AN-2058 LM10520 20A Adaptive Voltage Scaling (AVS) Evaluation Board

1 General Description

The LM10520 is a single-phase Energy Management Unit (EMU) that actively reduces system-level power consumption by utilizing a continuous, real-time, closed-loop Adaptive Voltage Scaling (AVS) scheme. The AVS technology enables optimum energy management delivery to the load in order to maximize system-level energy savings.

The LM10520 evaluation board is capable of delivering up to 20A with an output voltage range of 0.6V to 1.2 V. It includes a DOSA compatible edge connector to enable convenient evaluation of AVS on a high performance ASIC or FPGA which typically require between 10A - 20A. Most of the features of the device can be accessed through jumper settings and the PWI interface.

The LM10520 evaluation kit ships with 2 adaptor boards. The PWI2USB board allows connection to a PC for GUI control of the device. The AVS adaptor board stacks on top of the USB2PWI board and provides a header to connect to the LM10520. The AVS adaptor board also provides power connectors to conveniently apply high current loads and high voltage inputs that USB can not provide.

2 Operation Range

Parameter	Min	Max	Units
PVIN	~5	14	V
IPVIN		~3	A
AVIN(1)	4.75	5.25	V
IAVIN		100	mA
VOUT	0.72	1.2	V
IOUT	0	20	A

(1) AVIN improves efficiency, but is not required.

3 Features

- Closed-loop/Adaptive Voltage Scaling (AVS)
- PWI 1.0/PWI 2.0 compatible
- Startup with a pre-biased output load
- Adjustable soft-start/tracking support
- PGOOD flag and shutdown
- Under Voltage Lock Out (UVLO)
- Over Voltage Protection (OVP)
- Ability to synchronize switching frequency
- Cycle-by-cycle current limiting
- Thermal Shutdown

4 Applications

- Point of Load regulation
- Servers and networking cards
- Set-top-box processors
- Video processors and graphic cards
- Medical and industrial processors

5 System Diagram

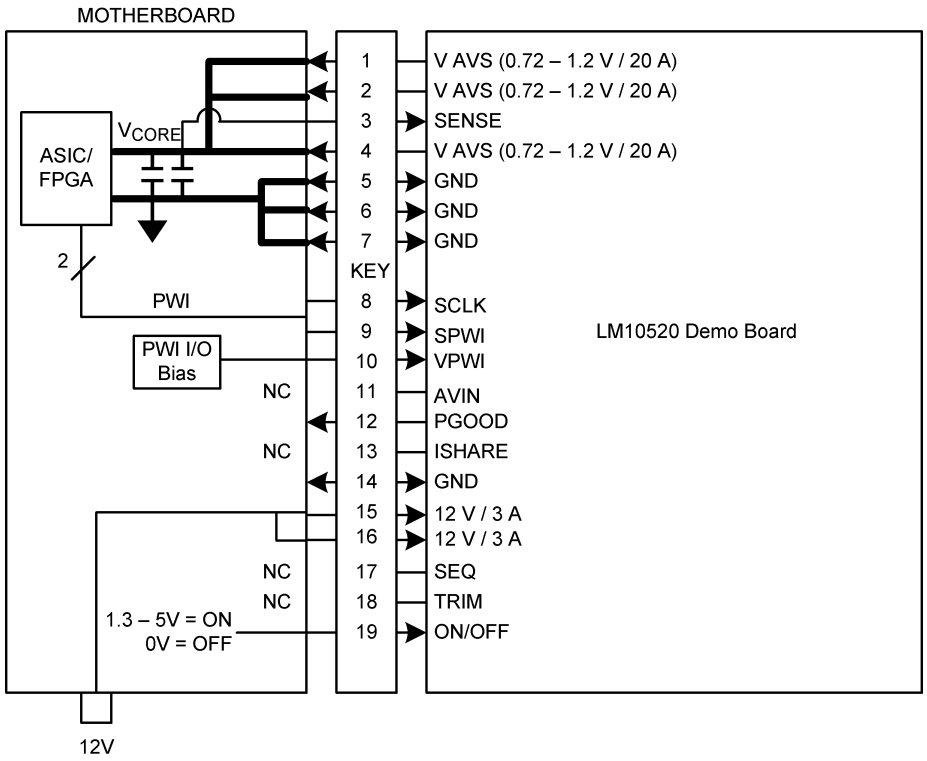

Figure 1. 20A Module System Connections

6 Connections

Dimensions are in inches

Pin Diameter is 0.025 inches.

