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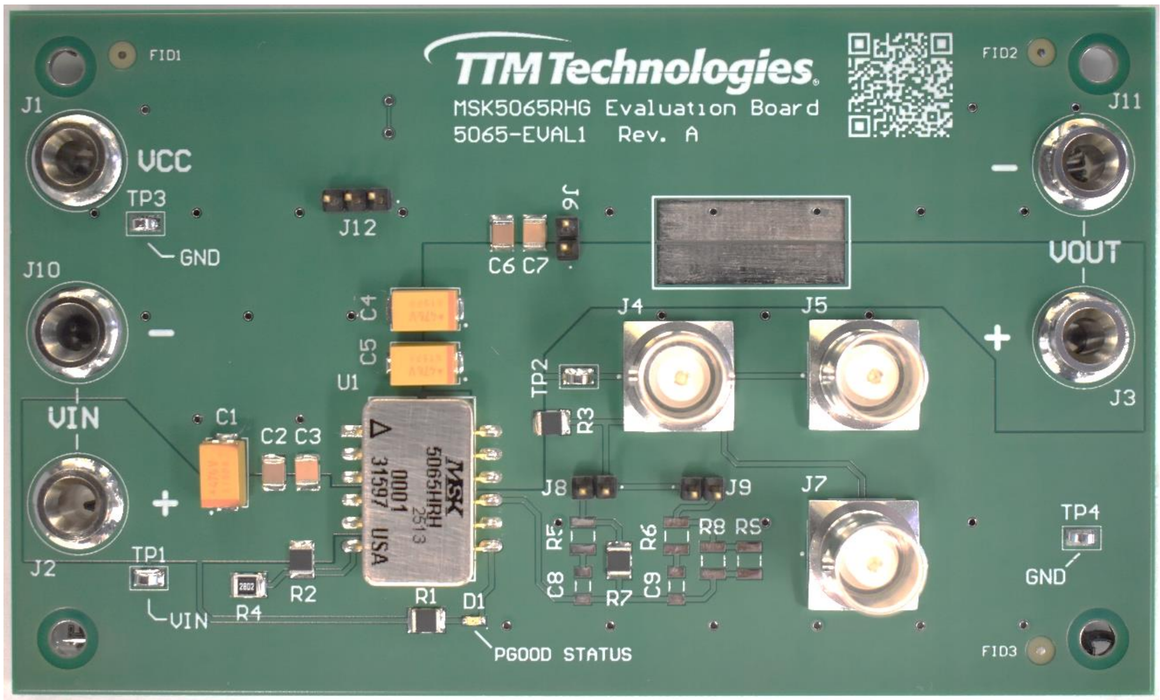
Application Note 042, Rev A

MSK5065RHG Evaluation Board User's Guide



Introduction

The MSK5065RHG is a Radiation Hardened adjustable output 500 kHz step down switching regulator capable of delivering up to 3A of current to the load. The MSK5065RHG simplifies design of high efficiency radiation hardened switching regulators that use a minimum amount of board space. The MSK5065RH is packaged in a hermetically sealed 12 pin flatpack, and is available with straight, or gull wing lead forms.

This evaluation board provides a platform from which to evaluate new designs with ample real estate to make changes and evaluate results. More compact and single layer layouts are achievable in real applications. Evaluation early in the design phase reduces the likelihood of excess ripple, instability, or other issues, from becoming a problem at the application PCB level.

This application note should be read in conjunction with the MSK5065RH data sheet. Reference the data sheet for additional application information and specifications.

Setup

Reference schematic on page 7. Use standard banana plugs to connect to the power supply and test equipment. J2 is input for the positive supply rail, with J10 being the input for the return. D1 functions as a fault indicator LED. D1 connects to PGood. If this diode turns on it means the device is out of regulation.

The board is designed to be powered by 12V. The ENABLE pin (pin 6) signal is generated by the voltage divider formed by R2 and R4. The divider also creates an under voltage lock out threshold of approximately 6.82V. If the user desires to use the board at an input voltage other than 12V the voltage divider may need to be adjusted.

Two feedback paths have been provided. The as-built path requires a jumper to be installed on J8. Should the user desire to regulate to a different voltage either remove the jumper from J8, install on J9 and populate the desired combination of C9, R6, R8, and/or R9. The two feedback paths provide the user the option to quickly return to the as-shipped configuration to serve as a health check. The user may also change R7 directly if they so choose.

Use separate or Kelvin connections to connect input and output monitoring equipment. When measuring output ripple voltage with an oscilloscope probe, the wire from the probe to the ground clip will act as an antenna, picking up excessive noise. For improved results, the test hook and ground clip should be removed from the probe and measurements taken with a ground spring. This reduces the noise seen on the waveform.

BNC connectors J4, J5, and J7 operate around R3. R3 is a 10Ω test resistor provided for use with equipment capable of generating Bode plots. The user connects the desired VNA with J4 being the injection point, J7 being the input and J5 the output of the regulator's control loop.

The board also features a transient load generator, detailed in the schematic on page 8. To use the transient generator it is recommended to use a separate 12V supply (positive input to J1) with J10 being the return. The transient generator is enabled by installing a jumper on J6 and J12. The J12 jumper is used to tie the reset pin high (to disable pulse loading) or low (to enable pulse loading). The circuit was designed to be used with the regulator output set to 3.3V. The generator, when enabled, pulls a constant 1A through R13 and pulses an additional 1A through R10 at an approximate 1% duty cycle.

