

## ISL71043M, ISL71041M

Radiation Tolerant Single-Ended Current Mode PWM Controllers

The [ISL71043M](#) and [ISL71041M](#) are PWM controllers suitable for a wide range of power conversion applications including boost, flyback, and isolated output configurations. Fast signal propagation and output switching characteristics make these ideal products for existing and new designs.

Features include up to 13.2V operation, 2.9mA operating current, 90µA typical start-up current, adjustable operating frequency to 1MHz and, 1A current drive capability with 35ns rise and 29ns fall times.

The ISL71041M and ISL71043M are available in an 8 LD TDFN package and the ISL71043M is also available in an 8 LD SOIC package. Both packages are specified across the extended temperature range of -55°C to +125°C.

### Applications

- Current mode switching power supplies
- Isolated buck and flyback regulators
- Boost regulators
- Direction and speed control in motors
- Control of high current FET drivers

### Features

- 1A MOSFET gate driver
- 90µA typical start-up current, 125µA maximum
- 35ns propagation delay current sense to output
- Fast transient response with Peak Current mode control
- 9V to 13.2V operation
- Adjustable switching frequency to 1MHz
- 35ns rise time and 29ns fall time with 1nF output load
- Trimmed timing capacitor discharge current for accurate dead time/maximum duty cycle control
- 1.5MHz bandwidth error amplifier
- Tight tolerance voltage reference over line, load, and temperature
- ±3% current limit threshold
- Ni/Pd/Au-Ag lead finish (Tin (Sn) free)
- Characterized radiation levels - ISL71041M
  - Low Dose Rate (LDR) (0.01rad(Si)/s): 30krad(Si)
- Radiation acceptance testing - ISL71043M
  - Low Dose Rate (LDR) (0.01rad(Si)/s): 50krad(Si)
- Single event burnout LET 43MeV•cm<sup>2</sup>/mg

**Table 1. Key Differences Between Family of Parts**

Part Number	Rising UVLO (V)	Maximum Duty Cycle (%)	Packages Available
ISL71041M	7.0	50	8 Ld TDFN
ISL71043M	8.4	100	8 Ld TDFN, 8 Ld SOIC