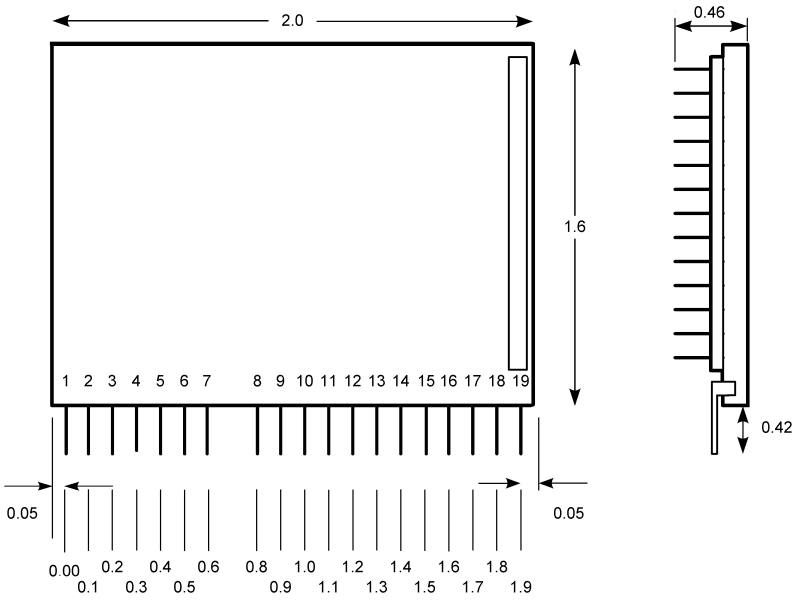

Figure 2. Board Dimensions

7 Pin Descriptions

Pin	Parameter	Description
1	VOUT	AVS output voltage
2	VOUT	AVS output voltage
3	SENSE	AVS output voltage feedback. Route a separate (low current) trace from this pin to the point of load.
4	Vout	AVS output voltage
5	GND	
6	GND	
7	GND	
8	SCLK	PWI clock
9	SPWI	PWI data
10	VPWI	PWI supply input 3.3V/ 2.5V/ 1.8V
11	AVIN	Analog input voltage. 4.5V - 5.5V
12	PGOOD	Power good signal output
13	I Share	Not used
14	GND	
15	VIN	Power input voltage.
16	VIN	Power input voltage.
17	SEQ	Not used
18	TRIM	Not used
19	ON/OFF	Drive this pin between 1.3V and AVIN to enable the output voltage. Pulling this pin to ground shuts down the output and the device.

8 Typical Performance Curves

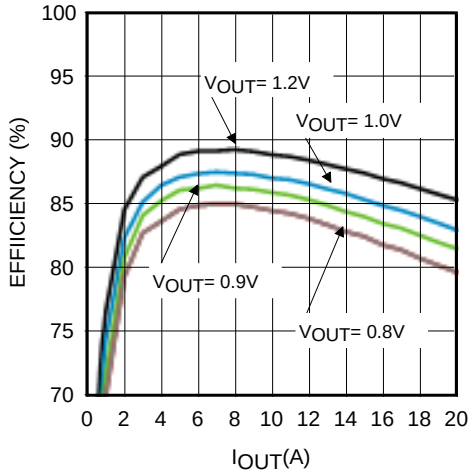

Figure 3. Efficiency (PV_{IN} = 12V, AVIN = 4.5V, fs = 300 kHz

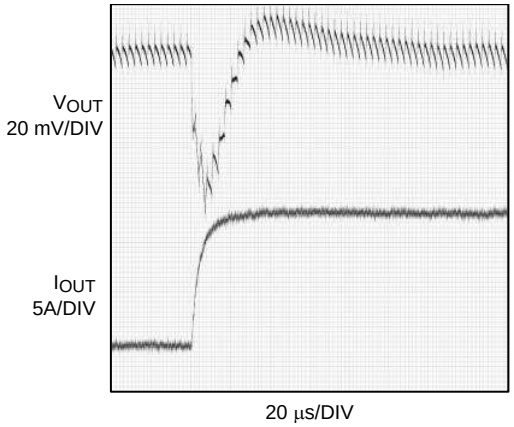

Figure 4. Load Transient Response

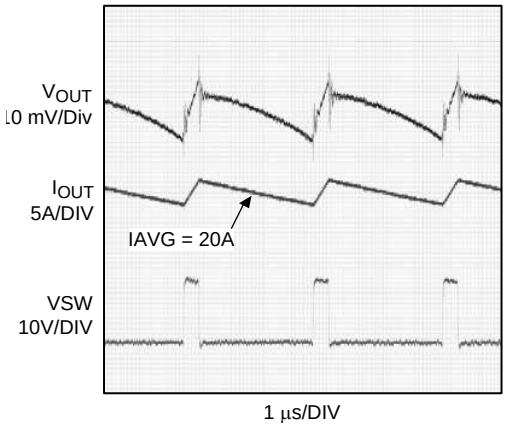

Figure 5. Switching Waveforms

9 Startup Guide

9.1 Standalone

The LM10520 evaluation board can operate from a single bias at PVIN (5 to 14V). VOUT is enabled via the ON/OFF pin. It is recommended that this pin be actively driven high or low.

9.2 Connected to PC/GUI

The LM10520 evaluation board can be connected to a PC and controlled from a GUI by connecting it to the USB2PWI and AVS adaptor boards. The USB2PWI board provides 5V power and PWI communication, while the AVS adaptor board provides a 19-pin DOSA compliant header to connect the LM10520 board into.

The AVS adaptor board provides several options for powering and loading the LM10520 evaluation board. Jumper settings for these configurations are described in Table 1, and shown in a simplified schematic in Figure 6.

The default configuration provides means for a simple evaluation of LM10520 requiring only a USB connection. However, because of the limited power output of USB, the LM10520 should not be loaded at its output for this configuration.

For a wider range of input and output voltage/current, external power supplies and loads can be connected to the AVS adaptor via the banana jacks. See Table 1 for jumper settings to route power through the banana jacks.