Note 1: *The MSK5065RHG has a maximum minimum on time requirement of 260nS corresponding to a minimum duty cycle of 13% at 500kHz switching frequency. Forcing the device to operate at less than the minimum on time may result in irregular switching waveforms and present the appearance of instability.*

Output Voltage Programming

$V_{OUT} = V_{ref} * (1+R_t/1000)$
$R_{FB} = 1000\Omega * ((V_{OUT}/V_{ref})-1)$
Given: $V_{ref} = 0.600$V Typ.
Factory Configuration: $R_t = 4.42K\Omega$
$V_{OUT} = 0.600V * (1+4.42K\Omega/1K\Omega) = 3.25V$

Efficiency

Typical efficiency curves for 12V input and 5V input are shown in Figure 1.

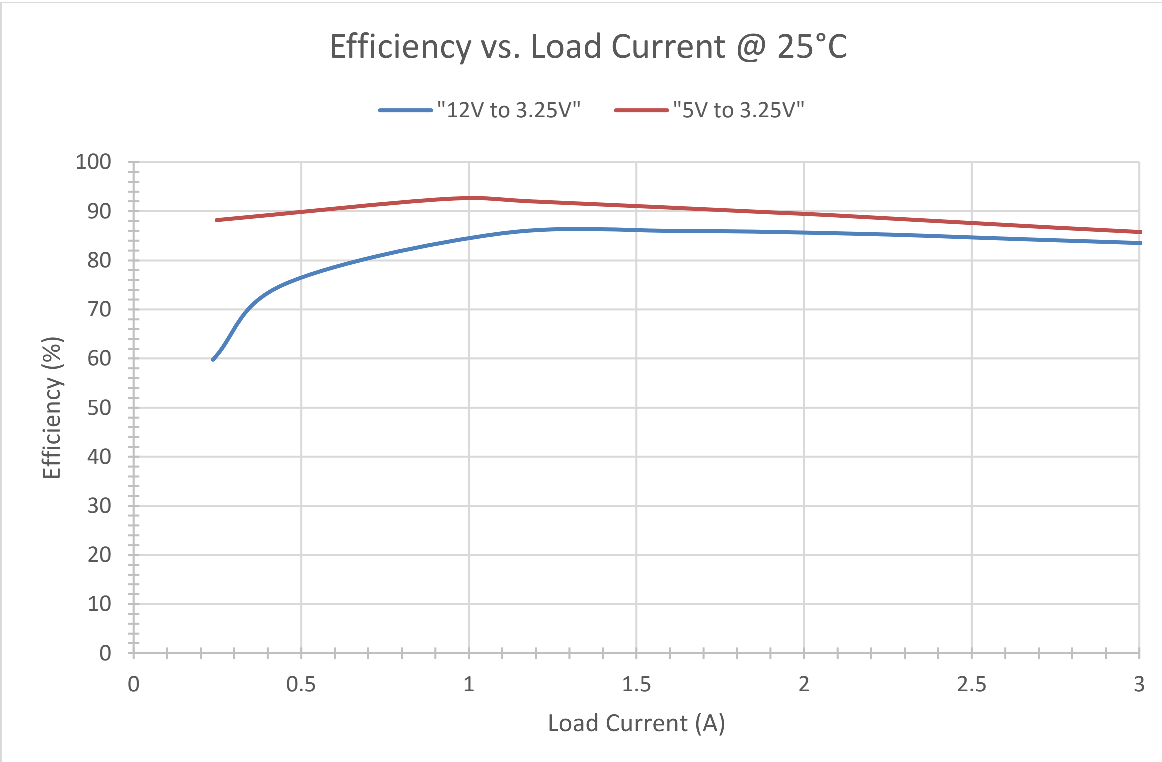
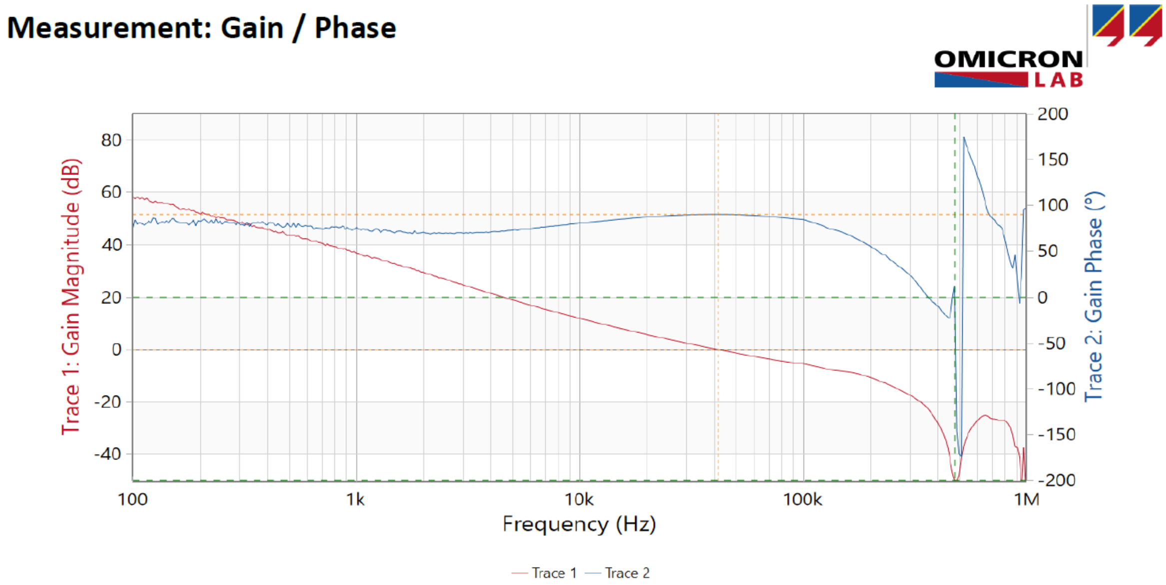


