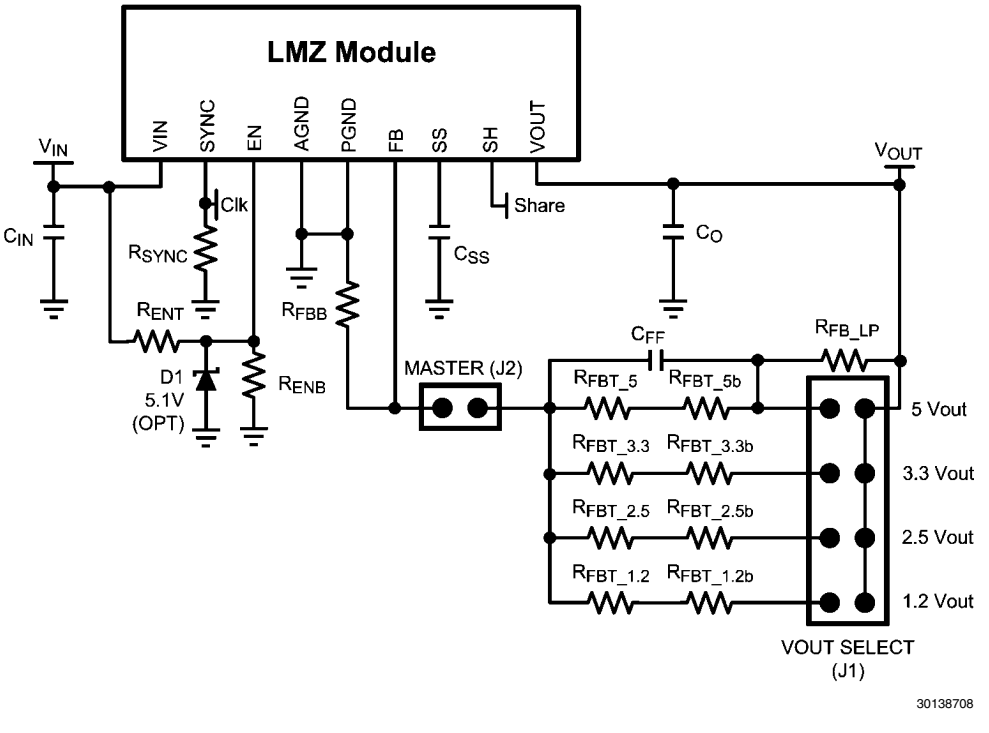


FIGURE 1.

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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.

Board Connection Diagram

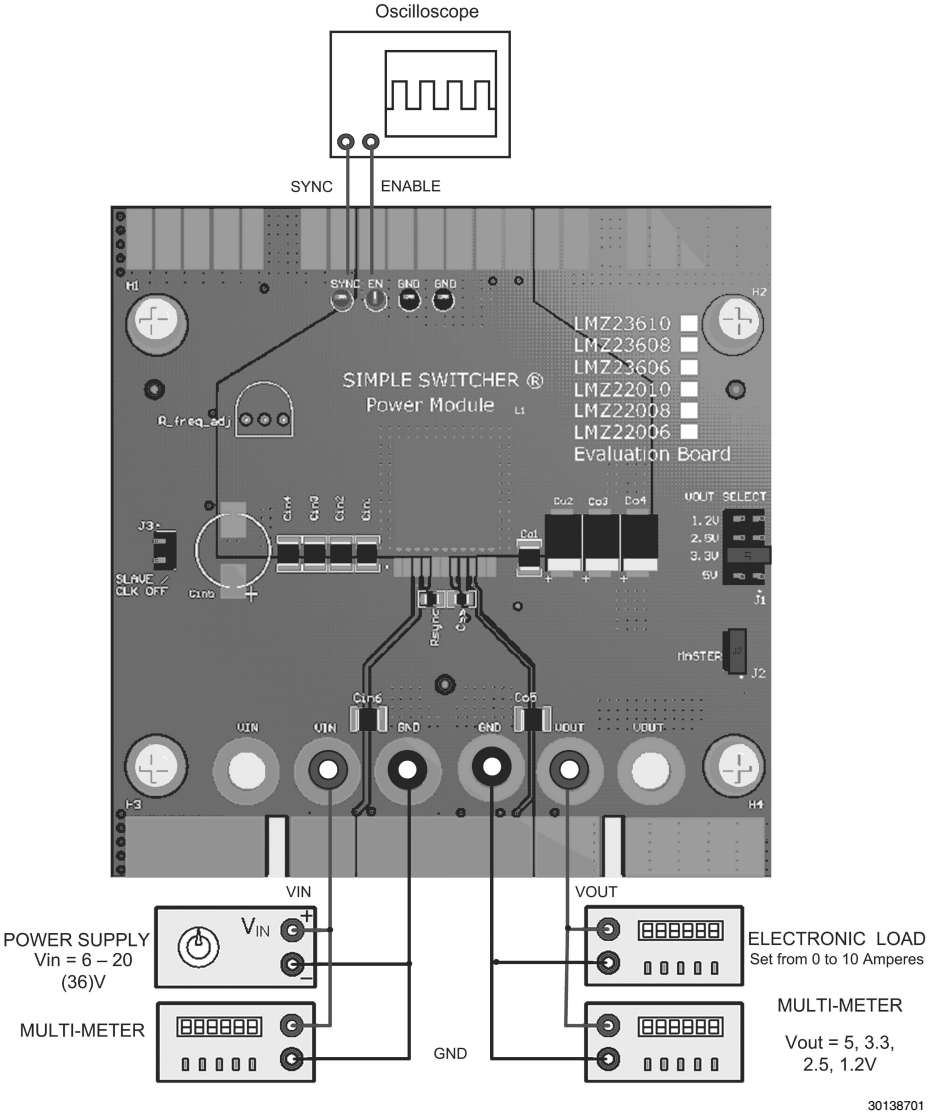


FIGURE 2.