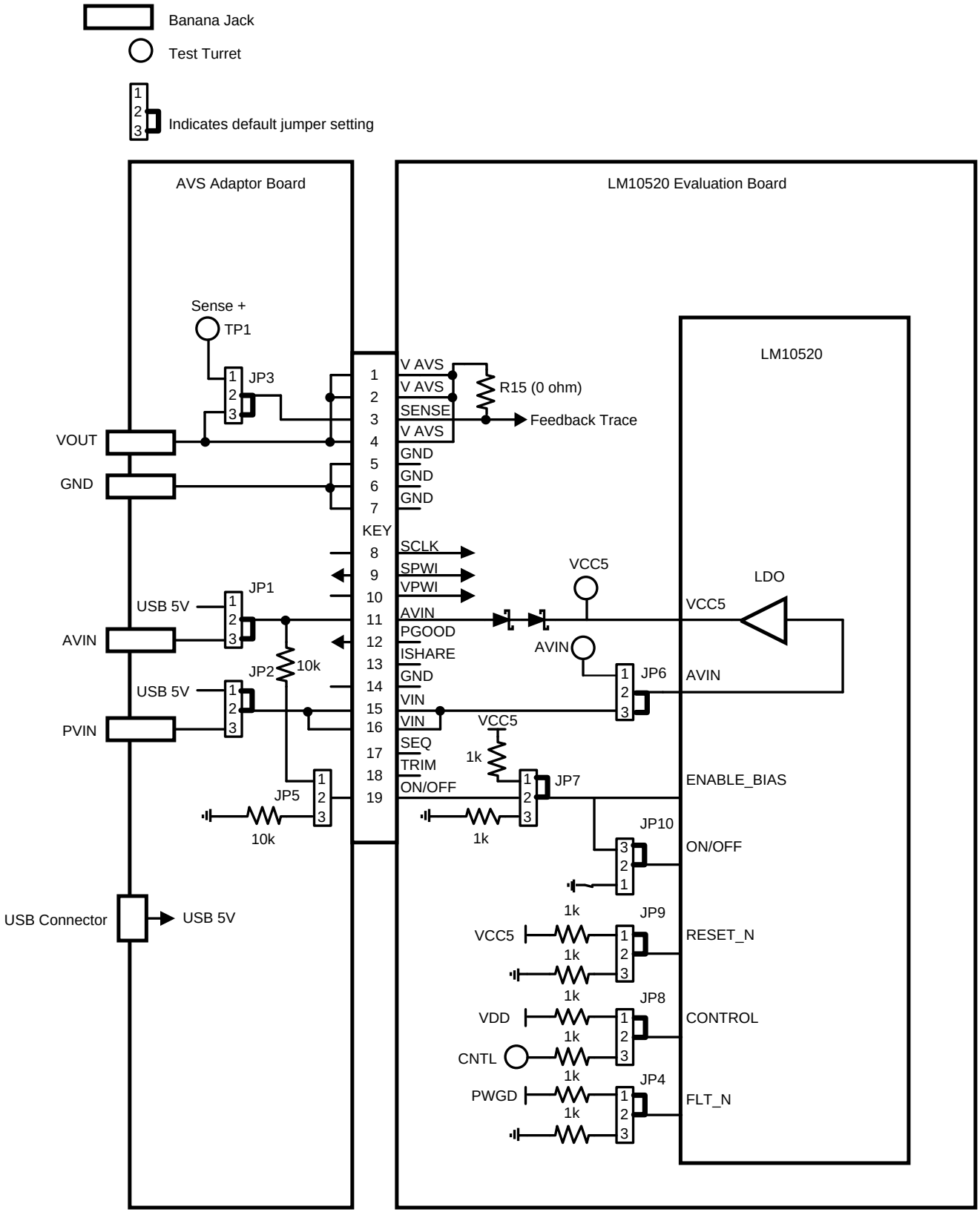

Figure 6. Simplified Schematic of the Jumper Options on the LM10520 Evaluation and AVS Adaptor Boards

Table 1. AVS Adaptor Jumper Settings

Jumper	Description	Connection	Configuration
JP1	AVIN[1]	1-2	AVIN connected to USB 5V
		2-3	AVIN provided by LM10520 internal rail (if AVIN banana jack left floating), or AVIN provided externally (if power is provided to AVIN banana jack/DOSA connector)
JP2	PVIN	1-2	PVIN connected to USB 5V
		2-3	PVIN provided externally
JP3	Sense +	1-2	Feedback signal taken from remote sense terminal
		2-3	Feedback signal taken from local feedback trace.
JP4	Sense -	1-2	Feedback ground taken from remote sense terminal.
		2-3	Feedback ground taken from local trace.
JP5	ON/OFF pullup	1-2	LM10520 eval board ON/OFF pulled up to AVIN.
		2-3	LM10520 eval board ON/OFF weak pull down to GND

(1) JP1 only selects how AVIN power is routed to the DOSA receptacle J1. Jumper JP6 on the LM10520 eval board selects how power is routed to the AVIN pin of LM10520.

Table 2. LM10520 Evaluation Board Jumper Settings

Jumper	Connection	Description
JP4	1-2	Connects FLT_N to PWGD
	2-3	Connects FLT_N to GND
JP6	1-2	Connects AVIN to external input
	2-3	Connects AVIN to VIN
JP7	1-2	Connects ENABLE_BIAS to VCC5
	2-3	Connects ENABLE_BIAS to GND
JP8	1-2	Connects CONTROL to VDD
	2-3	Connects CONTROL to external input
JP9	1-2	Connects RESET_N to VCC5
	2-3	Connects RESET_N to GND
JP10	1-2	Connects ON/OFF to GND
	2-3	Connects ON/OFF to ENABLE_BIAS