Figure 1

Loop Stability

Phase margin and gain margin are measures of stability in closed loop systems. Phase margin indicates relative stability, the tendency to oscillate during its damped response to an input change such as a line voltage step or a load step. Additionally, the phase margin measures how much phase variation is needed at the gain crossover frequency to lose stability. Gain margin is also an indication of relative stability. Gain margin measures how much the gain of the system can increase before the system becomes unstable. Together, these two numbers give an estimate of the safety margin for closed-loop stability. The smaller the stability margins, the more likely the circuit will become unstable.

One method for measuring the stability of a feedback circuit employs a network analyzer. Use an isolation transformer / adapter to isolate the grounded output analyzer from the feedback network. Connect the output of the isolation transformer across R3 using J4. Inject a swept frequency signal into the feedback loop, and plot the loop's gain and phase response between 100 Hz and 1 MHz. This provides a full picture of the frequency response on both sides of the unity gain frequency. Figure 2 illustrates typical results for 12.0V in, 3.25V out, at 2.8A Iout. The phase margin is the phase value at the unity gain frequency, or about 90 Deg. The gain margin is the gain at the 0° phase frequency, or approximately 50dB.



	Cursor 1	Cursor 2	
Frequency	479.502 kHz	41.711 kHz	
Trace 1	**Magnitude (dB)**	**Magnitude (dB)**	
Measurement	-49.94 dB	0 dB	
Trace 2	**Phase (°)**	**Phase (°)**	
Measurement	0 °	90.433 °	

Figure 2

The measurements in Figure 2 show that this regulator is overdamped. The system is very stable but not optimized for transient performance. As discussed in the product datasheet, the regulator is compensated internally. Transient performance of this design can be improved by reducing the value of each of the output capacitors. Another option would be to reduce the overall output capacitance by changing to a single lower value low ESR tantalum capacitor. Doing so will increase the ripple voltage, but this can be addressed by the addition of an LC filter on the output.

An alternate method to look at phase margin is to step the output load and monitor the response of the system to the transient. Filtering may be required to remove switching frequency components of the signal to make the small transients more visible. Any filter used for this measurement must be carefully designed such that it will not alter the signal of interest. A well behaved loop will settle back quickly and smoothly (Figure 3-C) and is termed critically damped, whereas a loop with poor phase or gain margin will either ring as it settles (Figure 3-B) under damped, or take too long to achieve the setpoint (Figure 3-A) over damped. The number of rings indicates the degree of stability, and the frequency of the ringing shows the approximate unity-gain frequency of the loop. The amplitude of the signal is not particularly important, as long as the amplitude is not so high that the loop behaves nonlinearly. This method is easy to implement in labs not equipped with network analyzers, but it does not indicate gain margin or evidence of conditional stability. In these situations, a small shift in gain or phase caused by production tolerances or temperature could cause instability even though the circuit functioned properly in development.

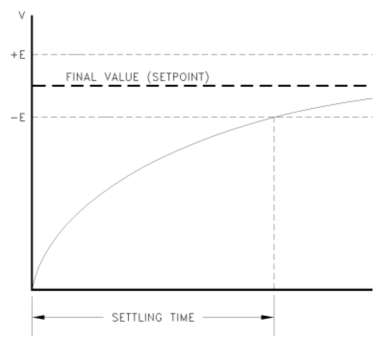


Figure 3-A

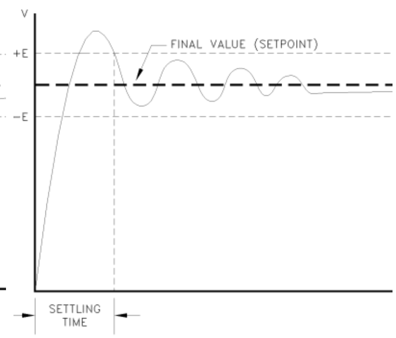


Figure 3-B

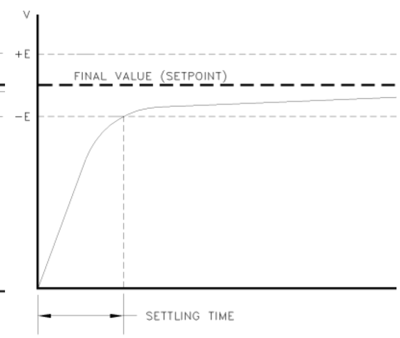


Figure 3-C

The transient load generator was used to perform the step load shown in Figure 4. The yellow trace is the input signal to the FET driver. The green trace is the regulator output with a one Amp load, which is pulsed to two Amps when the FET is on.