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# 1. Overview

## 1.1 Typical Application Schematics

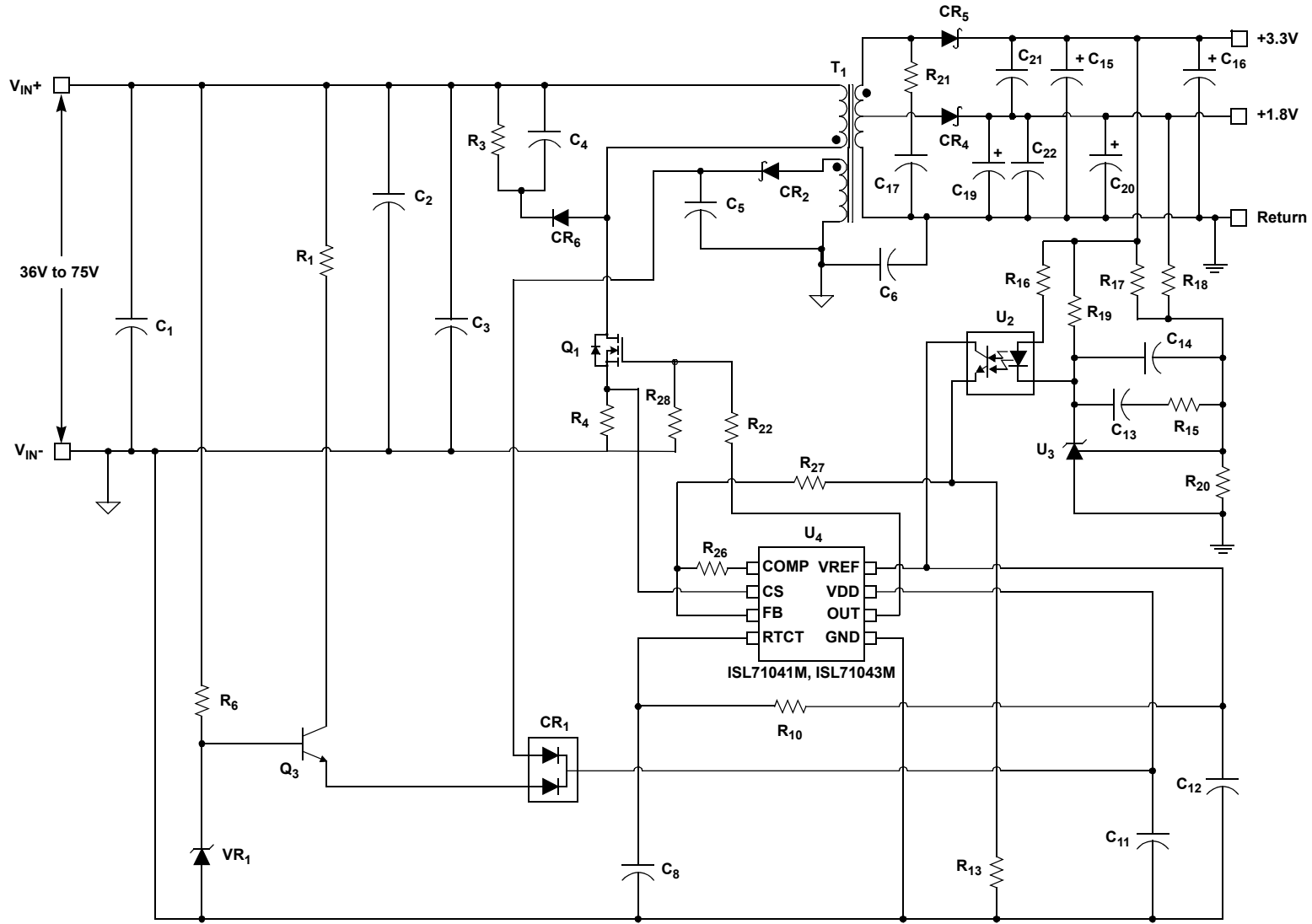


Figure 1. 48V Input Dual Output Flyback

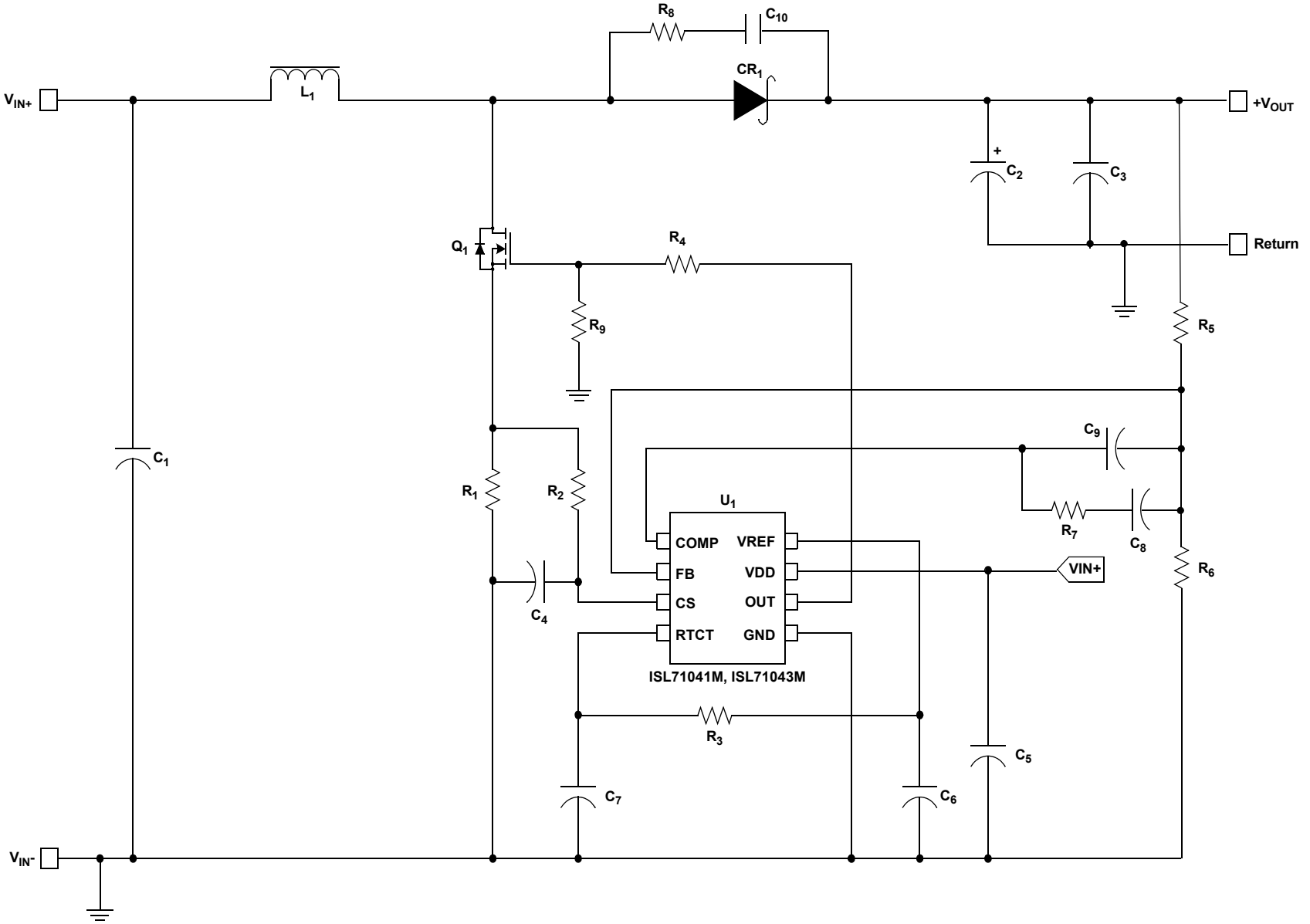


Figure 2. Boost Converter

## 1.2 Functional Block Diagram

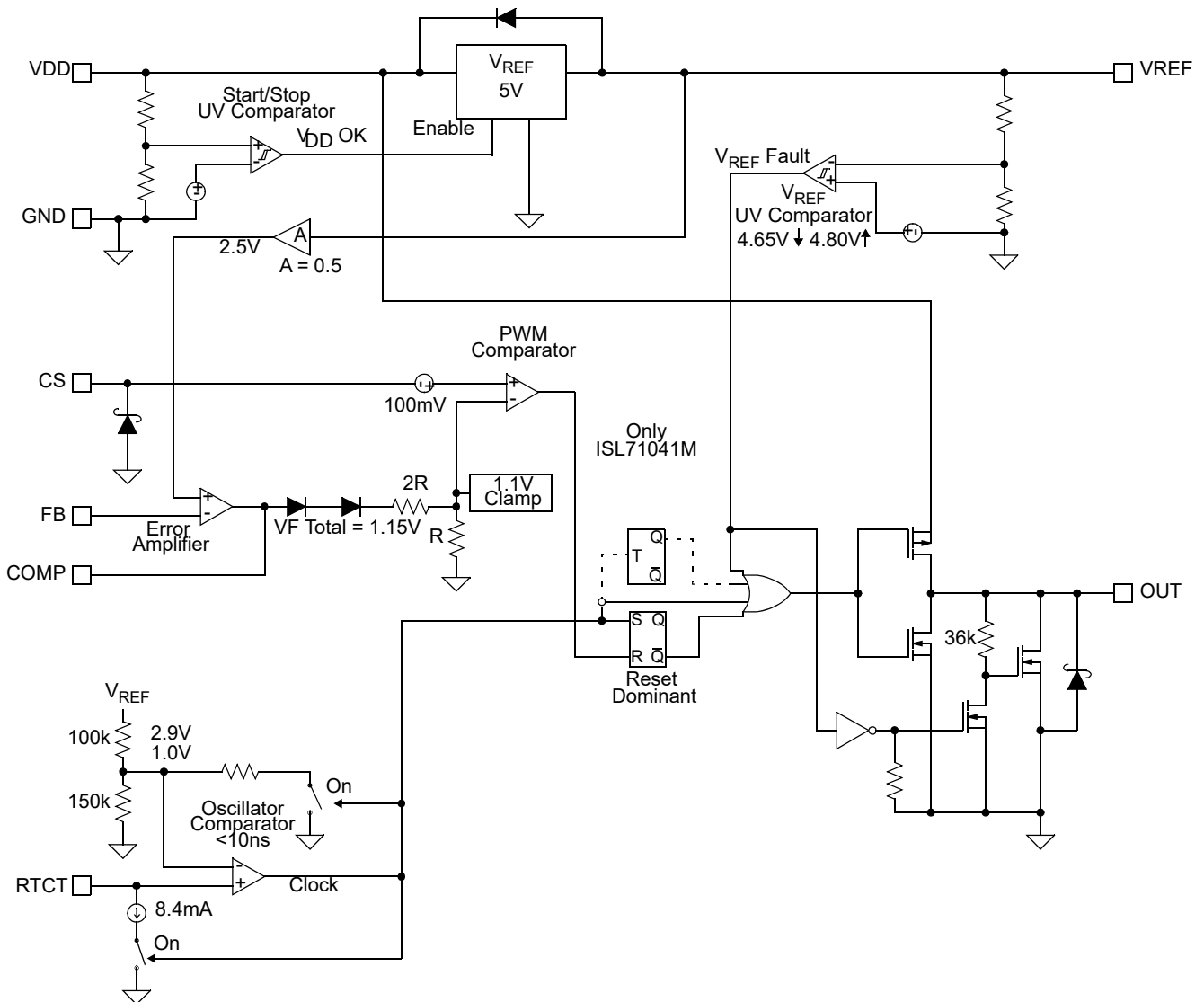
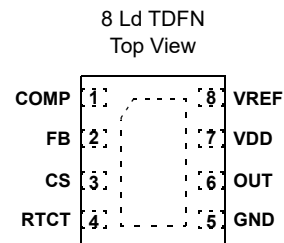
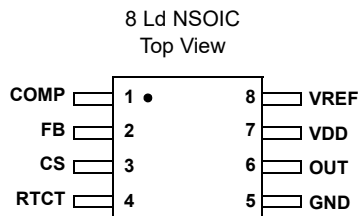


Figure 3. Block Diagram

## 2. Pin Information

### 2.1 Pin Assignments



## 2.2 Pin Descriptions

Pin #	Pin Name	Description
1	COMP	The output of the error amplifier and the input of the PWM comparator. The control loop frequency compensation network is connected between the COMP and FB pins.
2	FB	The output voltage feedback is connected to the inverting input of the error amplifier through this pin. The noninverting input of the error amplifier is internally tied to a reference voltage.
3	CS	The current sense input to the PWM comparator. The range of the input signal is nominally 0V to 1.0V and has an internal offset of 100mV.
4	RTCT	<p>The oscillator timing control pin. Set the operational frequency and maximum duty cycle by connecting a resistor, RT, between VREF and this pin and a timing capacitor, CT, from this pin to GND. The oscillator produces a sawtooth waveform with a programmable frequency range up to 1.0MHz. The charge time, t<sub>C</sub>, the discharge time, t<sub>D</sub>, the RTCT oscillator frequency, f, and the maximum duty cycle, D<sub>MAX</sub>, can be approximated using <a href="#">Equation 1</a> through <a href="#">Equation 4</a>:</p> <p>(EQ. 1) <math>t_C \approx 0.533 \cdot RT \cdot CT</math></p> <p>(EQ. 2) <math>t_D \approx -RT \cdot CT \cdot \ln \left( \frac{0.008 \cdot RT - 3.83}{0.008 \cdot RT - 1.71} \right)</math></p> <p>(EQ. 3) <math>f = 1 / (t_C + t_D)</math></p> <p>(EQ. 4) <math>D = t_C \cdot f</math></p> <p>The equations have increased error at higher frequencies due to propagation delays. <a href="#">Figure 4</a> can be used as a guideline in selecting the capacitor and resistor values required for a given oscillator frequency for the ISL71041M and ISL71043M.</p>
5	GND	GND is the power and small signal reference ground for all functions.
6	OUT	The drive output to the power switching device. This high current output is able to drive the gate of a power MOSFET with peak currents of 1.0A. This GATE output is actively held low when V <sub>DD</sub> is below the UVLO threshold.
7	VDD	<p>The power connection for the device. The total supply current depends on the load applied to OUT. The total I<sub>DD</sub> current is the sum of the operating current and the average output current. Use the operating frequency, f, and the MOSFET gate charge, Q<sub>g</sub>, to calculate the average output current using <a href="#">Equation 5</a>:</p> <p>(EQ. 5) <math>I_{OUT} = Q_g \times f</math></p> <p>To optimize noise immunity, bypass VDD to GND with a ceramic capacitor as close to the VDD and GND pins as possible.</p>
8	VREF	The 5.00V reference voltage output. ±2% tolerance over line, load, and operating temperature. The recommended bypass to GND capacitor is in the range 0.1µF to 0.22µF. A typical value of 0.15µF can be used.
-	EPAD	<p>Applicable to TDFN package only.</p> <p>The exposed pad should be connected externally to GND. Put as many vias as possible in this pad connecting to other PCB layers to improve heat dissipation.</p>

### 3. Specifications

#### 3.1 Absolute Maximum Ratings

**Caution:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

Parameter	Minimum	Maximum	Unit
V <sub>DD</sub>	GND - 0.3	+30.0	V
V <sub>DD</sub> <sup>[1]</sup>	GND - 0.3	+14.7	V
OUT	GND - 0.3	V <sub>DD</sub> + 0.3	V
Signal Pins	-	6.0	V
Peak Current on OUT	-	1	A
Maximum Junction Temperature	-	+150	°C
Maximum Storage Temperature Range	-65	+150	°C
Human Body Model (Tested per JS-001-2017)	-	1.5	kV
Machine Model (Tested per JESD22-A115C)	-	200	V
Charged Device Model (Tested per JS-002-2014)	-	1	kV
Latch-Up (Tested per JESD-78E; Class 2, Level A) at 125°C	-	100	mA

1. Tested in a heavy ion environment at LET = 43MeV·cm<sup>2</sup>/mg at +125°C (TC) for SEB.

#### 3.2 Outgas Specifications

Specification (Tested per ASTM E595, 1.5)	Value	Unit
Total Mass Loss <sup>[1]</sup>	0.06	%
Collected Volatile Condensable Material <sup>[1]</sup>	<0.01	%
Water Vapor Recovered	0.03	%

1. Outgassing results meet NASA requirement soft total mass loss <1% and collected volatile condensable material of <0.1%.

#### 3.3 Thermal Specifications

Parameter	Package	Symbol	Conditions	Typical Value	Unit
Thermal Resistance	8 Ld SOIC Package	$\theta_{JA}$ <sup>[1]</sup>	Junction to ambient	105	°C/W
		$\theta_{JC}$ <sup>[2]</sup>	Junction to case	50	
	8 Ld 4x4 TDFN Package	$\theta_{JA}$ <sup>[3]</sup>	Junction to ambient	41	
		$\theta_{JC}$ <sup>[4]</sup>	Junction to case	2.5	

- $\theta_{JA}$  is measured in free air with the component mounted on a high-effective thermal conductivity test board in free air. See [TB379](#).
- For  $\theta_{JC}$ , the case temperature location is the package top center.
- $\theta_{JA}$  is measured in free air with the component mounted on a high-effective thermal conductivity test board with direct attach features. See [TB379](#).
- For  $\theta_{JC}$ , the case temperature location is the center of the exposed metal pad on the package underside.