Table 3. LM10520 Input/Measurement Headers

Header	Description
JP1	Connects VCC5 to PWGD LED indicator
JP2	Tracking input for startup tracking
JP3	Clock input for Sync function
P1	DOSA compliant connector
P2	Remote sense measurement. Pins 1-2 measure SENSE to GND. By default, GND is local GND. By removing R13 and connecting pin 3 of the header to the remote GND, pins 1-2 will measure SENSE to remote GND. See schematics.
P3	PWI header
P4	VOUT measurement
P5	Switch node measurement

10 Options

10.1 Adjusting the Default Output Voltage

The default output voltage of LM10520 is set by the feedback resistor divider ratio, R_{FB1} and R_{FB2}. The default output voltage can be expressed as:

$$V_{OUT(DEFAULT)} = 0.6 \times \left(1 + \frac{Rfb1}{Rfb2}\right) \quad (1)$$

The LM10520 demo board ships with R_{FB1} and R_{FB2} = 10 kΩ, which yields a 1.2V default output voltage. Resistor ratios for common default output voltages are shown in Table 4.

Table 4. Default Output Voltages

Default Output Voltage	R_{FB1}	R_{FB2}
1.0V	10K	15K
0.9V	10K	20K

10.2 AVIN Pin

The AVIN pin can accept a 4.5 – 5.5V input, which is used to bias the analog circuitry of the LM10520. Slightly higher conversion efficiency (when using a 12V power input rail) can be achieved by providing AVIN.

10.3 SENSE Pin

The SENSE pin (header P1, pin 3) provides the option for remote feedback connection, so that the LM10520 regulates VCORE as seen at the remote location. This has the benefit of regulating out the IR drops seen across the connector and traces. However, remote sensing is inherent in the AVS loop, and there is no benefit to connecting the SENSE pin when AVS is enabled.

By default, the SENSE pin is connected to the three VAVS pins by a 0Ω resistor (R13) on the LM10520 evaluation board. To enable remote sensing, make R13 open, and ensure that the sense pin is connected to the VAVS rail on the motherboard. If the sense pin is not connected to VAVS, the LM10520 will have no feedback, and the output voltage could go as high as the VIN rail.

11 VPWI

PWI is a push-pull interface, and thus the master and slave I/O needs to drive to the same voltage. LM10520 has a VPWI input, which determines the high voltage for the PWI I/O. VPWI needs to be the same voltage as the I/O on the slave's PWI clock and data pins. VPWI must be provided in order for the PWI interface to communicate.

12 PowerWise® Interface Address Selection

A 1% resistor at R22 sets the PWI address.

PWI Standard	Description	Min	Typ	Max	Unit
RPWI1.0	Address selection resistor for PWI-1.0	**0**	20		kΩ
RPWI2.0-0	Address selection resistor for PWI-2.0, address 0		40.2		kΩ
RPWI2.0-1	Address selection resistor for PWI-2.0, address 1		60.4		kΩ
RPWI2.0-2	Address selection resistor for PWI-2.0, address 2		80.6		kΩ
RPWI2.0-3	Address selection resistor for PWI-2.0, address 3		100		kΩ
RPWI2.0-4	Address selection resistor for PWI-2.0, address 4		120		kΩ
RPWI2.0-5	Address selection resistor for PWI-2.0, address 5		140		kΩ
RPWI2.0-6	Address selection resistor for PWI-2.0, address 6		160		kΩ
RPWI2.0-7	Address selection resistor for PWI-2.0, address 7		180	8	kΩ

13 Operating Ratings

The LM10520 evaluation board can provide a 0.72 to 1.2V, 0 to 20A output. Its default voltage upon startup is 1.2V. Using PWI voltage commands, the output voltage can be changed.

14 Thermal Considerations

The LM10520 evaluation board has not been tested for thermal derating and air flow requirements. In general, the board temperature rise for a 12V single rail input to 1.2V output providing a 10A load with no air flow is about 40°C - 50°C. Therefore, for any load > 10A, it is recommended to place a fan near the board.

15 LM10520 Evaluation Board Bill of Materials

Designator	Comment	Footprint	Manufacturer
C1	ECJ-2VB1H153K	0805	Panasonic
C2	TMK107BJ474KA-T	0603	Taiyo Yuden
C3	C1608C0G1H101J	0603	TDK
C4, C9	GRM21BR71H105KA12L	0805	Murata
C5	C1608X7R1H102K	0603	TDK
C6	C1608C0G1H180J	0603	TDK
C7	C3216X7R1H105K	1206	TDK
C8	C3225X7R1H225K/2.50	1210	TDK
C10, C11	C4532X7R1E226M	1812M	TDK
C12	UMK107B7104KA-T	0603	Taiyo Yuden
C13, C14	2R5TPE220M9		Taiyo Yuden
C15	GRM1885C1H182JA01D	0603	Murata
D1	LNJ311G83RA	Diode_1206	Panasonic
D2, D3, D4	MBR120LSFT1G	SOD-123	ON Semiconductor
D5	Vishay SL22-E3/52T	SMB	Vishay
L1	SER2010-202ML	IHLP6767	Coilcraft
Q1	NDS331N	SOT23A	Fairchild Semiconductor
Q2, Q3	IRF6633	IRF6722	Internation Rectifier
Q5	IRF6609	IRF6609	Internation Rectifier
R1, R2, R3, R4, R14, R16, R17, R18, R20, R23	CRCW08051K00FKEA	0805	Vishay
R5	MCR03EZPJ000	805	Rohm Semiconductor
R6	CRCW0805100KFKEA	0805	Vishay
R7, R11, R26	CRCW080510R0FKEA	0805	Vishay
R8	CRCW060320K0FKEA	0603	Vishay
R9	RC0603FR-071K82L	0603	Yageo
R10	CRCW060327R0FKEA	0603	Vishay
R12	CRCW060340K2FKEA	603	Vishay
R13, R15	CRCW06030000Z0EA	0603	Vishay
R19	CRCW060310R0FKEA	0603	Vishay
R21, R22, R24	NL	0603	
R27, R33	CRCW060310K0FKEA	0603	Vishay
R28, R29, R31, R32	CRCW060362R21FNEA	0603	Vishay
R30	RL3264SW4-005M	M-RES-LKV25	Vishay
R34	CRCW0603280RFKEA	0603	Vishay
Rfb1, Rfb2	CRCW080510K0FKEA	0805	Vishay
U1	LM10520	TSSOP-28	Texas Instruments