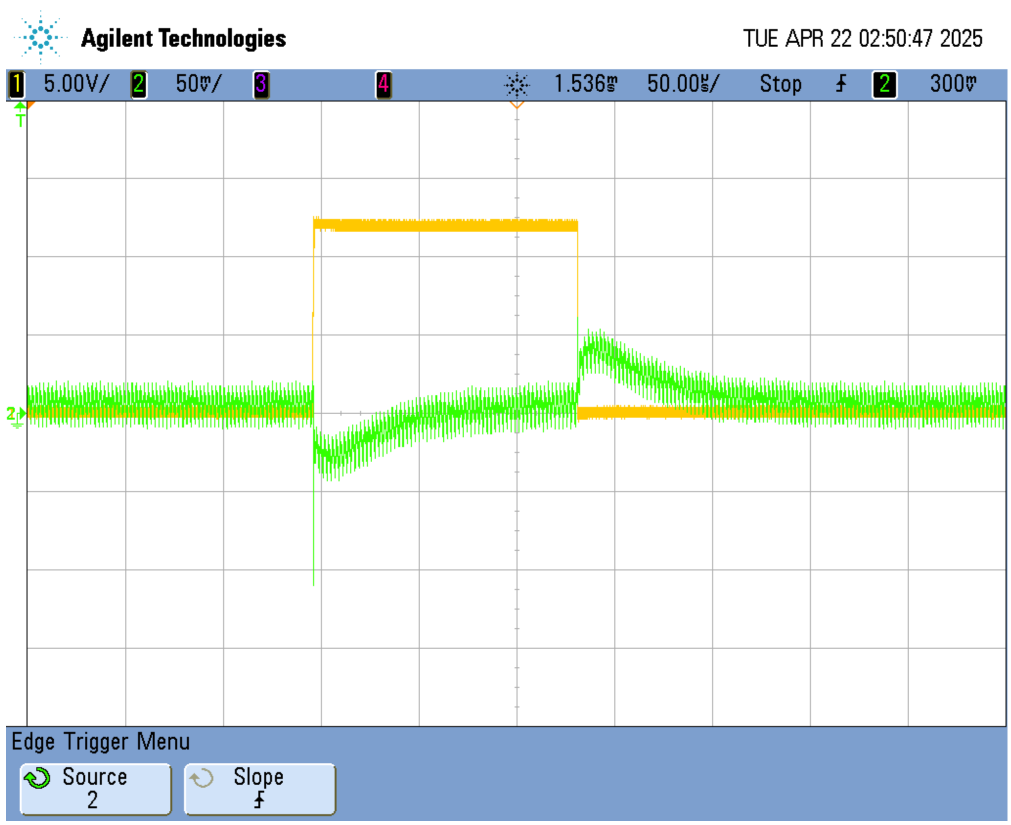


Figure 4

Input/Output Capacitors

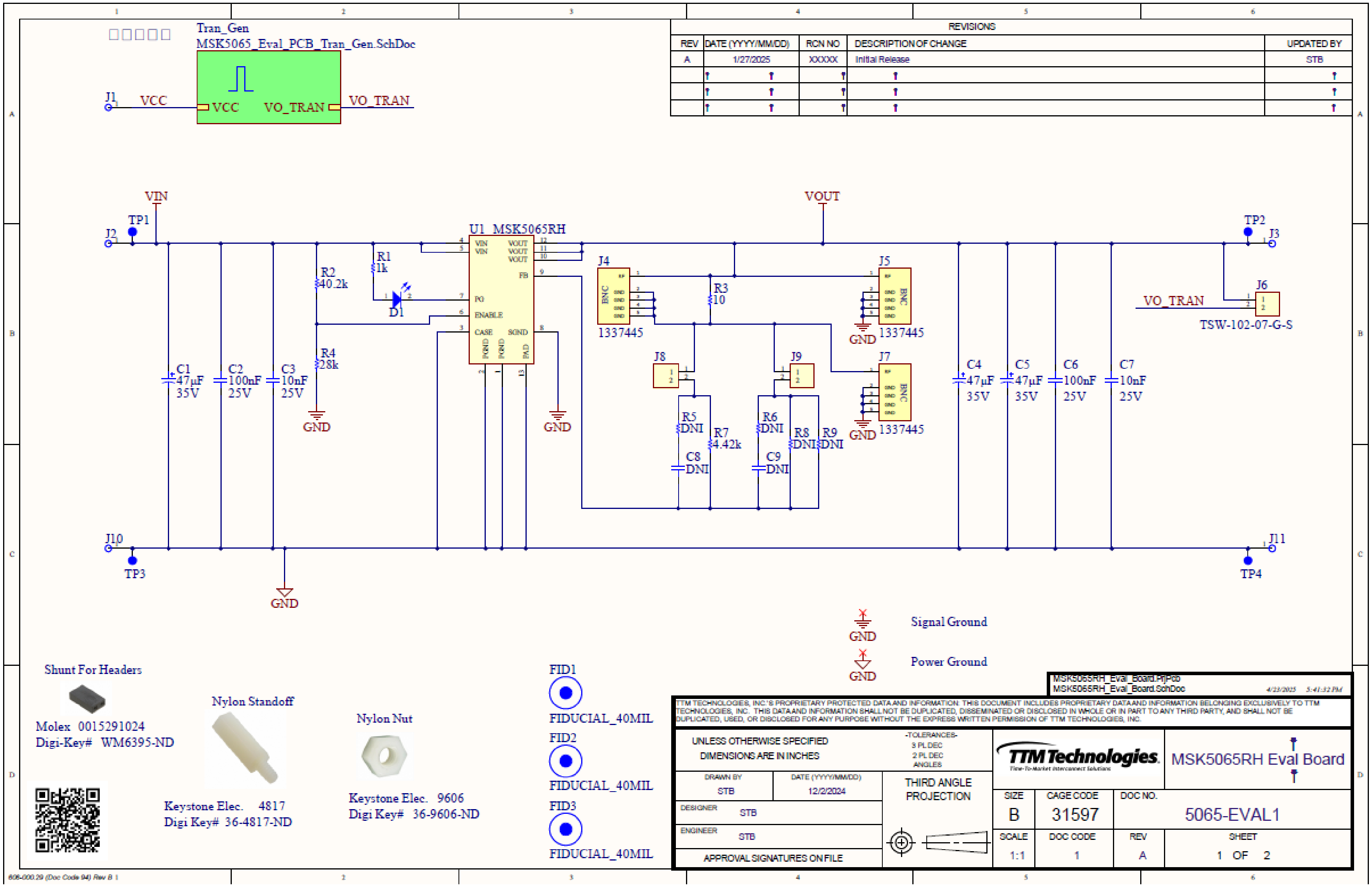
The input capacitor C1 was selected as an AVX TBM Series 47µF tantalum capacitors and was chosen due to their low ESR. See BOM for specific part number. The input ripple current for a buck converter is high, approximately $I_{OUT}/2$. Tantalum capacitors become resistive at higher frequencies, requiring careful ripple-rating selection to prevent excessive heating. Measure the capacitor case rise above ambient in the worst case thermal environment of the application, and if it exceeds 10°C, increase the voltage rating or lower the ESR rating. Ceramic capacitors' ESL (effective series inductance) tends to dominate their ESR, making them less susceptible to ripple-induced heating. Ceramic capacitors filter high frequencies well, C2 and C3 were chosen for that purpose, and it is important to note that they should be placed as close as possible to the device pins for optimal performance. As with any switching regulator circuit, input capacitor selection in your unique application must be informed by its upstream power distribution network impedance (Zout). Discussion of Middlebrook's stability criteria is beyond the scope of this application note. However, the reader is encouraged to become familiar with the concept.