### 3.4 Recommended Operating Conditions

Parameter	Minimum	Maximum	Unit
V <sub>DD</sub>	9	13.2	V
Temperature	-55	+125	°C

### 3.5 Electrical Specifications

Recommended operating conditions unless otherwise noted. V<sub>DD</sub> = 13.2V, R<sub>T</sub> = 10kΩ, C<sub>T</sub> = 3.3nF, T<sub>A</sub> = -55°C to +125°C. Typical values are at T<sub>A</sub> = +25°C. **Boldface limits apply across the operating temperature range, -55°C to +125°C.**

Parameter	Symbol	Test Conditions	Min <sup>[1]</sup>	Typ	Max <sup>[1]</sup>	Unit
<b>Undervoltage Lockout</b>						
Start Threshold	UVLO_V <sub>START</sub>	ISL71041M	<b>6.5</b>	7.0	<b>7.5</b>	V
Start Threshold		ISL71043M	<b>8.0</b>	8.4	<b>9.0</b>	V
Stop Threshold	UVLO_V <sub>STOP</sub>	ISL71041M	<b>6.1</b>	6.7	<b>6.9</b>	V
Stop Threshold		ISL71043M	<b>7.3</b>	7.6	<b>8.0</b>	V
Hysteresis	UVLO_Hyst	ISL71041M	-	0.4	-	V
Hysteresis		ISL71043M	-	0.8	-	V
Start-Up Current, I <sub>DD</sub>	I <sub>DDSu</sub>	V <sub>DD</sub> < Start Threshold	-	90	<b>125</b>	μA
Operating Current, I <sub>DD</sub>	I <sub>DDOp</sub>		-	2.9	<b>4.0</b>	mA
Operating Supply Current, I <sub>D</sub>	IDO <sub>p_LOAD</sub>	Includes 1nF GATE loading	-	4.7	<b>5.5</b>	mA
	I <sub>DDq</sub>	[2]	-	2.9	<b>4.0</b>	mA
<b>Reference Voltage</b>						
Overall Accuracy	V <sub>REF</sub>	Over line (V <sub>DD</sub> = 9V to 13.2V), load of 1mA and 10mA	<b>4.925</b>	5.0	<b>5.050</b>	V
Long Term Stability [3]	V <sub>REF_ST</sub>	T <sub>A</sub> = +125°C, 1000 hours	-	5	-	mV
Current Limit, Sourcing	I <sub>SOURCE</sub>		<b>-20</b>	-40	-	mA
Current Limit, Sinking	I <sub>SINK</sub>		<b>5</b>	20	-	mA
<b>Current Sense</b>						
Input Bias Current	CS_I <sub>BIAS</sub>	V <sub>CS</sub> = 1V	<b>-1.0</b>	-	<b>1.0</b>	μA
Input Signal, Maximum	V <sub>MAX_IN</sub>		<b>0.97</b>	1.00	<b>1.03</b>	V
Gain, A <sub>CS</sub> = ΔV <sub>COMP</sub> /ΔV <sub>CS</sub>	COMP_Gain	0 < V <sub>CS</sub> < 910mV, V <sub>FB</sub> = 0V	<b>2.75</b>	2.82	<b>3.15</b>	V/V
CS to OUT Delay	TPCStoOUT		-	35	<b>60</b>	ns
<b>Error Amplifier</b>						
Open Loop Voltage Gain	AVOL		-	90	-	dB
Unity Gain Bandwidth	UGB		-	1.5	-	MHz
Reference Voltage, V <sub>REF</sub>	EA_V <sub>REF</sub>	V <sub>FB</sub> = V <sub>COMP</sub>	<b>2.475</b>	2.5	<b>2.530</b>	V
FB Input Bias Current, FB I <sub>IB</sub>	FB_I <sub>BIAS</sub>	V <sub>FB</sub> = 0V	<b>-1.5</b>	-0.2	<b>1.5</b>	μA
COMP Sink Current	COMP_I <sub>OL</sub>	V <sub>COMP</sub> = 1.5V, V <sub>FB</sub> = 2.7V	<b>1.0</b>	5	-	mA
COMP Source Current	COMP_I <sub>OH</sub>	V <sub>COMP</sub> = 1.5V, V <sub>FB</sub> = 2.3V	<b>-0.4</b>	-0.5	-	mA
COMP V <sub>OH</sub>	COMP_V <sub>OH</sub>	V <sub>FB</sub> = 2.3V	<b>4.80</b>	-	<b>V<sub>REF</sub></b>	V



## ISL71043M, ISL71041M Datasheet

Recommended operating conditions unless otherwise noted.  $V_{DD} = 13.2V$ ,  $R_T = 10k\Omega$ ,  $C_T = 3.3nF$ ,  $T_A = -55^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_A = +25^\circ C$ . **Boldface limits apply across the operating temperature range,  $-55^\circ C$  to  $+125^\circ C$ .** (Cont.)

Parameter	Symbol	Test Conditions	Min <sup>[1]</sup>	Typ	Max <sup>[1]</sup>	Unit
COMP $V_{OL}$	COMP_ $V_{OL}$	$V_{FB} = 2.7V$	<b>0.4</b>	-	<b>1.0</b>	V
Power Supply Rejection Ratio	PSRR	Frequency = 120Hz, $V_{DD} = 9V$ to 13.2V	-	80	-	dB
<b>Oscillator</b>						
Frequency Accuracy	Freq_ $V_{MAX}$	Initial, $T_A = +25^\circ C$	48	51	54	kHz
Frequency Variation with $V_{DD}$	Freq_PSRR	$T_A = +25^\circ C$ , $(f_{13.2V} - f_{9V})/f_{12V}$	-1.0	0.2	1.0	%
Temperature Stability <sup>[3]</sup>			-	5	-	%
Amplitude, Peak-to-Peak	RTCTV <sub>pp</sub>	Static Test	-	1.75	-	V
RTCT Valley Voltage	RTCTV <sub>DIS</sub>	Static Test	-	1.0	-	V
Discharge Current	RTCTI <sub>DIS</sub>	RTCT = 2.0V	<b>6.5</b>	7.8	<b>8.5</b>	mA
<b>Output</b>						
Gate $V_{OH}$ <sup>[4]</sup>	$V_{OH}$	$V_{DD}$ to OUT, $I_{OUT} = -100mA$	-	0.5	<b>1.0</b>	V
Gate $V_{OL}$ <sup>[4]</sup>	$V_{OL}$	OUT to GND, $I_{OUT} = 100mA$	-	0.5	<b>1.0</b>	V
Gate $V_{OH}$ <sup>[4]</sup>	$V_{OH}$	$V_{DD}$ to OUT, $I_{OUT} = -8mA$	-	40	<b>80</b>	mV
Gate $V_{OL}$ <sup>[4]</sup>	$V_{OL}$	OUT to GND, $I_{OUT} = 8mA$	-	40	<b>80</b>	mV
Peak Output Current <sup>[3]</sup>	$I_{OPK}$	$C_{OUT} = 1nF$	-	1.0	-	A
Rise Time	OUT_RT	$C_{OUT} = 1nF$	-	35	<b>60</b>	ns
Fall Time	OUT_FT	$C_{OUT} = 1nF$	-	29	<b>40</b>	ns
Output Off State Leakage	IDoff	$V_{DD} = 5V$	-	-	<b>50</b>	$\mu A$
<b>PWM</b>						
Maximum Duty Cycle	MAX_Duty	COMP = $V_{REF}$ (ISL71041M)	<b>47</b>	48	<b>50</b>	%
		COMP = $V_{REF}$ (ISL71043M)	<b>94</b>	96	-	
Minimum Duty Cycle	MIN_Duty	COMP = GND	-		<b>0</b>	%

- Parameters with Min and/or Max limits are 100% tested at  $+25^\circ C$ , unless otherwise specified. Temperature limits established by characterization and are not production tested.
- This is the  $V_{DD}$  current consumed when the device is active but not switching. Does not include gate drive current.
- Compliance to limits is assured by characterization and design.
- See [ISL71043M Radiation Acceptance Test Limits](#) for the ISL71043M test limits for this specification.

### 3.5.1 ISL71043M Radiation Acceptance Test Limits

ISL71043M LDR acceptance testing is held to the same electrical specifications as the [Electrical Specifications](#), except for the expanded limits below. Typical values of key parameters after 50krad(Si) are shown in [Table 6](#).

Recommended operating conditions unless otherwise noted.  $V_{DD} = 13.2V$ ,  $R_T = 10k\Omega$ ,  $C_T = 3.3nF$ . Typical values are at  $T_A = +25^\circ C$ . **Boldface limits apply over a total ionizing dose of 50krad(Si) at +25°C with exposure at a low dose rate of <10mrad(Si)/s**

Parameter	Symbol	Test Conditions	Min <sup>[1]</sup>	Typ	Max <sup>[1]</sup>	Unit
<b>Output</b>						
Gate $V_{OH}$	$V_{OH}$	$V_{DD}$ to OUT, $I_{OUT} = -100mA$		0.8	<b>2.0</b>	V
Gate $V_{OL}$	$V_{OL}$	OUT to GND, $I_{OUT} = 100mA$		0.5	<b>2.0</b>	V
Gate $V_{OH}$	$V_{OH}$	$V_{DD}$ to OUT, $I_{OUT} = -8mA$		50	<b>160</b>	mV
Gate $V_{OL}$	$V_{OL}$	OUT to GND, $I_{OUT} = 8mA$		40	<b>160</b>	mV

- Parameters with Min and/or Max limits are 100% tested at +25°C, unless otherwise specified. Temperature limits established by characterization and are not production tested.