Edge Connector Diagram

Edge Connector

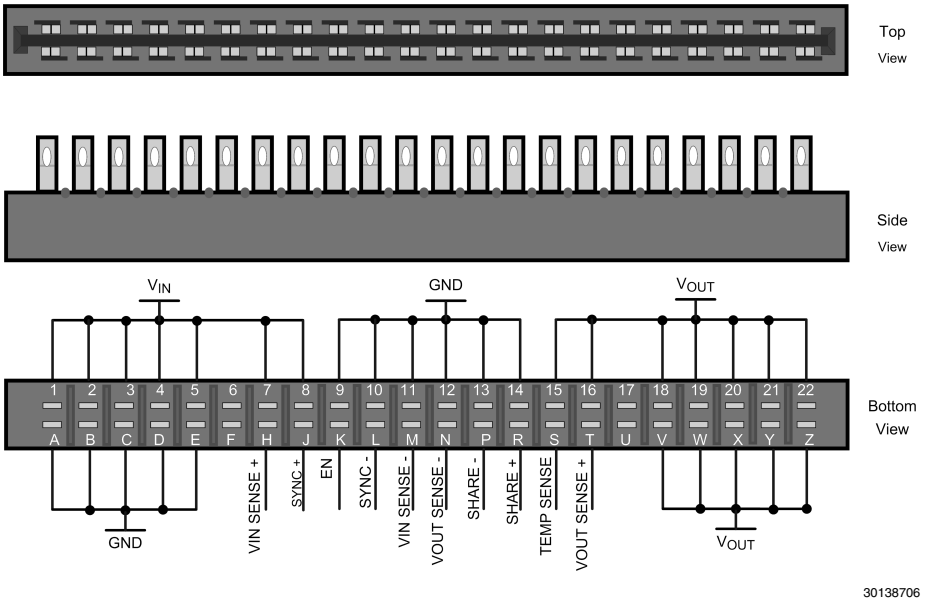


FIGURE 3.

The evaluation board is also compatible with the 44-pin edge connector shown in *Figure 3*. The table below explains the 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

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 datasheet for adjusting the feedback resistors.

Current Sharing

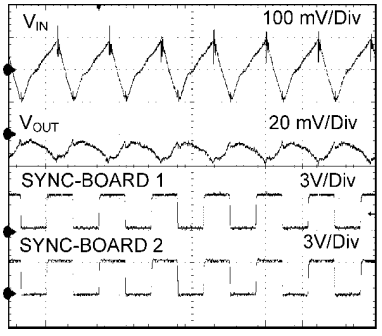
Current sharing is easy to evaluate. The next steps should be implemented only while the power to the device is off.

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.

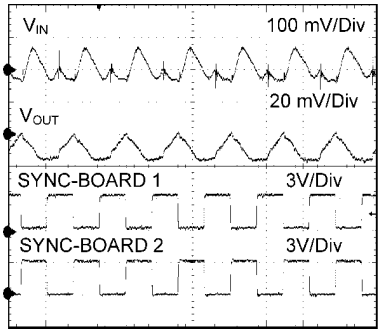
The advantage to running the clocks out of phase is to reduce the current stress on the input and output capacitors. For two modules the clocks should be run 180 degrees out of phase, for three modules the clocks should be run 120 degrees out of phase an so on. Although local input bypass capacitors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

Output Voltage Ripple with Two Boards Synchronized to 350Khz



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Output Voltage Ripple with Two Boards Synchronized with 180° Phase Shift



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FIGURE 4.