The output capacitors C4 and C5 are also AVX TBM series 47µF tantalum capacitors. At switching frequencies, ripple voltage is more a function of ESR than of absolute capacitance value. If lower output ripple voltage is required, reduce the ESR by choosing a different capacitor or place more capacitors in parallel. For very low ripple, an additional LC filter on the output may be a more suitable solution. The output contains very narrow voltage spikes caused by the parasitic inductance of C4 and C5. Ceramic capacitors C6 and C7 remove these spikes on the demo board. In application, trace impedance and local bypass capacitors will perform this function.

Current Limitations

Continuous operation beyond the maximum continuous rating of 3A may damage the device.

Schematic



Tran_Gen
MSK5065_Eval_PCB_Tran_Gen.SchDoc
J1
VCC
VO_TRAN
REVISIONS
REV
DATE (YYYY/MM/DD)
RCN NO
DESCRIPTION OF CHANGE
UPDATED BY
A
1/27/2025
XXXXX
Initial Release
STB
VIN
VOUT
TP1
J2
U1 MSK5065RH
VIN
VOUT
FB
PG
ENABLE
CASE
SGND
PGND
PAD
R1 1k
R2 40.2k
R4 28k
D1
R3 10
J4
J5
J6
J7
J8
J9
1337445
BNC
GND
TSW-102-07-G-S
TP2
J3
C1 47µF 35V
C2 100nF 25V
C3 10nF 25V
C4 47µF 35V
C5 47µF 35V
C6 100nF 25V
C7 10nF 25V
R5 DNI
R6 DNI
R7 4.42k
R8 DNI
R9 DNI
C8 DNI
C9 DNI
J10
TP3
J11
TP4
Signal Ground
Power Ground
Shunt For Headers
Molex 0015291024
Digi-Key# WM6395-ND
Nylon Standoff