## 4. Typical Performance Curves

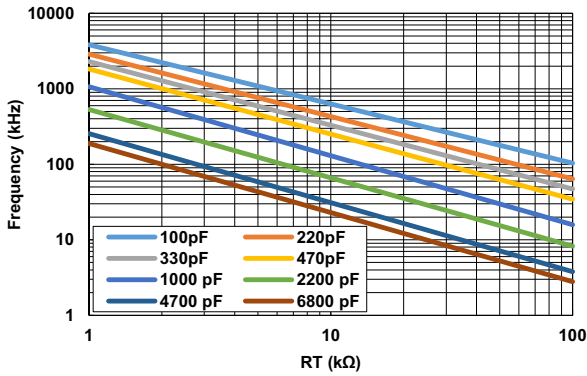


Figure 4. Resistance for CT Capacitor Values

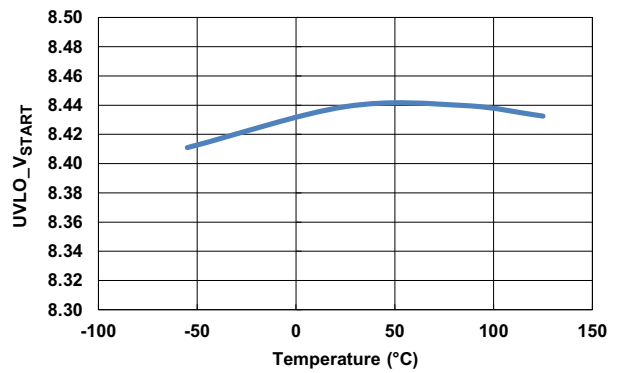


Figure 5. Start Threshold Over Temperature

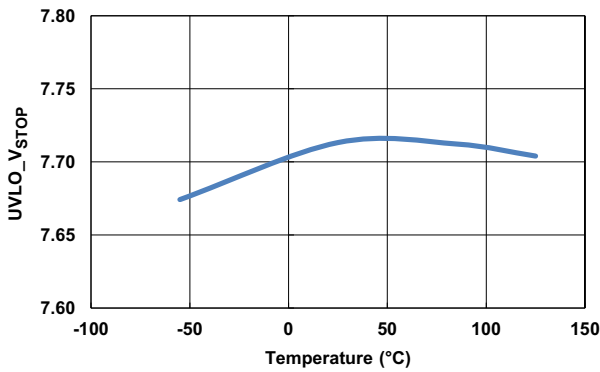


Figure 6. Stop Threshold Over Temperature

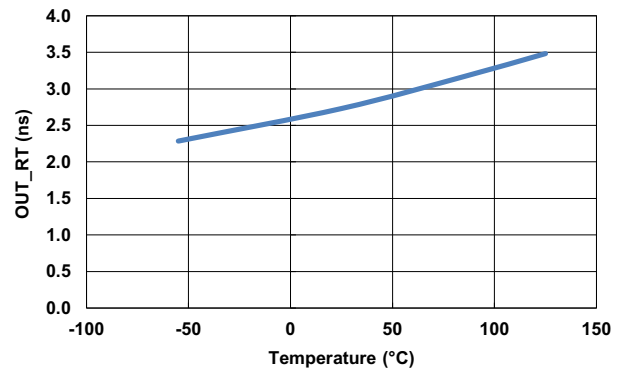


Figure 7. Rise Time Over Temperature

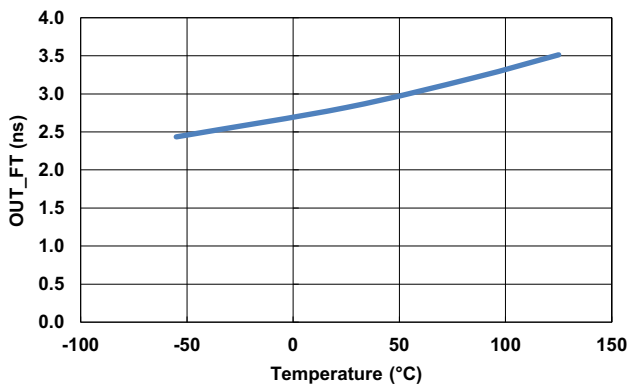


Figure 8. Fall Time Over Temperature

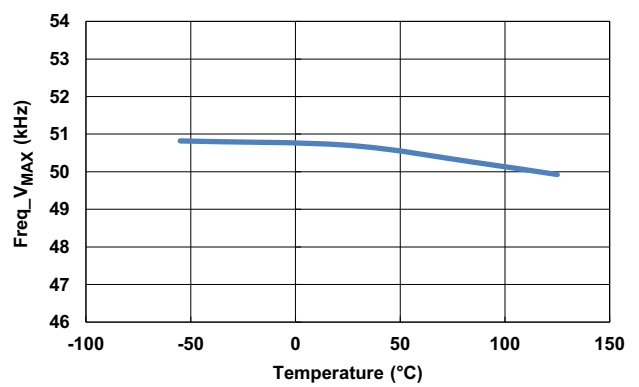


Figure 9. Frequency Accuracy Over Temperature

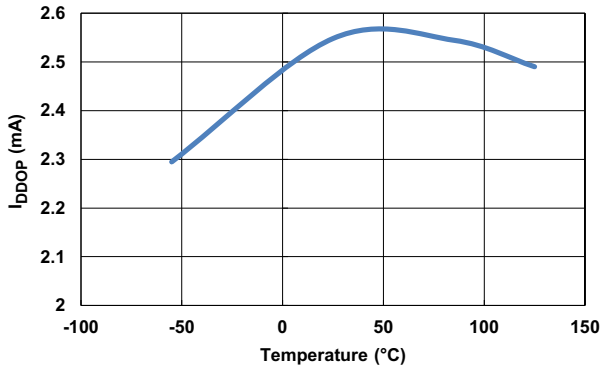


Figure 10. Operating Current Over Temperature

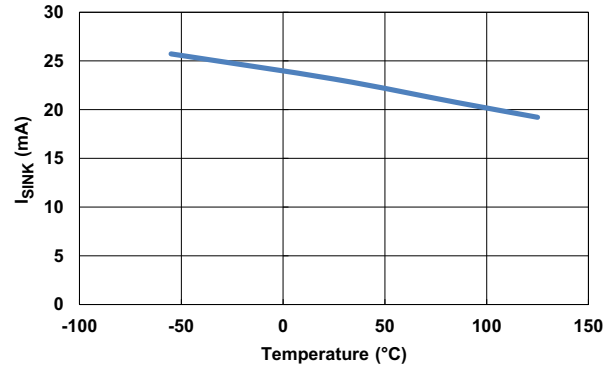


Figure 11. Current Limit, Sinking Over Temperature

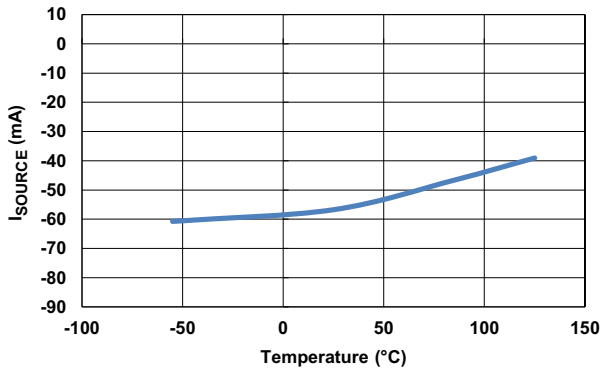


Figure 12. Current Limit, Sourcing Over Temperature

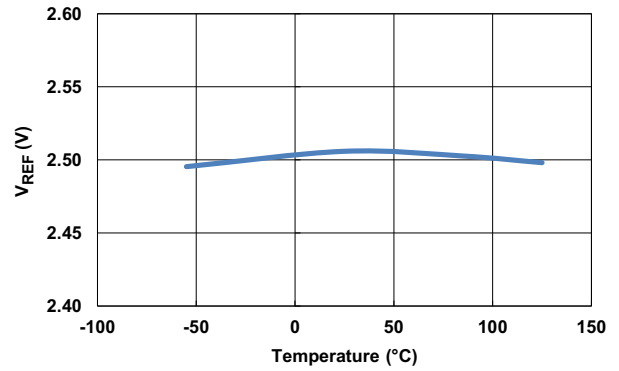


Figure 13. Reference Voltage Over Temperature

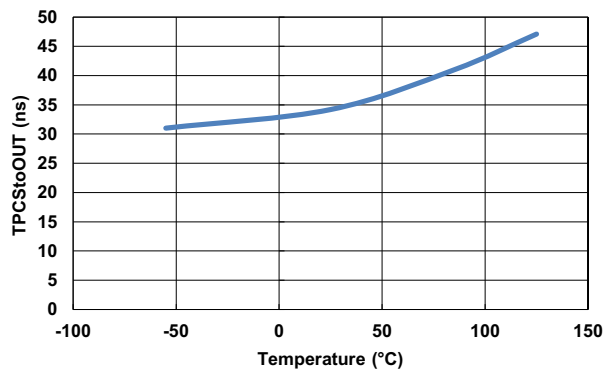


Figure 14. CS to Out Delay Over Temperature

## 5. Functional Description

### 5.1 Features

The ISL71041M and ISL71043M current mode PWM makes them an ideal choice for low-cost flyback and forward topology applications.

### 5.2 Oscillator

The ISL71041M and ISL71043M devices have a sawtooth oscillator with a programmable frequency range to 1MHz that can be programmed with a resistor from VREF and a capacitor to GND on the RTCT pin (see Figure 4 for the resistor and capacitance required for a given frequency).

### 5.3 Soft-Start Operation

Soft-start must be implemented externally. Figure 15 shows one method that clamps the voltage on COMP.

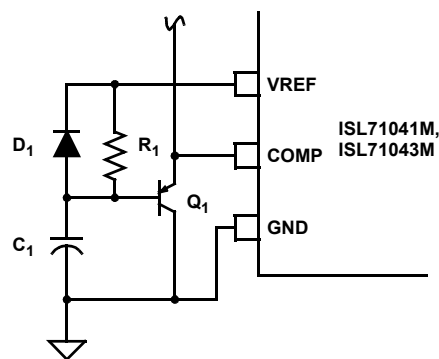


Figure 15. Soft-Start

The COMP pin is clamped to the voltage on capacitor  $C_1$  plus a base-emitter junction by transistor  $Q_1$ .  $C_1$  is charged from VREF through resistor  $R_1$  and the base current of  $Q_1$ . At power-up,  $C_1$  is fully discharged, COMP is at  $\sim 0.7V$ , and the duty cycle is zero. As  $C_1$  charges, the voltage on COMP increases and the duty cycle increases in proportion to the voltage on  $C_1$ . When COMP reaches the steady-state operating point, the control loop takes over and soft-start is complete.  $C_1$  continues to charge up to  $V_{REF}$  and no longer affects COMP. During power-down, diode  $D_1$  quickly discharges  $C_1$  so that the soft-start circuit is properly initialized before the next power-on sequence.