Master Slave Connection

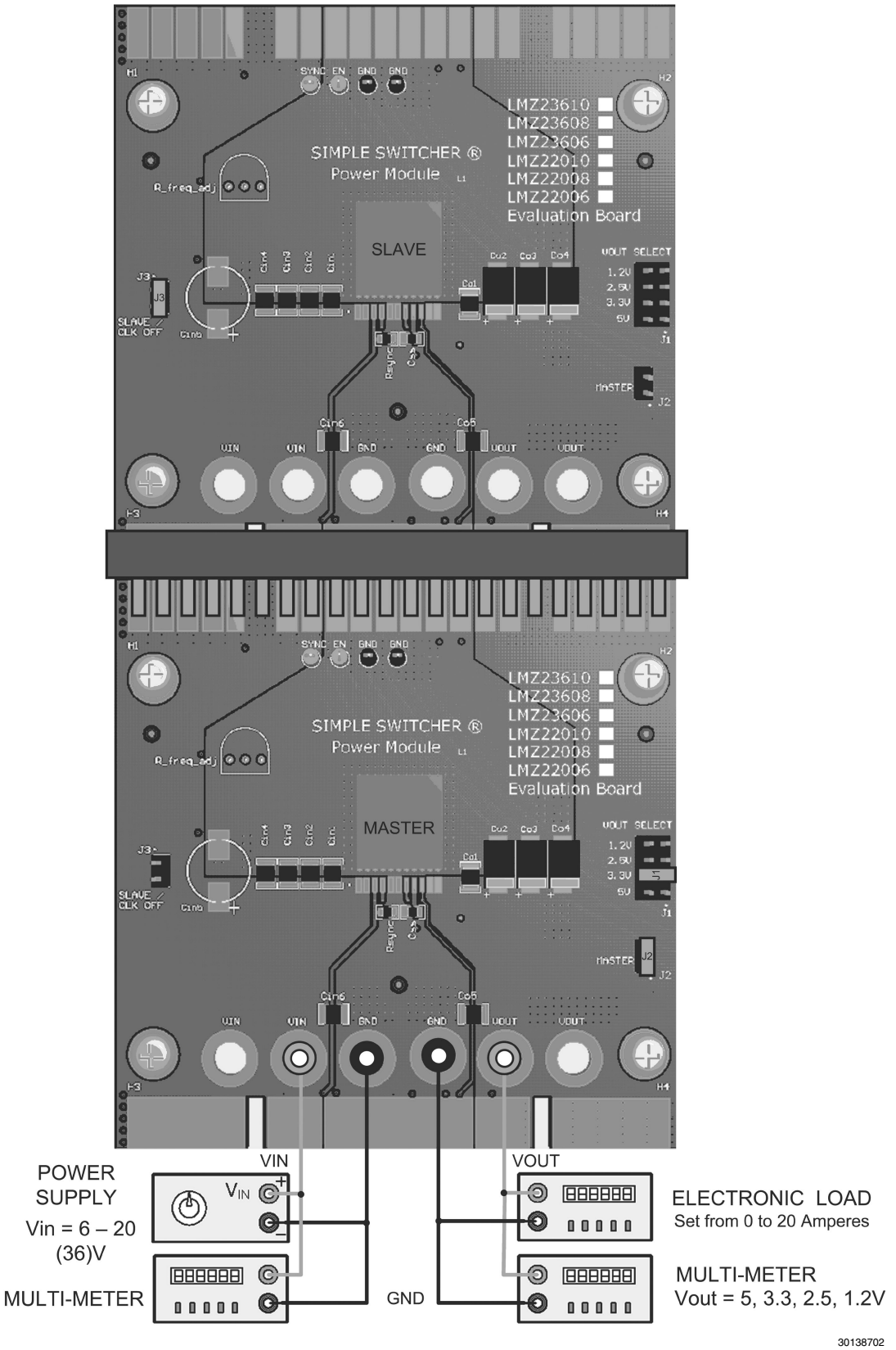


FIGURE 5.