Keystone Elec. 4817
Digi Key# 36-4817-ND
Nylon Nut
Keystone Elec. 9606
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FID2
FID3
FIDUCIAL_40MIL
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MSK5065RH_Eval_Board.SchDoc
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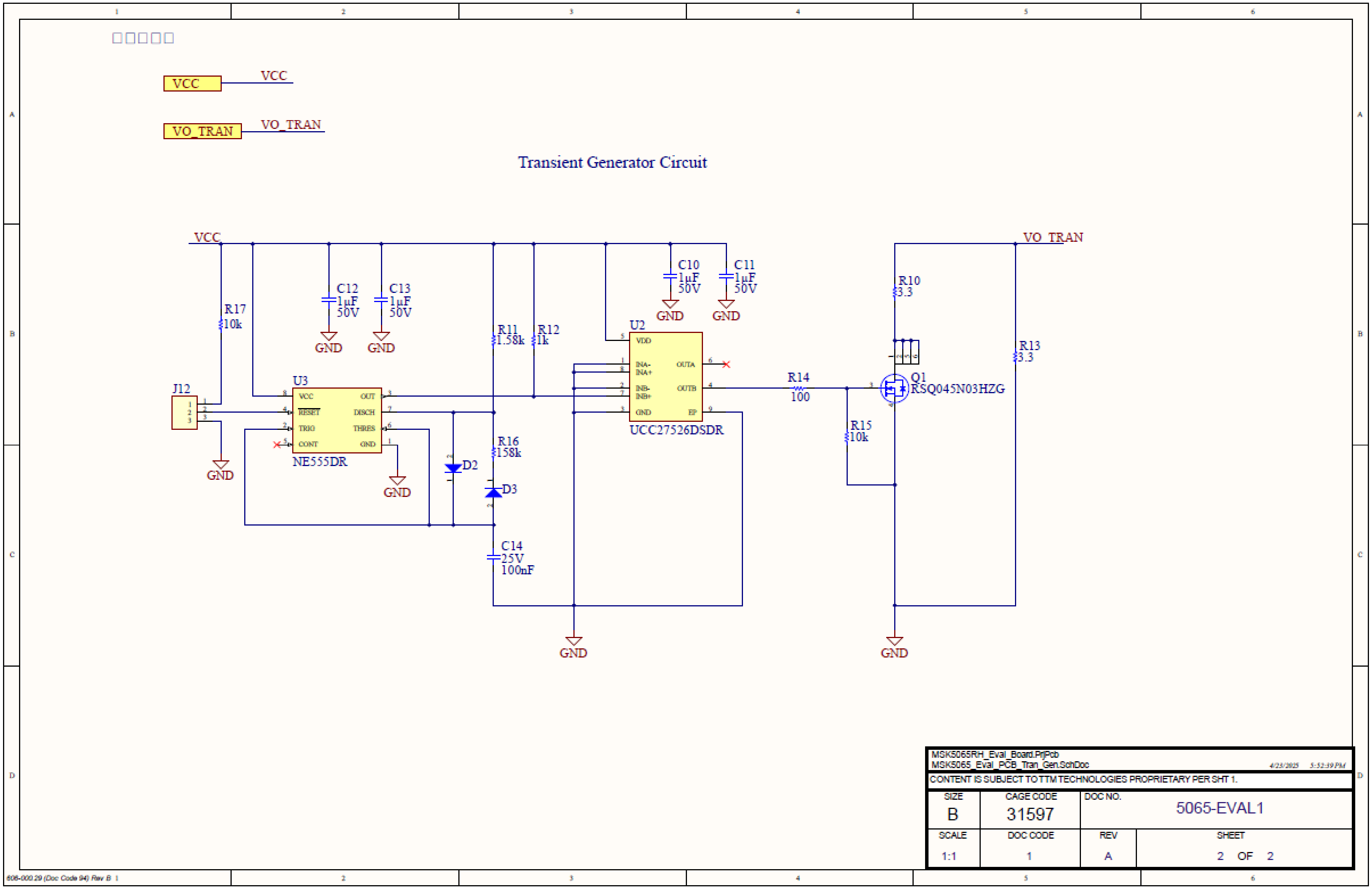
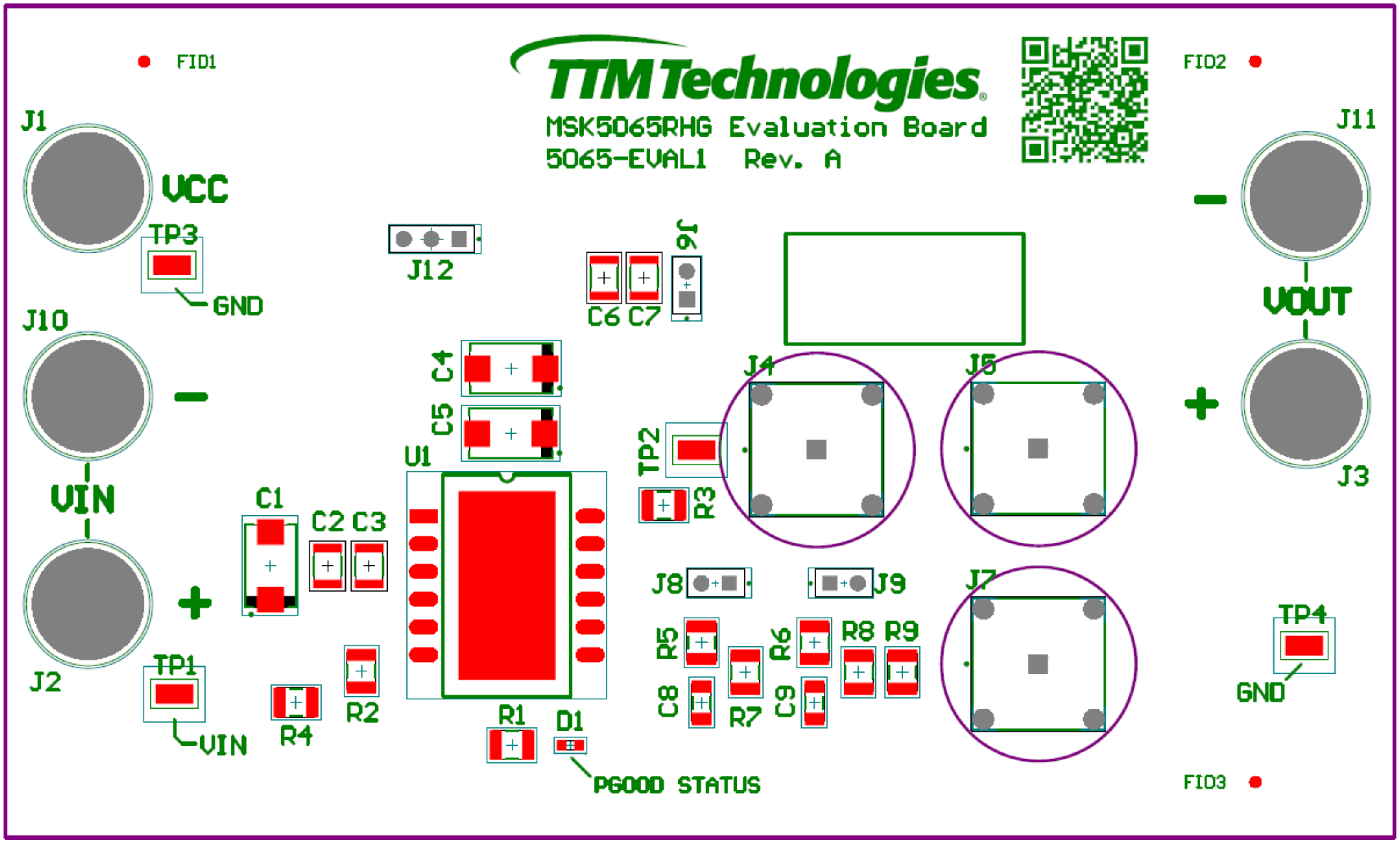
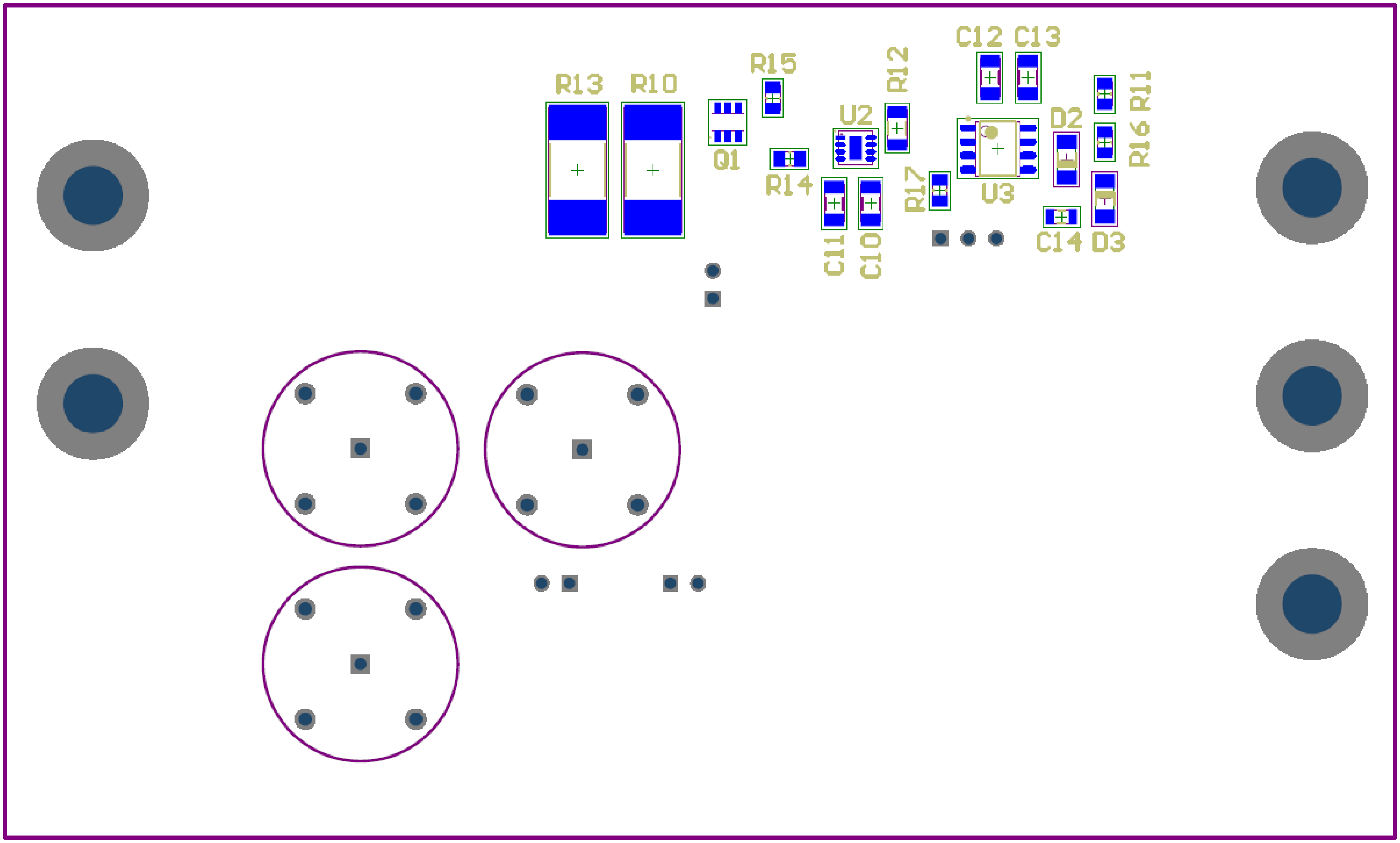
DIMENSIONS ARE IN INCHES
-TOLERANCES-
3 PL DEC
2 PL DEC
ANGLES
DRAWN BY
STB
DATE (YYYY/MM/DD)
12/2/2024
THIRD ANGLE PROJECTION
DESIGNER STB
ENGINEER STB
APPROVAL SIGNATURES ON FILE
MSK5065RH Eval Board
SIZE B
CAGE CODE 31597
DOC NO. 5065-EVAL1
SCALE 1:1
DOC CODE 1
REV A
SHEET 1 OF 2