### 5.4 Gate Drive

The ISL71041M and ISL71043M devices are capable of sourcing and sinking 1A peak current. An optional external resistor can be placed between the totem-pole output of the IC (OUT pin) and the gate of the MOSFET to limit the peak current through the IC. This small series resistor also damps any oscillations caused by the resonant tank of the parasitic inductances in the traces of the board and the FET's input capacitance.

### 5.5 Slope Compensation

For applications where the maximum duty cycle is less than 50%, slope compensation can be used to improve noise immunity, particularly at lighter loads. The amount of slope compensation required for noise immunity is determined empirically, but is generally about 10% of the full scale current feedback signal. For applications where the duty cycle is greater than 50%, slope compensation is required to prevent instability.

Slope compensation can be accomplished by adding an external ramp to the current feedback signal or by subtracting the external ramp from the voltage feedback error signal. Adding the external ramp to the current feedback signal is the more popular method.

The small signal current-mode model<sup>[1]</sup> shows that the naturally-sampled modulator gain,  $F_m$ , without slope compensation is calculated in [Equation 6](#):

$$(EQ. 6) \quad F_m = \frac{1}{S_n t_{SW}}$$

where  $S_n$  is the slope of the sawtooth signal and  $t_{SW}$  is the duration of the half-cycle. When an external ramp is added, the modulator gain becomes [Equation 7](#):

$$(EQ. 7) \quad F_m = \frac{1}{(S_n + S_e)t_{SW}} = \frac{1}{m_c S_n t_{SW}}$$

where  $S_e$  is the slope of the external ramp and becomes [Equation 8](#):

$$(EQ. 8) \quad m_c = 1 + \frac{S_e}{S_n}$$

The criteria for determining the correct amount of external ramp can be determined by appropriately setting the damping factor of the double-pole located at the switching frequency. The double-pole is critically damped if the Q-factor is set to 1, over-damped for  $Q < 1$ , and under-damped for  $Q > 1$ . An under-damped condition can result in current loop instability.

$$(EQ. 9) \quad Q = \frac{1}{\pi(m_c(1-D) - 0.5)}$$

where  $D$  is the percent of on-time during a switching cycle. Setting  $Q = 1$  and solving for  $S_e$  yields [Equation 10](#):

$$(EQ. 10) \quad S_e = S_n \left( \left( \frac{1}{\pi} + 0.5 \right) \frac{1}{1-D} - 1 \right)$$

Because  $S_n$  and  $S_e$  are the on-time slopes of the current ramp and the external ramp, respectively, they can be multiplied by  $t_{ON}$  to obtain the voltage change that occurs during  $t_{ON}$ .

$$(EQ. 11) \quad V_e = V_n \left( \left( \frac{1}{\pi} + 0.5 \right) \frac{1}{1-D} - 1 \right) \quad V$$

where  $V_n$  is the change in the current feedback signal ( $\Delta I$ ) during the on-time and  $V_e$  is the voltage that must be added by the external ramp.

For a flyback converter,  $V_n$  can be solved in terms of input voltage, current transducer components, and primary inductance, yielding [Equation 12](#):

$$(EQ. 12) \quad V_e = \frac{D \cdot t_{SW} \cdot V_{IN} \cdot R_{CS}}{L_p} \left( \left( \frac{1}{\pi} + 0.5 \right) \frac{1}{1-D} - 1 \right) \quad V$$

where  $R_{CS}$  is the current sense resistor,  $t_{SW}$  is the switching period,  $L_p$  is the primary inductance,  $V_{IN}$  is the minimum input voltage, and  $D$  is the maximum duty cycle.

The current sense signal at the end of the ON time for CCM operation is [Equation 13](#):

$$(EQ. 13) \quad V_{CS} = \frac{N_s \cdot R_{CS}}{N_p} \left( I_O + \frac{(1-D) \cdot V_O \cdot t_{sw}}{2L_s} \right) \quad V$$

1. Ridley, R., *A New Continuous-Time Model for Current Mode Control*, IEEE Transactions on Power Electronics, Vol. 6, No. 2, April 1991.

where  $V_{CS}$  is the voltage across the current sense resistor,  $L_s$  is the secondary winding inductance, and  $I_O$  is the output current at current limit. Equation 13 assumes the voltage drop across the output rectifier is negligible.

Because the peak current limit threshold is 1V, the total current feedback signal plus the external ramp voltage must sum to this value when the output load is at the current limit threshold as shown in Equation 14:

$$(EQ. 14) \quad V_e + V_{CS} = 1V$$

Substituting Equation 12 and Equation 13 into Equation 14 and solving for  $R_{CS}$  yields Equation 15:

$$(EQ. 15) \quad R_{CS} = \frac{1}{\frac{D \cdot T_{sw} \cdot V_{IN}}{L_p} \cdot \left( \frac{1+0.5}{\pi} \frac{1}{1-D} - 1 \right) + \frac{N_s}{N_p} \cdot \left( I_O + \frac{(1-D) \cdot V_O \cdot t_{sw}}{2L_s} \right)}$$

Add slope compensation in the ISL71041M and ISL71043M devices using an external buffer transistor and the RTCT signal. A typical application sums the buffered RTCT signal with the current sense feedback and applies the result to the CS pin as shown in Figure 16.

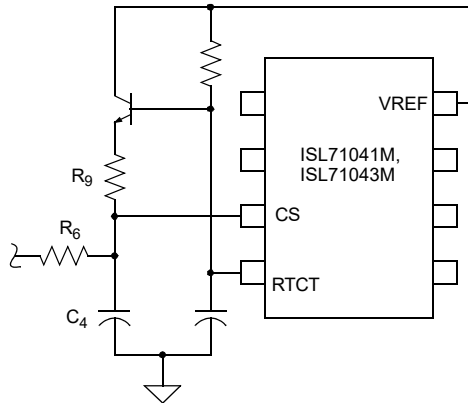


Figure 16. Slope Compensation

Assuming the designer has selected values for the RC filter ( $R_6$  and  $C_4$ ) placed on the CS pin, the value of  $R_9$  required to add the appropriate external ramp can be found by superposition.

$$(EQ. 16) \quad V_e = \frac{2.05D \cdot R_6}{R_6 + R_9} \quad V$$

The factor of 2.05 in Equation 16 arises from the peak amplitude of the sawtooth waveform on RTCT minus a base-emitter junction drop. That voltage multiplied by the maximum duty cycle is the voltage source for the slope compensation. Rearranging to solve for  $R_9$  yields Equation 17:

$$(EQ. 17) \quad R_9 = \frac{(2.05D - V_e) \cdot R_6}{V_e} \quad \Omega$$

The value of  $R_{CS}$  determined in Equation 15 must be rescaled so that the current sense signal presented at the CS pin is that predicted by Equation 13. The divider created by  $R_6$  and  $R_9$  makes this necessary.

$$(EQ. 18) \quad R'_{CS} = \frac{R_6 + R_9}{R_9} \cdot R_{CS}$$

Example:

$V_{IN} = 12V$ ,  $V_O = 48V$ ,  $L_s = 800\mu H$ ,  $N_s/N_p = 10$ ,  $L_p = 8.0\mu H$ ,  $I_O = 200mA$ , switching frequency,  $f_{SW} = 200kHz$   
duty cycle,  $D = 28.6\%$ ,  $R_6 = 499\Omega$

Solve for the current sense resistor,  $R_{CS}$ , using [Equation 15](#).

$$R_{CS} = 295m\Omega$$

Determine the amount of voltage,  $V_e$ , that must be added to the current feedback signal using [Equation 12](#).

$$V_e = 92.4mV$$

Use [Equation 17](#) to solve for the summing resistor,  $R_9$ , from CT to CS.

$$R_9 = 2.67k\Omega$$

Determine the new value of  $R_{CS}$  ( $R'_{CS}$ ) using [Equation 18](#).

$$R'_{CS} = 350m\Omega$$

Additional slope compensation may be considered for design margin. The previous discussion determines the minimum external ramp that is required. The buffer transistor that creates the external ramp from RTCT should have a sufficiently high gain ( $>200$ ) to minimize the required base current. Whatever base current is required reduces the charging current into RTCT and reduces the oscillator frequency.

## 5.6 Fault Conditions

A Fault condition occurs if  $V_{REF}$  falls below 4.65V. When a Fault is detected, OUT is disabled. When  $V_{REF}$  exceeds 4.80V, the Fault condition clears and OUT is enabled.

## 5.7 Ground Plane Requirements

Careful layout is essential for satisfactory operation of the device. A good ground plane must be used. A unique section of the ground plane must be designated for high di/dt currents associated with the output stage. Bypass VDD directly to GND with good high frequency capacitors.



## 6. Radiation Tolerance

The ISL71041M and ISL71043M are radiation tolerant devices for commercial space applications, Low Earth Orbit (LEO) applications, high altitude avionics, launch vehicles, and other harsh environments. The response of these devices to Total Ionizing Dose (TID) radiation effects and Single-Event Effects (SEE) have been measured, characterized, and reported in the following actions. However, TID performance is not guaranteed through radiation acceptance testing, nor is the SEE characterization performance guaranteed.

### 6.1 Total Ionizing Dose (TID) Testing

#### 6.1.1 Introduction

These tests were conducted to determine the sensitivity of the parts to the total dose environment. Test downpoints were 0krad(Si), 10krad(Si), 20krad(Si), and 30krad(Si). Total dose testing was performed using a Hopewell Designs N40 panoramic irradiator. Irradiations were performed at 0.00875 rad(Si)/s. A PbAl box was used to shield the test figure and devices under test against low energy secondary gamma radiation. The characterization matrix for the ISL71041M consisted of 7 samples irradiated under bias and 7 samples irradiated with all pins grounded. The characterization matrix for the ISL71043M consisted of 24 samples irradiated under bias and 12 samples irradiated with all pins grounded. Four control units for each part were used to ensure repeatable data. Two different wafers for each part were used. The bias configuration is shown in [Figure 17](#).