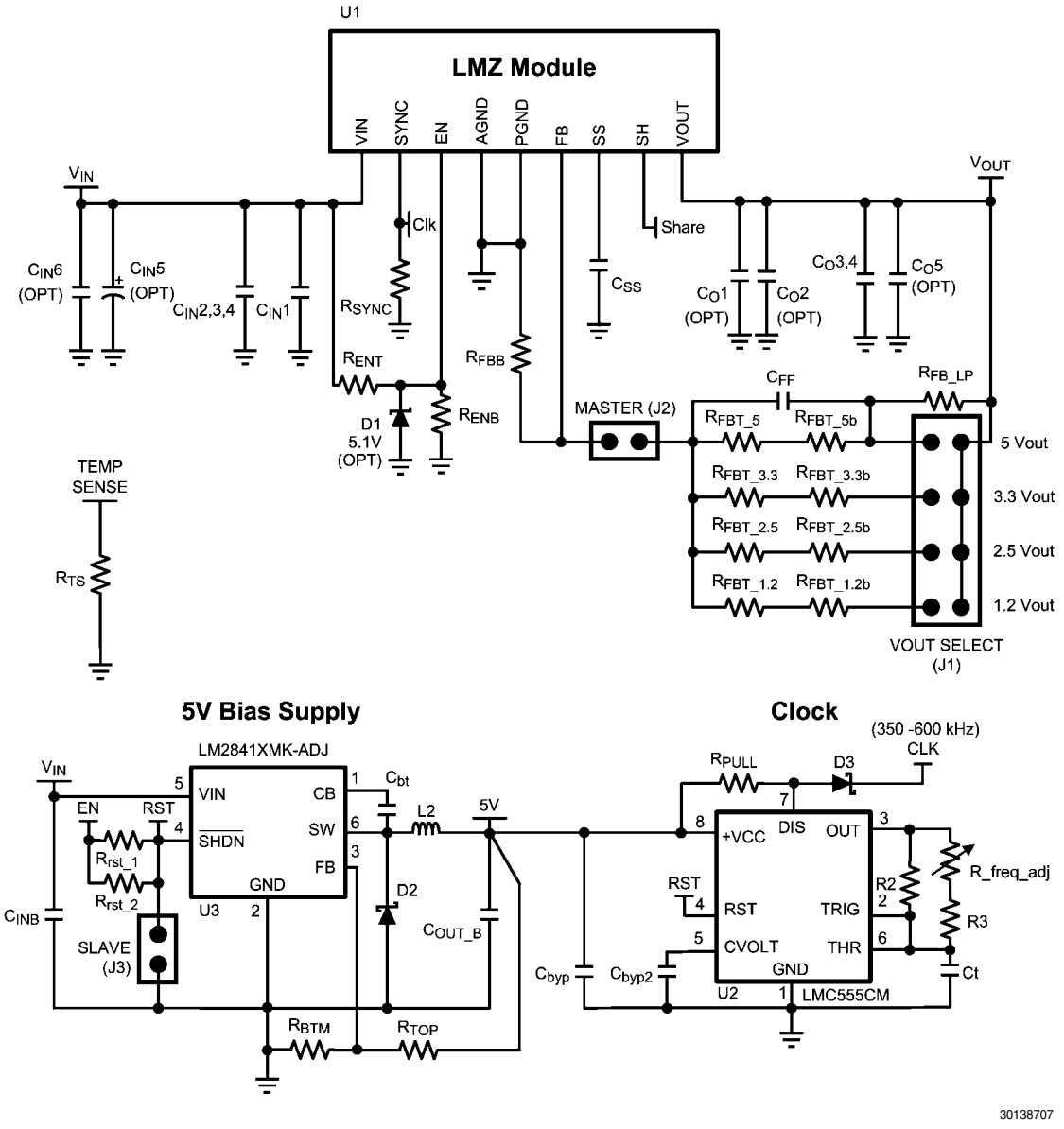


FIGURE 6. Evaluation Board Schematic

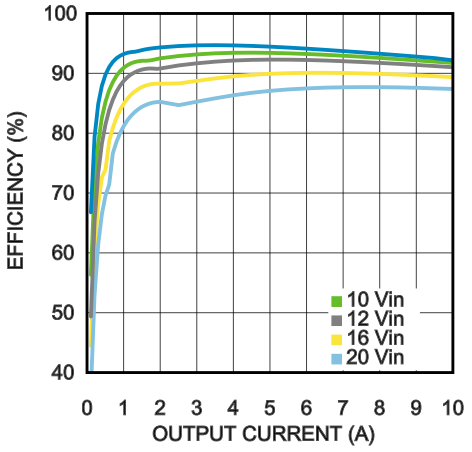
TABLE 1. Current Sharing Evaluation Board Bill of Materials, V_{IN} = 6V to 36V (20V), V_{OUT} = 1.2 / 3.3V / 5V, $I_{OUT\ (MAX)}$ = 10/08/06A

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
U1	SIMPLE SWITCHER®	TO-PMOD-11	National Semiconductor	LMZ23610/08/06 or LMZ22010/08/06	1
U2	Timer, 8-pin Narrow SOIC, Pb-Free	TSSOP-8	National Semiconductor	LMC555CM/NOPB	1
U3	300 mA/600 mA up to 42V Input Step-Down DC/DC Regulator	SOT23	National Semiconductor	LM2841XMK-ADJL/NOPB	1
Cin1 Cin6 Co1 Co5	0.047uF, X7R, 50V	0805	Kemet	C0805C473K5RACTU	4
Cin_b Cin2 Cin3 Cin4	10 µF, X7S, 50V	1210	TDK	C3225X7S1H106M	4
Cin5	150 µF, Aluminum Electrolytic, 50V	G	Panasonic	EEE-FK1H151P	1
Co2 Cout_b	47uF, X5R, 10V	1210	Murata	GRM32ER61A476KE20L	2
Co3 Co4	330µF, 6.3V, 0.015 ohm,	2917	Kemet	T520D337M006ATE015	2
Cff	4700 pF, X7R, 50V	0805	Kemet	C0805C472K5RACTU	1
Css 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 Rrst2 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
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

Designator	Description	Case Size	Manufacturer	Manufacturer P/N	Quantity
R_freq_adj	ADJ, 100K ohm, 0.5W	Round - 0.350" Dia x 0.150" H	Bourn	3352T-1-104LF	1
R2 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 EN	Test Point, TH, Miniature, Red		Keystone Electronics	5000	2
GND GND	Test Point, TH, Miniature, Black		Keystone Electronics	5001	2
GND GND VIN 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 J3	Header, 2x1, Gold plated, 230 mil above insulator	TH, 100mil	Samtec Inc.	TSW-102-07-G-S	2
SH-1 SH-2 SH-3	Shunt, 100mil, Gold plated, Black		Amp	382811-6	3
H1 H2 H3 H4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead		B and FFastener Supply	NY PMS 440 0025 PH	4
H5 H6 H7 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

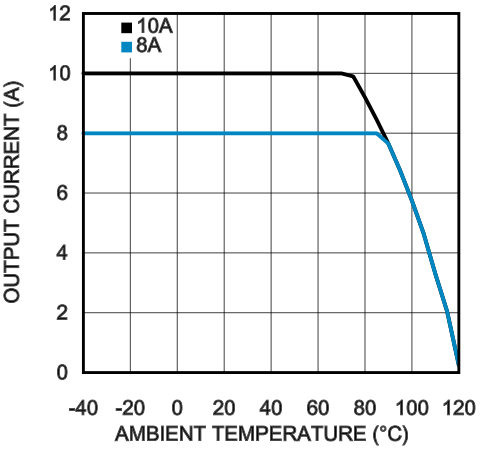
Performance Characteristics

Efficiency, V_{OUT} = 5.0V



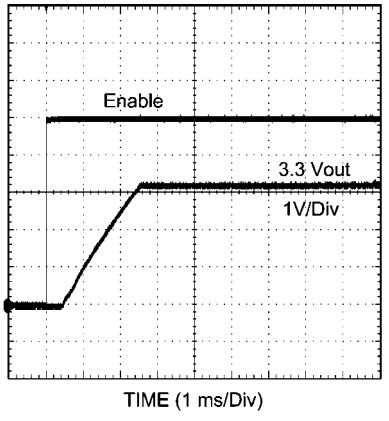
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Thermal Derating, V_{OUT} = 5.0V