16 Layout Artwork

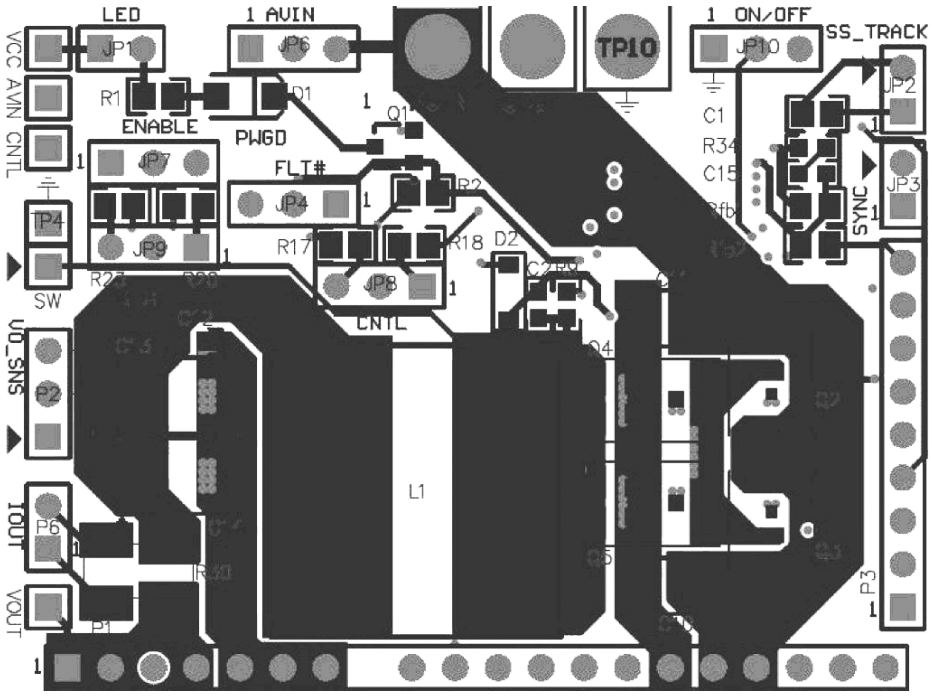

Figure 7. Top and Top Overlay

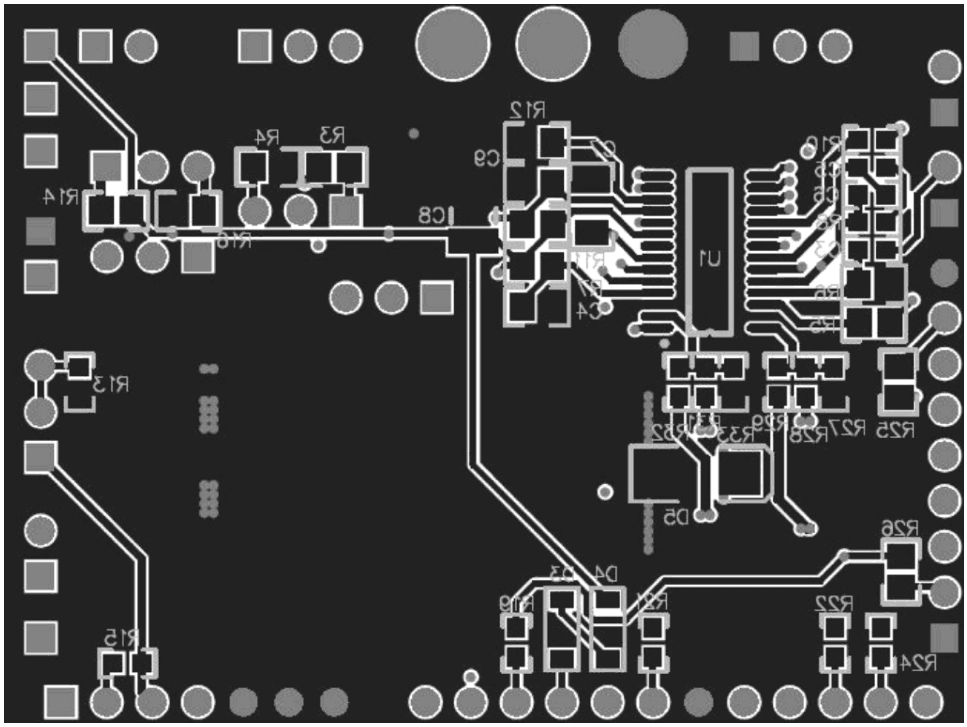

Figure 8. Bottom and Bottom Overlay

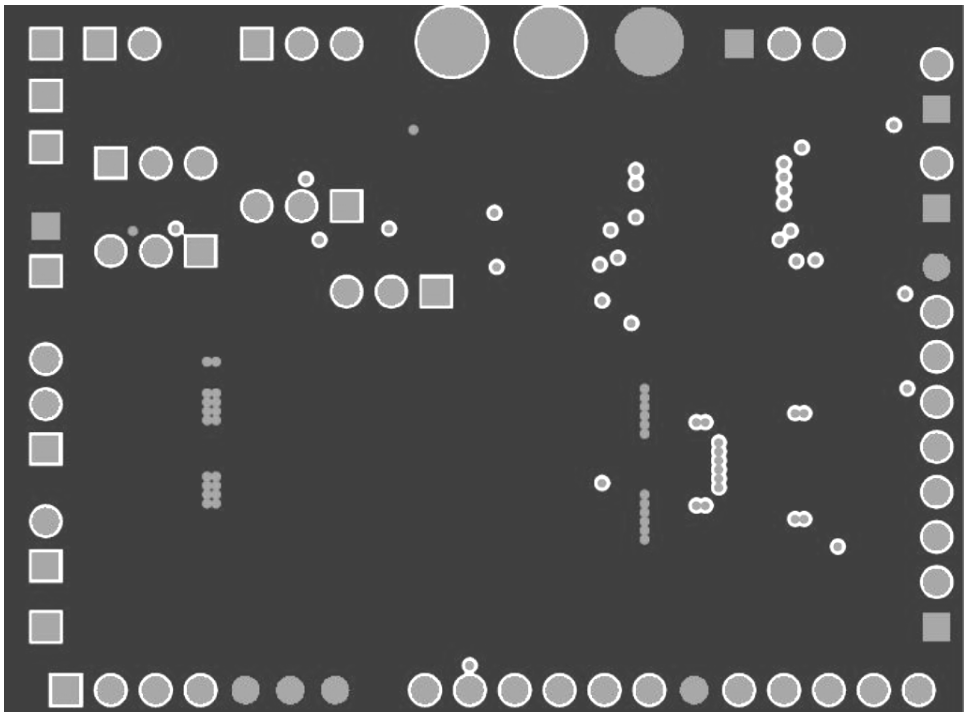