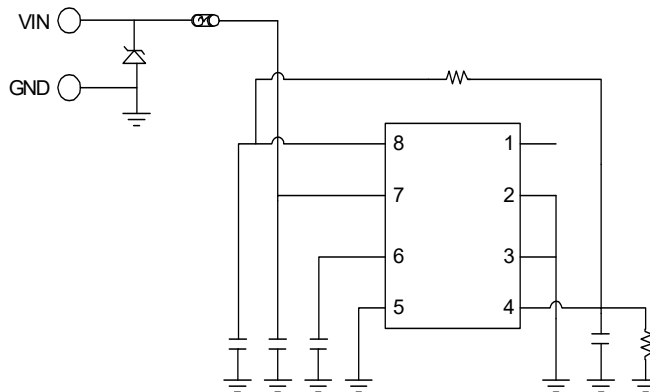


Figure 17. Irradiation Bias Configuration

All electrical testing was performed outside the irradiator using the production Automated Test Equipment (ATE), with data logging at each downpoint (including anneal). Downpoint electrical testing was performed at room temperature.

6.1.2 Results

Table 2 and Table 3 summarize the attributes data. Bin 1 indicates a device that passes all device specification limits.

Table 2. ISL71041M Total Dose Test Attributes Data

Dose Rate (mrad(Si)/s)	Bias	Sample Size	Downpoint	Bin1	Rejects
8.75	Figure 17	7	Pre-rad	7	0
			10krad(Si)	7	0
			20krad(Si)	7	0
			30krad(Si)	7	0
8.75	Grounded	7	Pre-rad	7	0
			10krad(Si)	7	0
			20krad(Si)	7	0
			30krad(Si)	7	0

Table 3. ISL71043M Total Dose Test Attributes Data

Dose Rate (mrad(Si)/s)	Bias	Sample Size	Downpoint	Bin1	Rejects
8.75	Figure 17	24	Pre-rad	24	0
			10krad(Si)	24	0
			20krad(Si)	24	0
			30krad(Si)	24	0
8.75	Grounded	12	Pre-rad	12	0
			10krad(Si)	12	0
			20krad(Si)	12	0
			30krad(Si)	12	0

Figure 18 through Figure 23 show data for key parameters at all downpoints. The plots show the average as a function of total dose for each of the irradiation conditions; we chose to use the average because of the relatively large sample sizes. All parts showed excellent stability over irradiation.

### 6.1.3 Typical Radiation Performance

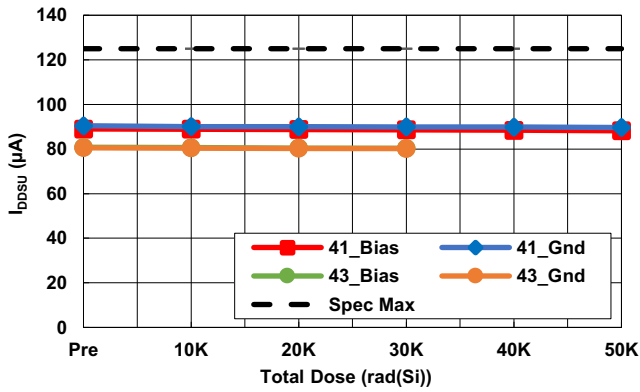


Figure 18. Start-Up Current vs TID

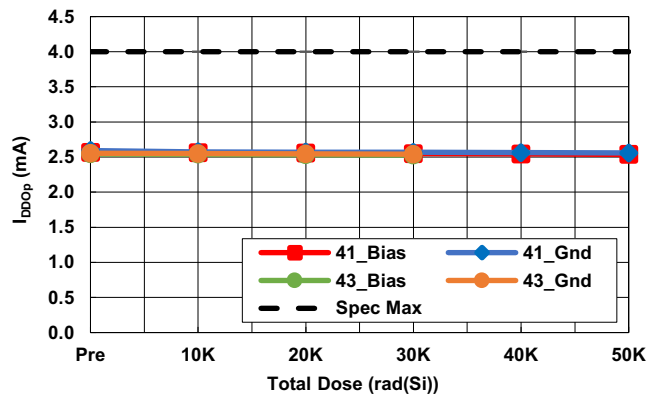


Figure 19. Operating Current vs TID

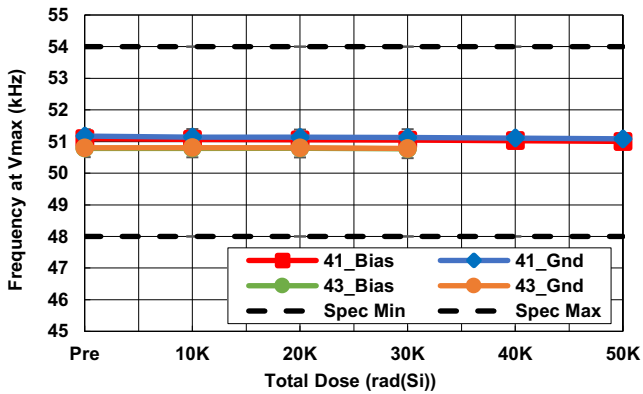


Figure 20. Frequency Accuracy vs TID

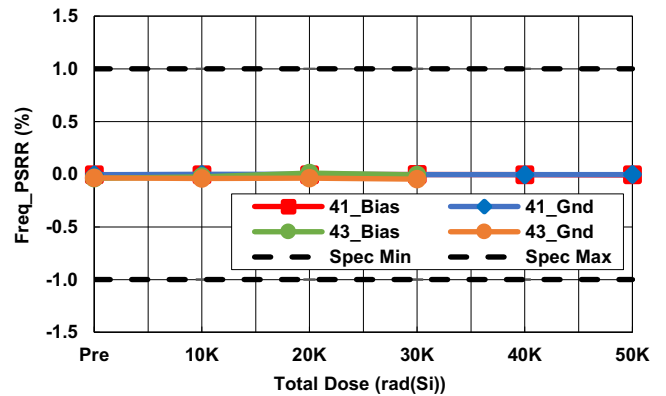


Figure 21. Frequency Variation with  $V_{DD}$  vs TID

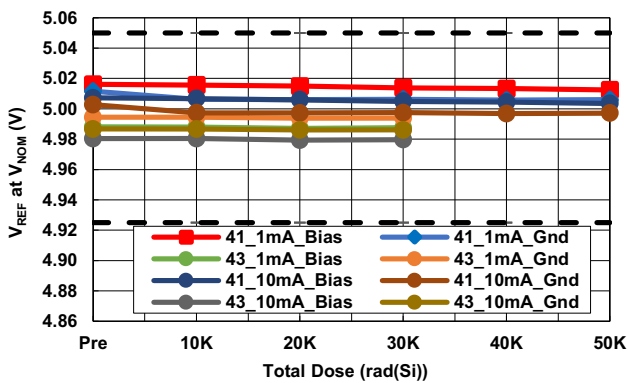


Figure 22. Overall Accuracy vs TID

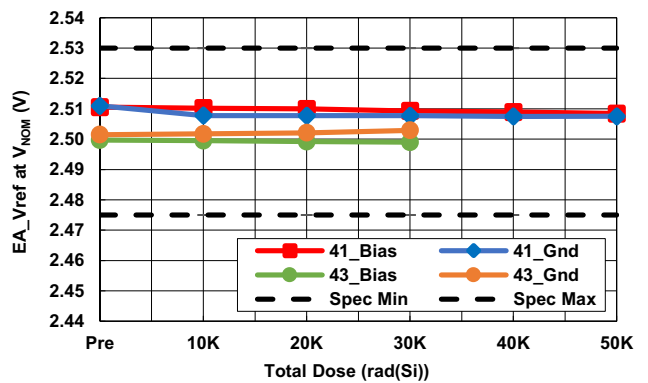


Figure 23. Reference Voltage vs TID

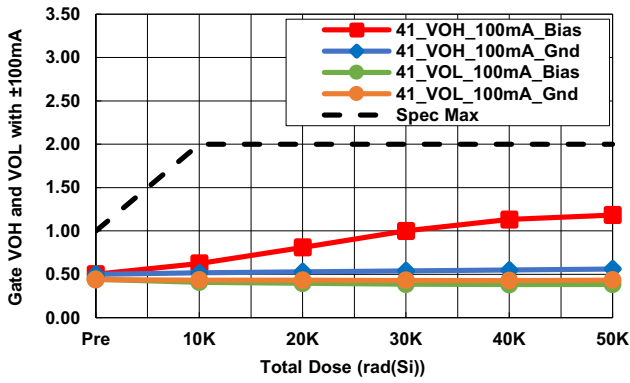


Figure 24. 100mA Gate Drive vs TID

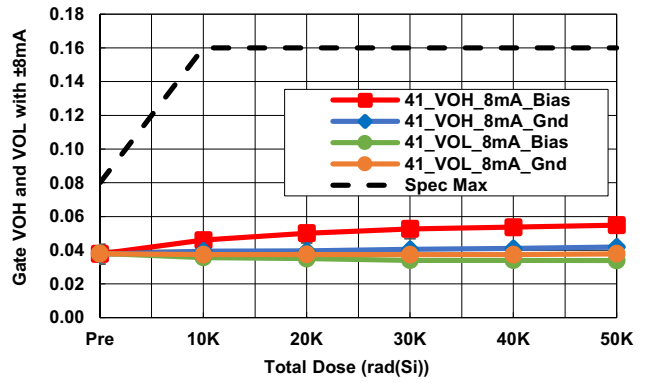


Figure 25. 8mA Gate Drive vs TID

### 6.1.4 Conclusion

ATE characterization testing showed no rejects to the datasheet limits at all downpoints. Variables data for selected parameters is presented in Figure 18 through Figure 23. No differences between biased and unbiased irradiation were noted, and the part is not considered bias sensitive.