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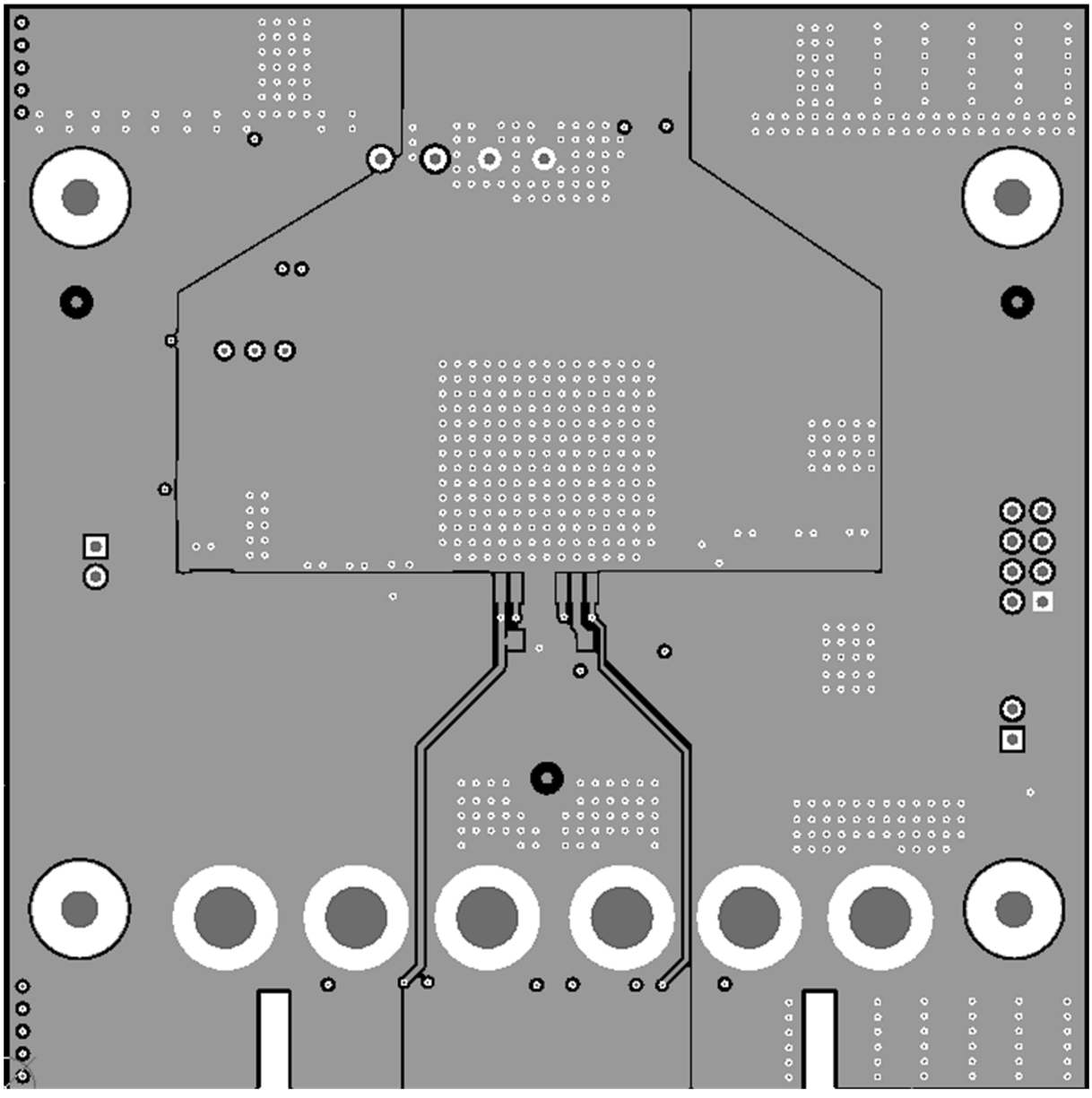
Startup, V_{IN} = 12V, V_{OUT} = 3.3V



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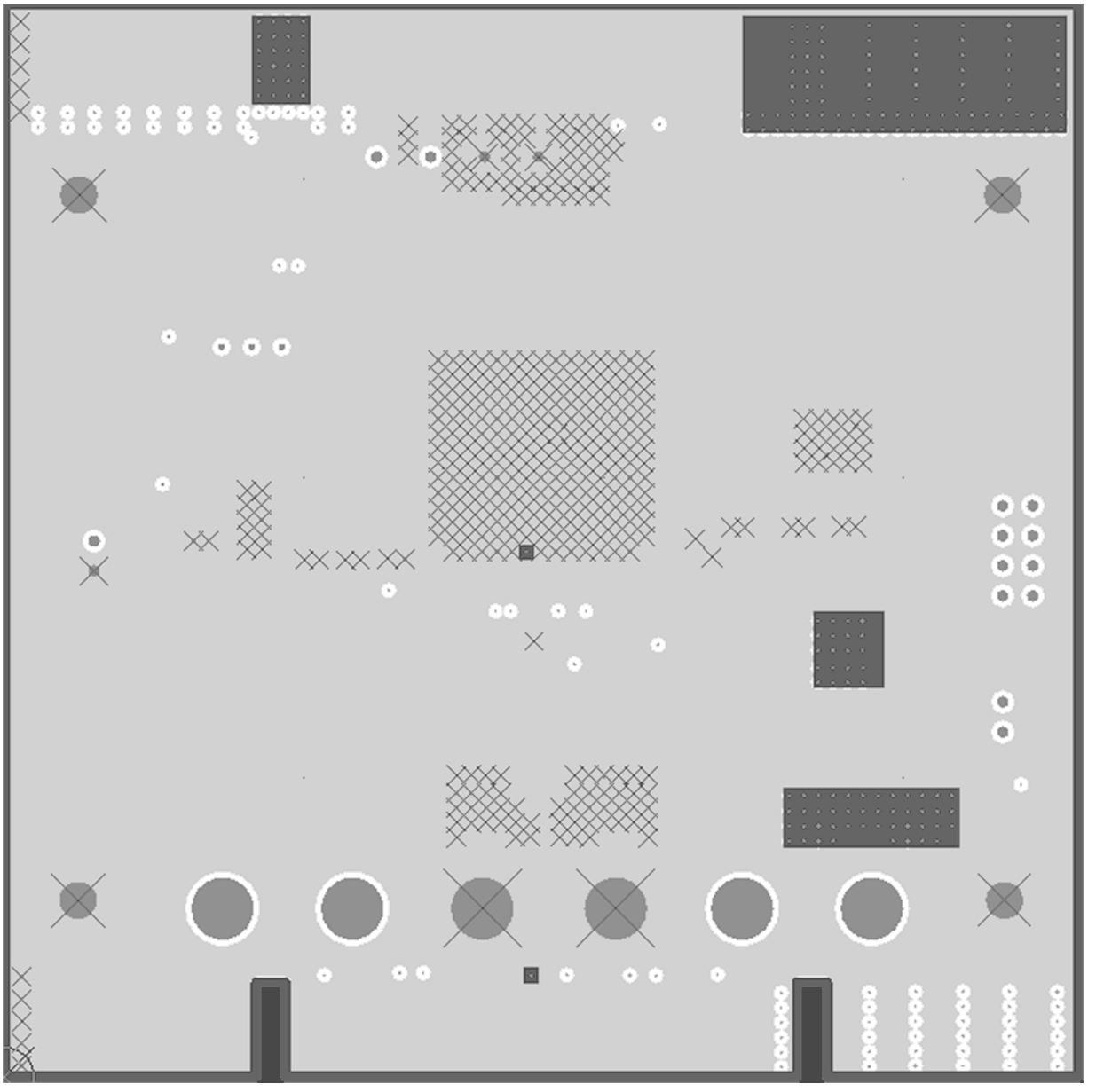
PCB Layout Diagrams