Figure 9. Mid-Layer 1

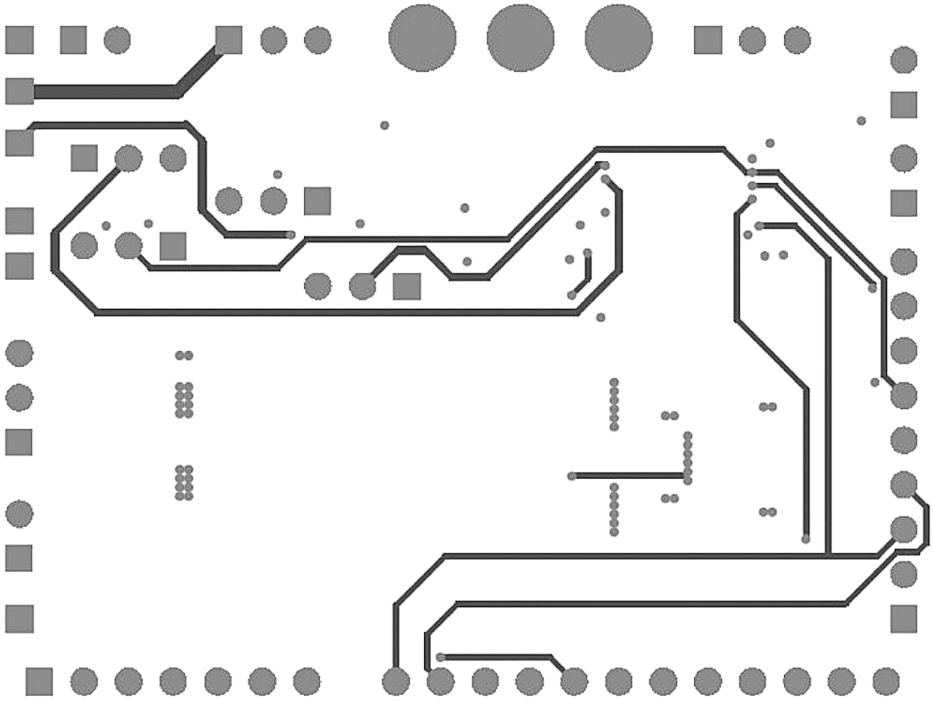

Figure 10. Mid-Layer 2

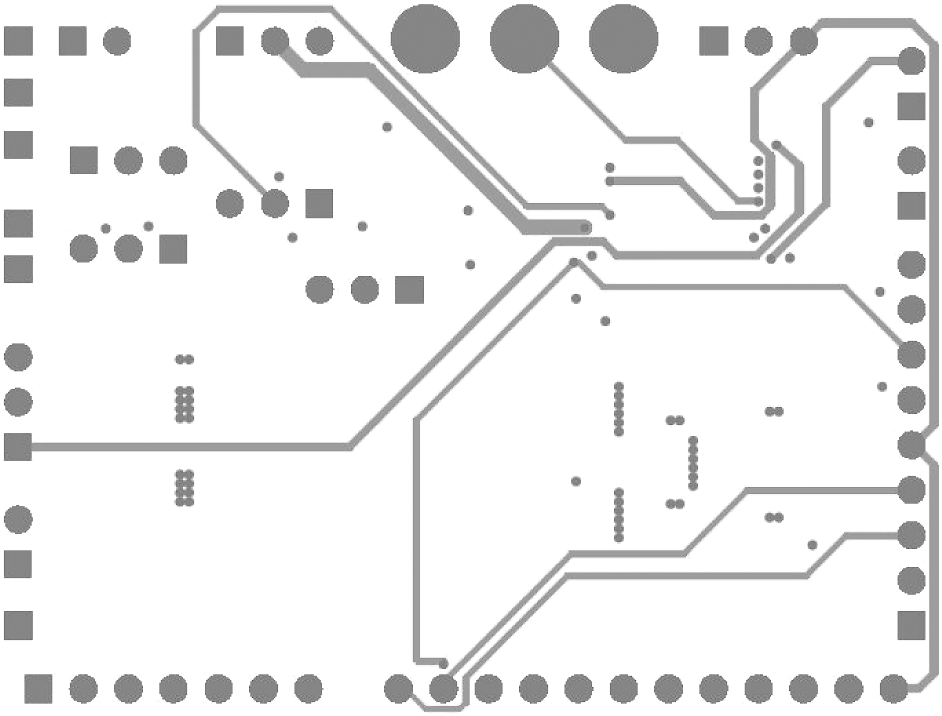

Figure 11. Mid-Layer 3

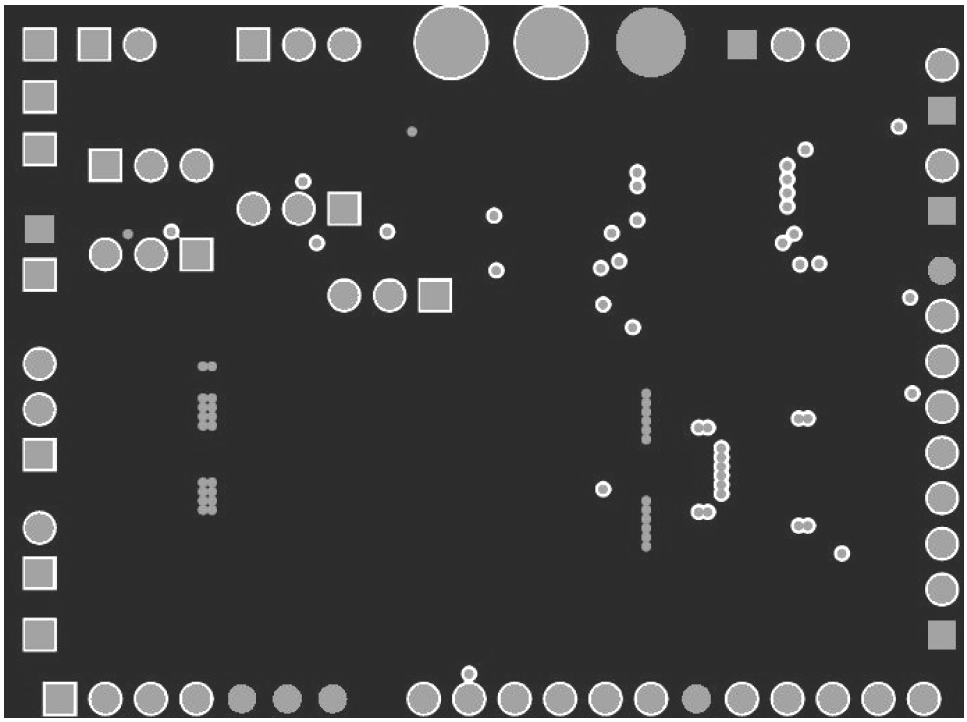