Table 4. ISL71041M Response of Key Parameters vs TID

Parameter	Symbol	Condition	Bias	0krad(Si)	10krad(Si)	20krad(Si)	30krad(Si)	40krad(Si)	50krad(Si)	Unit
Start-Up Current	$I_{DDSu}$	-	Bias	89.016	88.940	88.789	88.618	88.449	88.185	$\mu A$
			GND	90.447	90.059	90.020	89.939	89.866	89.655	$\mu A$
Operating Current	$I_{DDOp}$	9V	Bias	2.523	2.515	2.511	2.505	2.499	2.492	mA
			GND	2.547	2.528	2.525	2.523	2.518	2.514	mA
		12V	Bias	2.568	2.560	2.556	2.550	2.544	2.537	mA
			GND	2.592	2.574	2.570	2.568	2.564	2.559	mA
		13.2V	Bias	2.579	2.571	2.567	2.561	2.555	2.548	mA
			GND	2.604	2.585	2.582	2.579	2.575	2.570	mA
Frequency	Freq	13.2V	Bias	51.093	51.068	51.053	51.046	51.032	51.004	kHz
			GND	51.172	51.141	51.134	51.124	51.113	51.086	kHz
Frequency Accuracy	Freq_PSR	-	Bias	-0.005	-0.006	-0.005	-0.003	-0.004	-0.006	%
			GND	-0.005	-0.002	-0.001	-0.005	-0.005	-0.003	%
Voltage Reference	$V_{REF}$	1mA	Bias	5.016	5.016	5.015	5.014	5.013	5.012	V
			GND	5.012	5.006	5.006	5.006	5.006	5.006	V
		10mA	Bias	5.007	5.007	5.006	5.005	5.004	5.004	V
			GND	5.003	4.997	4.997	4.997	4.997	4.997	V
Error Amp Reference	EA_VREF	12V	Bias	2.511	2.510	2.510	2.509	2.509	2.508	V
			GND	2.511	2.508	2.508	2.508	2.507	2.508	V
Gate $V_{OH}$	$V_{OH}$	-100mA	Bias	0.501	0.625	0.810	1.001	1.132	1.183	V
			GND	0.500	0.517	0.530	0.540	0.548	0.561	V
		-8mA	Bias	0.038	0.046	0.050	0.053	0.054	0.055	V
			GND	0.038	0.039	0.040	0.040	0.041	0.042	V

Table 4. ISL71041M Response of Key Parameters vs TID (Cont.)

Parameter	Symbol	Condition	Bias	0krad(Si)	10krad(Si)	20krad(Si)	30krad(Si)	40krad(Si)	50krad(Si)	Unit
Gate $V_{OL}$	$V_{OL}$	100mA	Bias	0.442	0.409	0.396	0.386	0.382	0.383	V
			GND	0.439	0.432	0.431	0.429	0.428	0.434	V
		8mA	Bias	0.038	0.036	0.035	0.034	0.034	0.034	V
			GND	0.038	0.037	0.037	0.037	0.037	0.038	V

Table 5. ISL71043M Response of Key Parameters vs TID (0, 10, 20, 30krad(Si) Lot A)

Parameter	Symbol	Condition	Bias	0krad(Si)	10krad(Si)	20krad(Si)	30krad(Si)	Unit
Start-Up Current	$I_{DDSu}$	13.2V	Biased	80.799	80.614	80.451	80.350	$\mu$ A
			Grounded	80.546	80.406	80.282	80.212	$\mu$ A
Operating Current	$I_{DDOp}$	9V	Biased	2.555	2.548	2.543	2.539	mA
			Grounded	2.565	2.560	2.556	2.552	mA
		12V	Biased	2.543	2.536	2.531	2.527	mA
			Grounded	2.554	2.548	2.544	2.540	mA
		13.2V	Biased	3.249	3.249	3.246	3.232	mA
			Grounded	3.263	3.259	3.263	3.243	mA
Frequency	Freq	13.2V	Biased	50.783	50.787	50.787	50.770	kHz
			Grounded	50.803	50.805	50.802	50.782	kHz
Frequency Accuracy	Freq_PSRR		Biased	-0.039	-0.025	0.010	-0.007	%
			Grounded	-0.035	-0.042	-0.039	-0.047	%
Voltage Reference	$V_{REF}$	1mA	Biased	4.988	4.988	4.987	4.988	V
			Grounded	4.994	4.994	4.993	4.994	V
		10mA	Biased	4.980	4.980	4.979	4.979	V
			Grounded	4.987	4.987	4.986	4.986	V
Error Amp Reference	EA_VREF	12V	Biased	2.500	2.499	2.499	2.499	V
			Grounded	2.501	2.502	2.502	2.502	V

Table 6. ISL71043M Response of Key Parameters vs TID (10, 30, 40, 50krad(Si) Lot B)

Parameter	Symbol	Condition	10krad(Si)	30krad(Si)	40krad(Si)	50krad(Si)	Unit
Start-Up Current	$I_{DDSu}$	13.2V	89.500	89.278	89.157	88.920	$\mu$ A
Operating Current	$I_{DDOp}$	9V	2.522	2.514	2.509	2.503	mA
		12V	2.567	2.559	2.554	2.548	mA
		13.2V	2.578	2.570	2.565	2.559	mA
Frequency	Freq	13.2V	51.117	51.100	51.087	51.061	kHz
Frequency Accuracy	Freq_PSRR		-0.004	-0.004	-0.005	-0.005	%
Voltage Reference	$V_{REF}$	1mA	5.011	5.010	5.010	5.009	V
		10mA	5.002	5.001	5.001	5.000	V
Error Amp Reference	EA_VREF	12V	2.509	2.509	2.508	2.508	V

Table 6. ISL71043M Response of Key Parameters vs TID (10, 30, 40, 50krad(Si) Lot B) (Cont.)

Parameter	Symbol	Condition	10krad(Si)	30krad(Si)	40krad(Si)	50krad(Si)	Unit
Gate $V_{OH}$	$V_{OH}$	-100mA	0.571	0.770	0.840	0.872	V
		-8mA	0.043	0.047	0.047	0.048	V
Gate $V_{OL}$	$V_{OL}$	100mA	0.421	0.407	0.405	0.408	V
		8mA	0.036	0.036	0.036	0.036	V

## 6.2 Single-Event Effects Testing

The intense heavy ion environment encountered in space applications can cause a variety of Single-Event Effects (SEE). SEE can lead to system-level performance issues including disruption, degradation, and destruction. For predictable and reliable space system operation, individual electronic components should be characterized to determine their SEE response. SEE testing was performed on the ISL71043M only and the results extend to include the ISL71041M. The following is a summary of the ISL71043M SEE testing.

### 6.2.1 SEE Test Facility

Testing was performed at the Texas A&M University (TAMU) Cyclotron Institute heavy ion facility on April 4, 2019. The overall test setup includes the test jig containing four evaluation boards mounted and wired through a 20ft cable to the data room. The end of the 20ft cable in the data room was connected to a switchboard. The switchboard was wired to the power supplies and monitoring equipment/scopes. The signals from the switchboard were connected to two LeCroy oscilloscopes, one set to capture transients due to pulse-width change and the other to capture on period change. The switchboard at the end of the 20ft cabling was found to require termination to keep the noise on the waveforms to a minimum. OUT and RTCT was terminated with a series combination of 1000pF and 51 $\Omega$  and the VOUT and VREF signals with a 10nF capacitor to ground.

### 6.2.2 SEE Test Setup

The SEB/L evaluation board was wired up in the open loop configuration as shown in [Figure 26](#). The biasing used for the SEB/L test runs was  $V_{DD} = 14.7V$ . The SET board was wired up in the closed loop configuration shown in [Figure 27](#). The biasing for the SET test runs was  $V_{DD} = 14.7V$ .

A SET occurs when a perturbation is detected. This can be a change in pulse-width, which can cause missing pulses. Scope 1 was set to trigger to pulse-width variations of around the nominal value. Measurements on Scope 1 are CH1 = OUT, CH2 = VOUT, CH3 = RTCT, CH4 = VREF, and TRIG = OUT PW. Scope 2 is set to trigger to missing pulse events. This setting triggers when two rising edges deviate from the nominal period by  $\pm 20\%$ . Measurements on Scope 2 are CH1 = OUT, CH2 = VOUT, CH3 = RTCT, CH4 = VREF, and TRIG = OUT period.