VCC
VO_TRAN
Transient Generator Circuit
J12
R17 10k
C12 1µF 50V
C13 1µF 50V
GND
U3
NE555DR
R11 1.58k
R12 1k
R16 158k
D2
D3
C14 25V 100nF
C10 1µF 50V
C11 1µF 50V
U2
UCC27526DSDR
R14 100
R15 10k
R10 3.3
R13 3.3
Q1 RSQ045N03HZG
MSK5065RH_Eval_Board.PrjPcb
MSK5065_Eval_PCB_Tran_Gen.SchDoc
CONTENT IS SUBJECT TO TTM TECHNOLOGIES PROPRIETARY PER SHT 1.
SIZE B
CAGE CODE 31597
DOC NO. 5065-EVAL1
SCALE 1:1
DOC CODE 1
REV A
SHEET 2 OF 2

PCB Assembly




R13
R10
R15
Q1
R14
U2
R12
C11
C10
R17
C12
C13
U3
D2
R11
R16
C14
D3

Bill of Materials

Manufacturer 1	Name	Description	Designator	Quantity
Kyocera AVX	TBME476K035LRSB0823	CAP TANT 47uF 10% 35V E	C1, C4, C5	3
Kyocera AVX	12103C104K4T	CAP CER 0.1uf 25V X7R 1210	C2, C6	2
Kyocera AVX	12103C103K4T	CAP CER 10nf 25V X7R 1210	C3, C7	2
	DNI_CAPC3216X180N	CAP CER DNI 1206	C8, C9	2
Kyocera AVX	12065C105K4T	CAP CER 1uf 50V X7R 1206	C10, C11, C12, C13	4
Kyocera AVX	08053C104K4T	CAP CER 0.1uf 25V X7R 0805	C14	1
Vishay Lite-On	LTST-C190EKT	LED Uni-Color Red 630nm 2-Pin Chip LED T/R	D1	1
Microchip Technology	1N4148UR-1	Switching Diode	D2, D3	2
	FIDUCIAL_40MIL	FIDUCIAL, 40MIL PAD, 120MIL COPPER CLEARANCE	FID1, FID2, FID3	3
Keystone Electronics	575-4	Banana Jack- Non-Insulated .218" Length	J1, J2, J3, J10, J11	5
TE Connectivity	1337445	CONN BNC JACK Straight, 50 OHM PCB. TE CONNECTIVITY	J4, J5, J7	3
Samtec	TSW-102-07-G-S	SAMTEC - TSW-102-07-G-S - Board-To-Board Connector, Unshrouded, TSW Series, Through Hole, Header, 2, 2.54 mm	J6, J8, J9	3
Samtec	TSW-103-07-G-S	SAMTEC - TSW-103-07-G-S - Board-To-Board Connector, Unshrouded, TSW Series, Through Hole, Header, 3, 2.54 mm	J12	1
Rohm	RSQ045N03HZG	Trans MOSFET N-CH 30V 4.5A 6-Pin TSMT T/R	Q1	1
Vishay Dale	CRCW12101K00FKEA	RES SMD 1K OHM 1% 1/2W 1210	R1	1
Vishay Dale	CRCW121040K2FKEA	RES SMD 40.2K OHM 1% 1/2W 1210	R2	1
Vishay	CRCW121010R0FKEA	RES SMD 10 OHM 1% 1/2W 1210	R3	1
Vishay Dale	CRCW121028K0FKEA	RES SMD 28K OHM 1% 1/2W 1210	R4	1
	DNI_RESC3225X60	RES SMD DNI 1/2W 1210	R5, R6, R8, R9	4
Vishay Dale	CRCW12104K42FKEA	RES SMD 4.42K OHM 1% 1/2W 1210	R7	1
TE Connectivity	35503R3FT	RES SMD 3.3 OHM 1% 5W 3550	R10, R13	2
Vishay	CRCW08051K58FKEA	RES SMD 1.58K OHM 1% 1/8W 0805	R11	1
Vishay	CRCW12061K00FKEA	RES SMD 1K OHM 1% 1/4W 1206	R12	1
Vishay Dale	CRCW0805100RFKEA	RES SMD 100 OHM 1% 1/8W 0805	R14	1
Vishay	CRCW080510K0FKEA	RES SMD 10K OHM 1% 1/8W 0805	R15, R17	2
Vishay	CRCW0805158KFKEA	RES SMD 158K OHM 1% 1/8W 0805	R16	1
Keystone Electronics	5015	TEST POINT, PCB, SMT	TP1, TP2, TP3, TP4	4
TTM Technologies	MSK5065RHG	RAD HARD 3A, 500KHZ SWITCHING REGULATOR	U1	1
Texas Instruments	UCC27526DSDR	5-A/5-A dual-channel gate driver with 5-V UVLO, enable, and dual TTL inputs 8-SON -40 to 140	U2	1
Texas Instruments	NE555DR	555 Type, Timer/Oscillator (Single) Surface Mount 8-SOIC	U3	1