Figure 12. Mid-Layer 4

17 Schematics

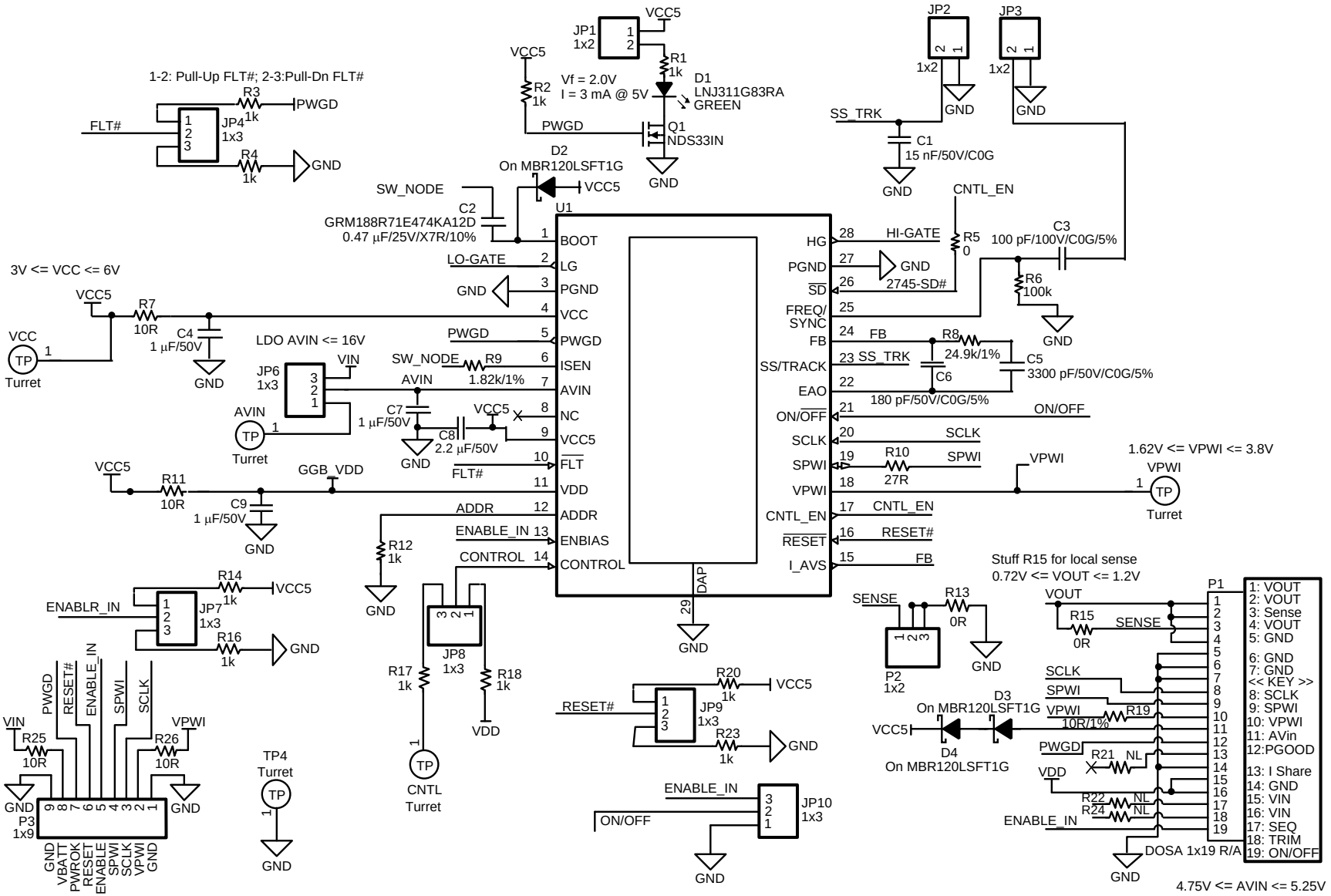

Figure 13. LM10520 Schematics: LM10520 and Low-Power Components

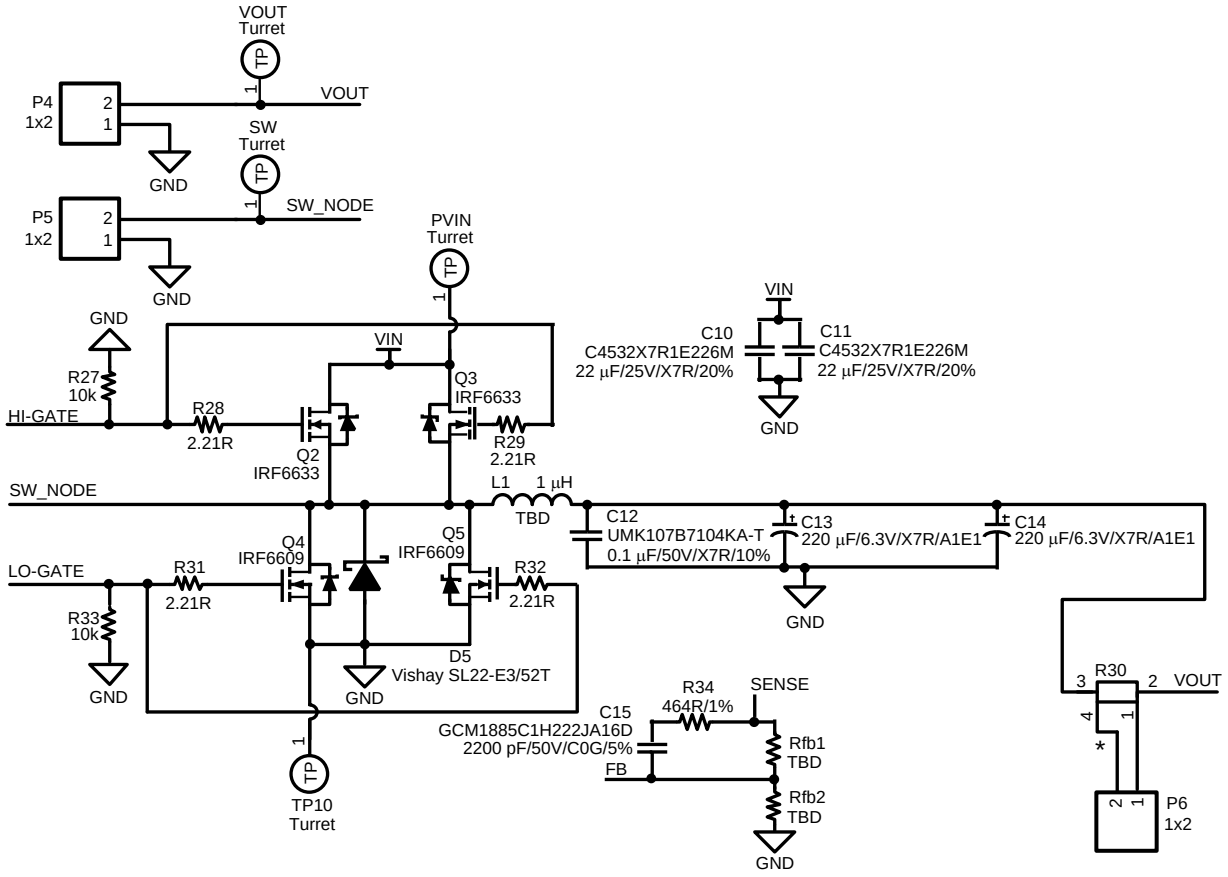

Figure 14. LM10520 Schematics: Power Stage

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3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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