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



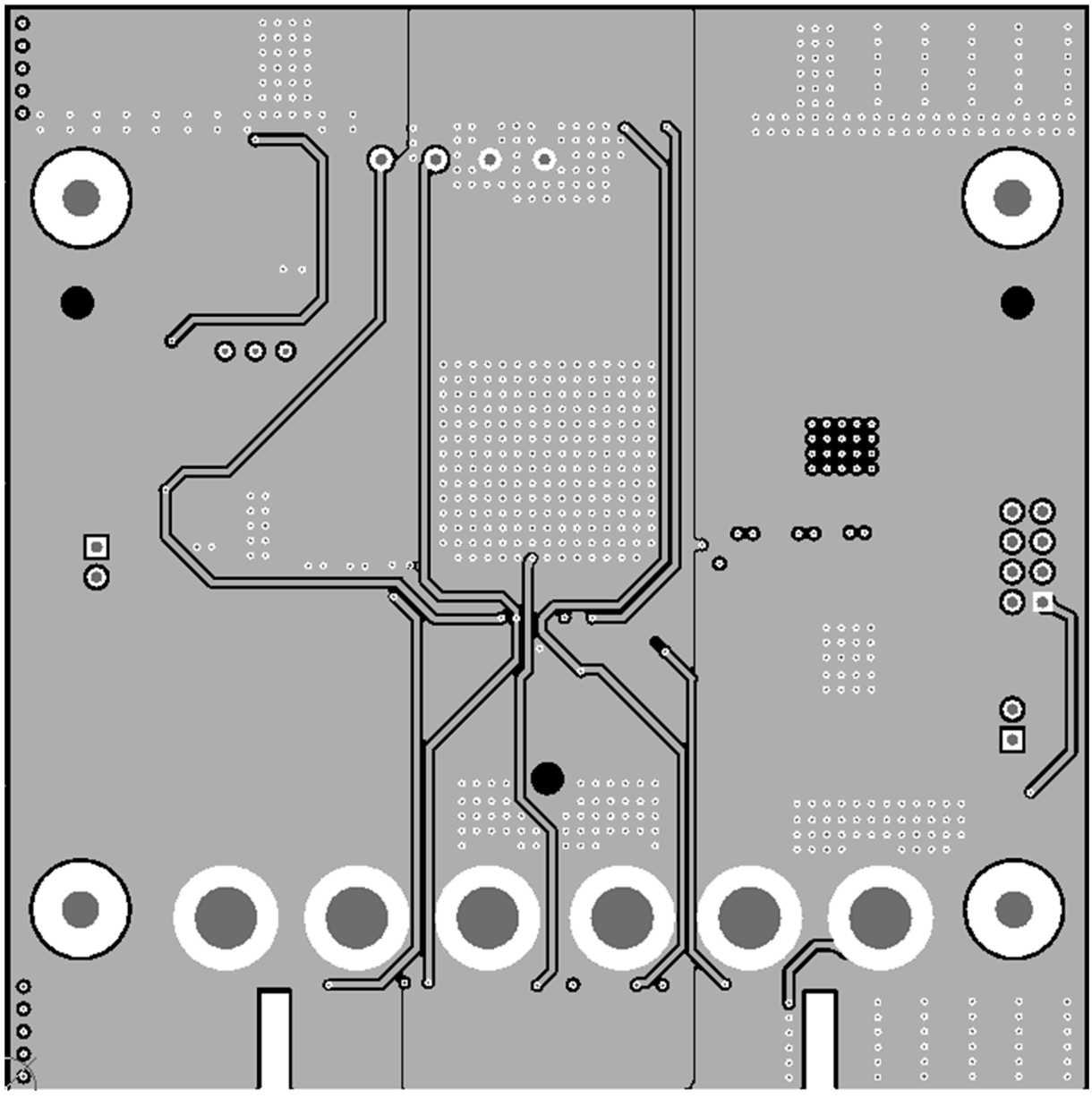
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FIGURE 7. Top Layer



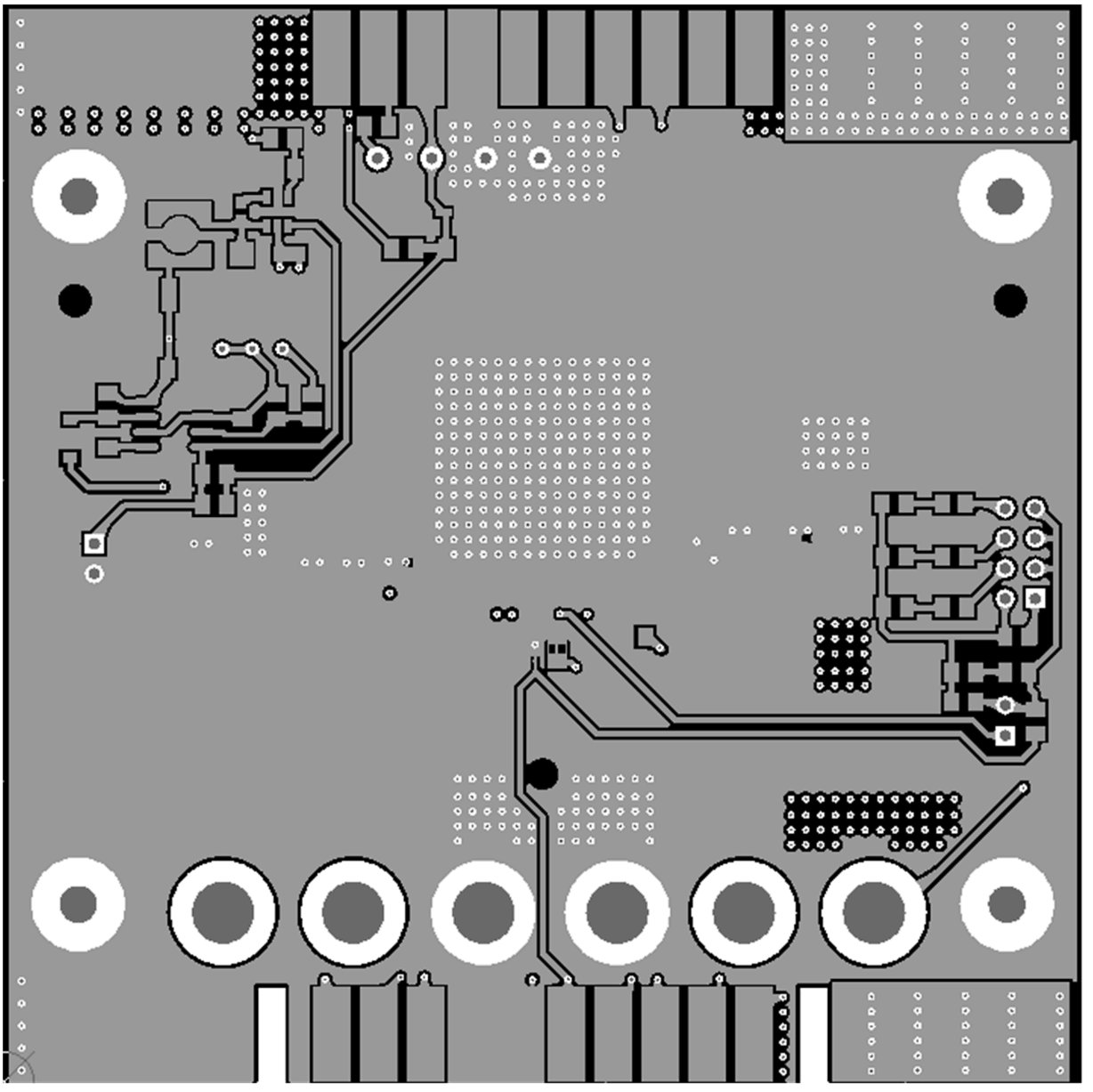
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FIGURE 8. Internal Layer I (Ground)
Heat Sinking Layer



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FIGURE 9. Internal Layer II (Routing)
Heat Sinking Layer



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FIGURE 10. Bottom Layer (Ground and Routing)
Heat Sinking Layer

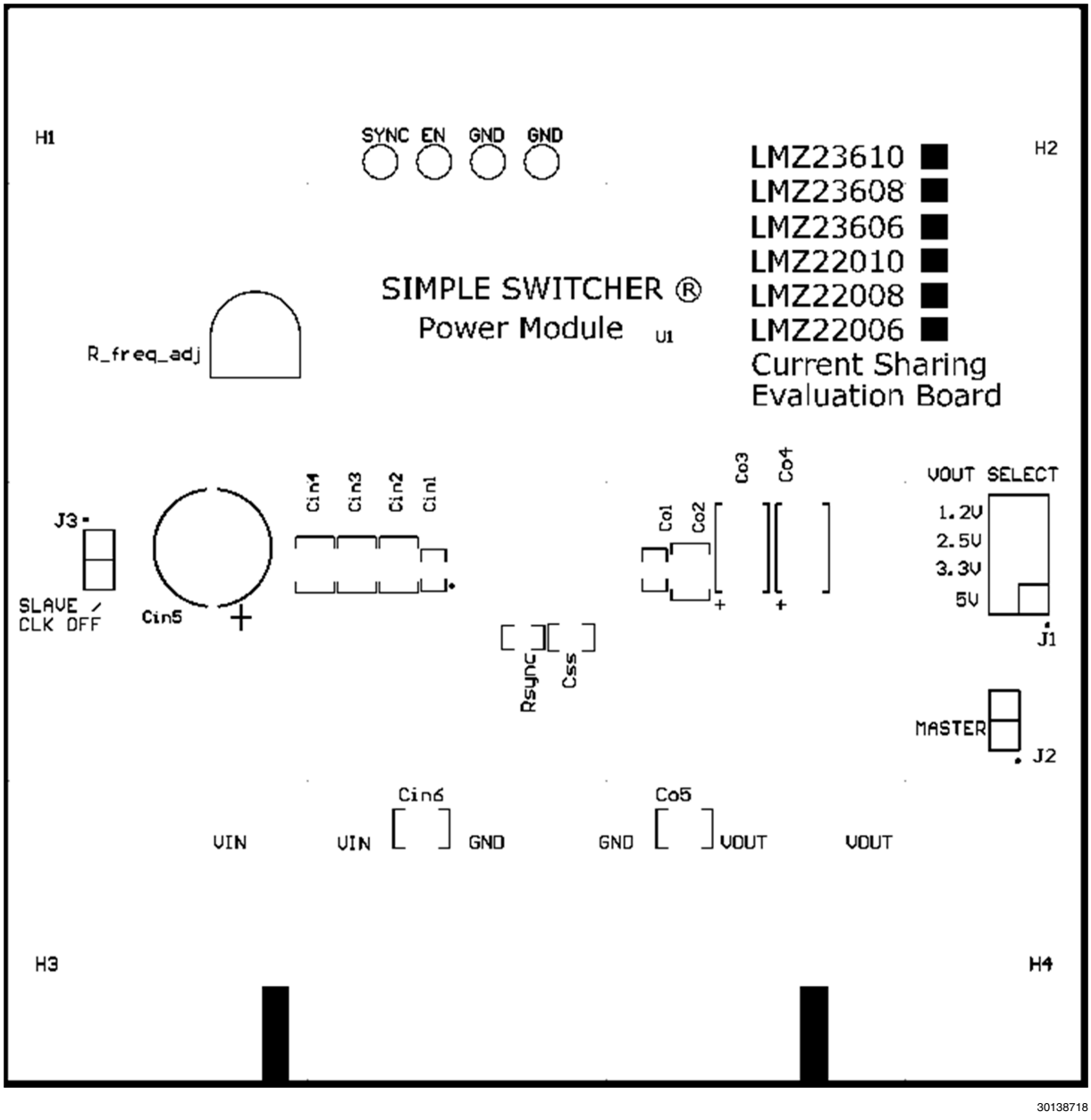


FIGURE 11. Top Silkscreen

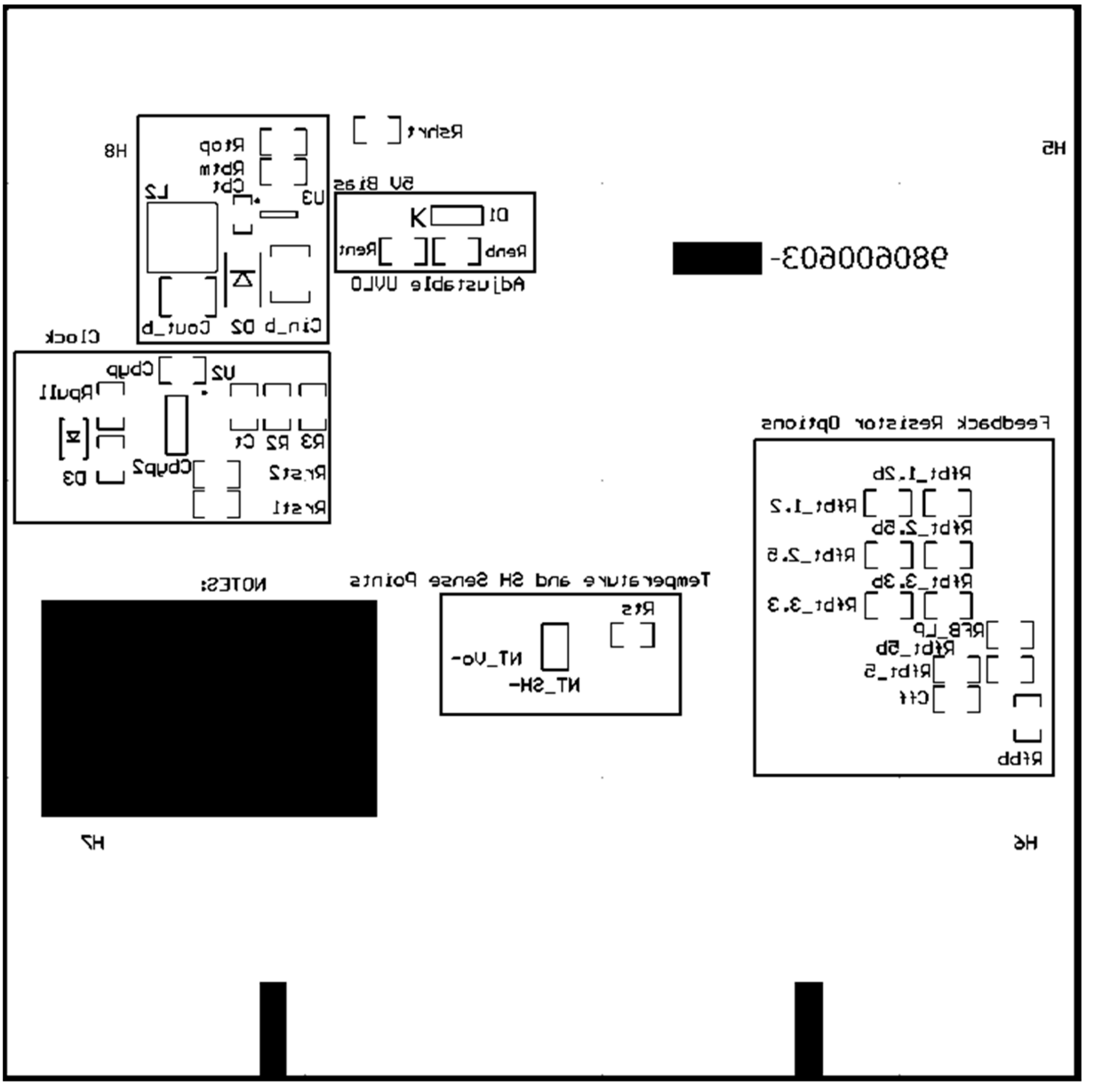


FIGURE 12. Bottom Silkscreen

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Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
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