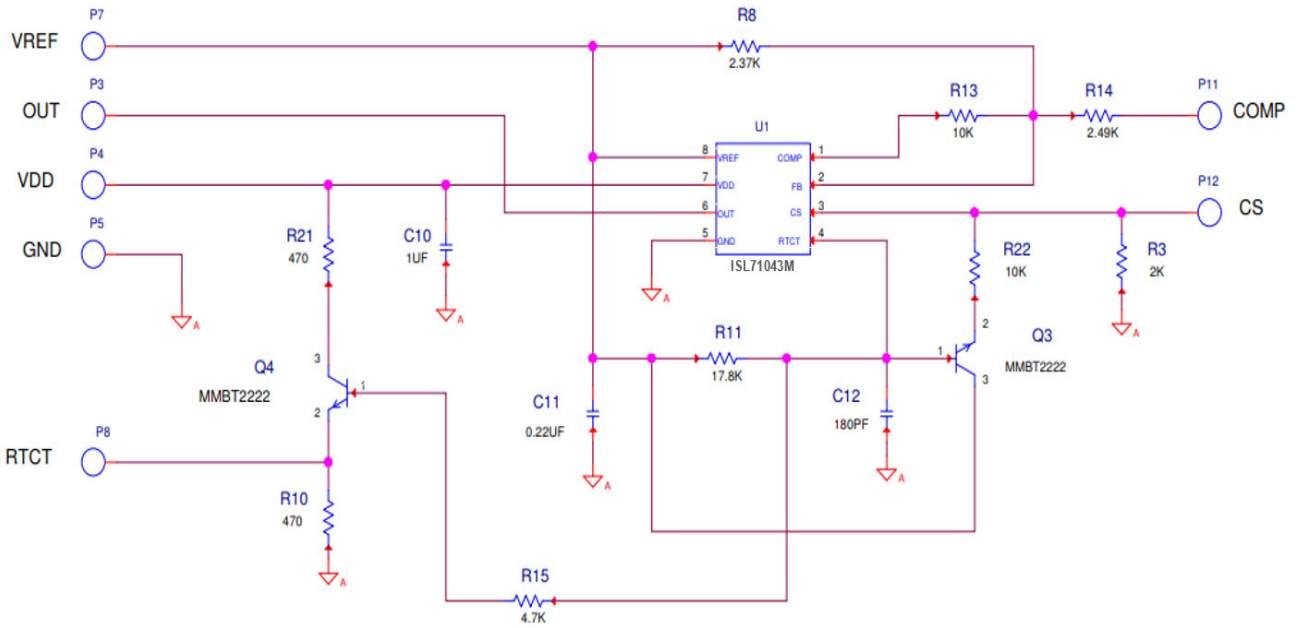


Figure 26. SEB/L Evaluation Board Schematic

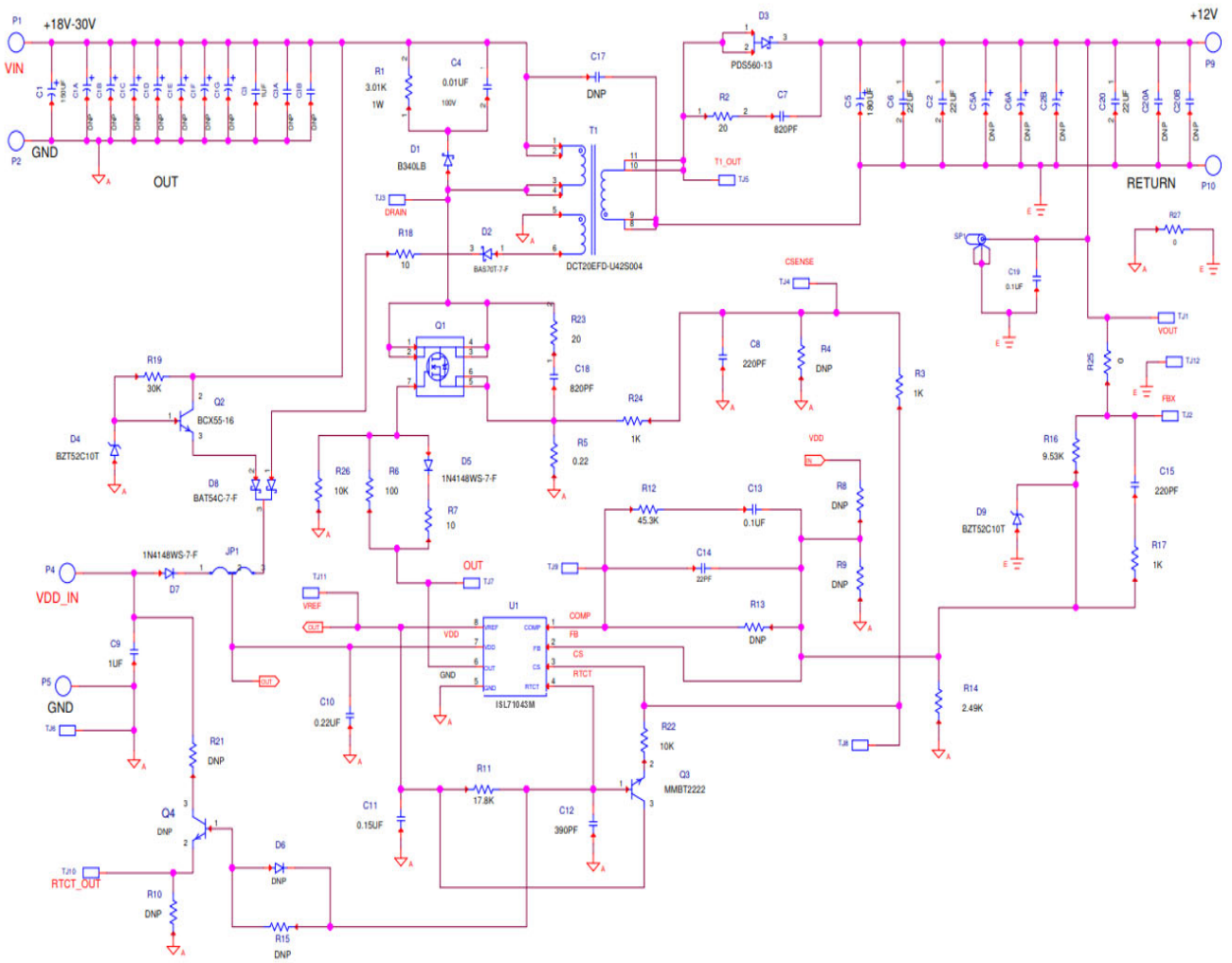


Figure 27. Schematic of SET Evaluation Board

### 6.2.3 Single Event Burnout and Latch-Up (SEB/L) Results

No SEB was observed for the device LET of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  ( $+125^\circ\text{C}$ ) and  $V_{\text{DD}} = 14.7\text{V}$ . No SEL events were observed for the device at LET value of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  ( $+125^\circ\text{C}$ ,  $V_{\text{REF Cap}} = 0.22\mu\text{F}$ ). A destructive event occurs when the supply current of the device increases greater than 5%.

### 6.2.4 SET Results

The device is sensitive to soft errors with a LET of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ . No soft error was observed, which caused more than one PWM output pulse dropout at LET value of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ . Extreme pulse-width waveforms are shown in Figure 28 through Figure 31.

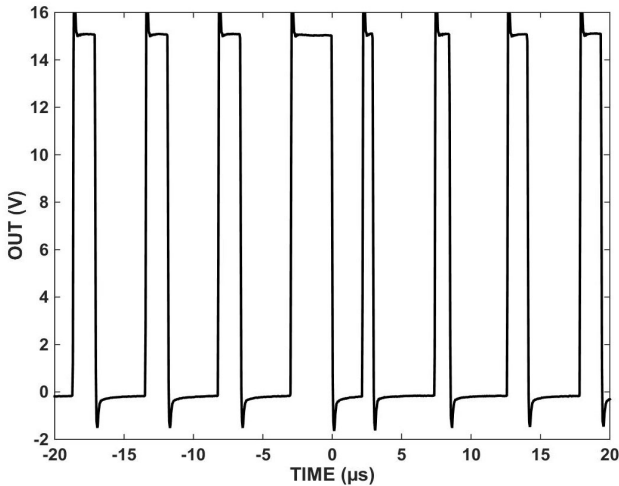


Figure 28. Extreme SET captures from DUT2 with  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  on the OUT signal with a  $\pm 20\%$  pulse-width trigger, maximum pulse-width high

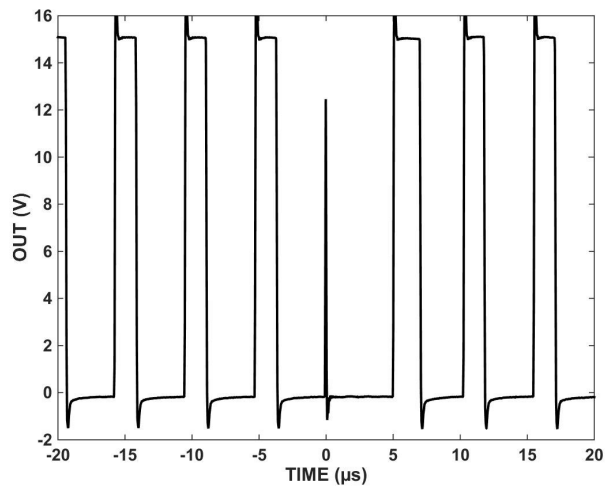


Figure 29. Extreme SET captures from DUT2 with  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  on the OUT signal with a  $\pm 20\%$  pulse-width trigger, maximum pulse-width low

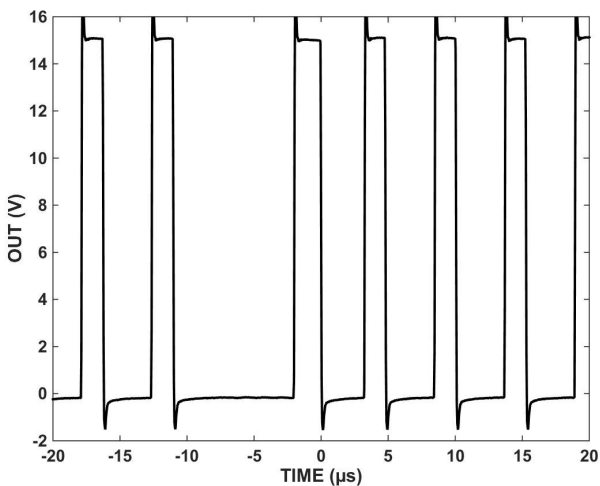


Figure 30. Extreme SET captures from DUT2 with  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  on the OUT signal with a  $\pm 20\%$  pulse-width trigger, minimum pulse-width high

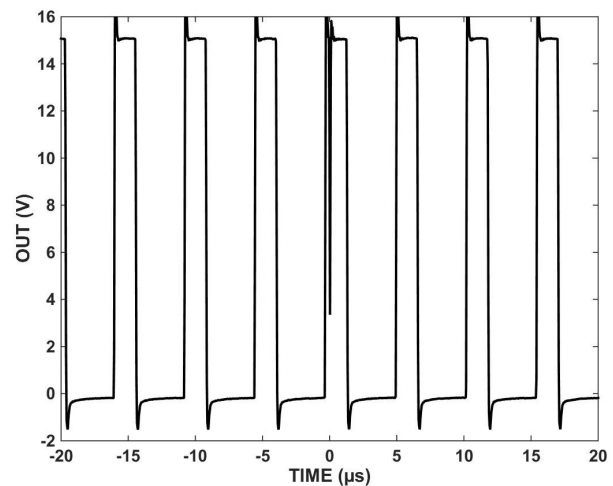


Figure 31. Extreme SET captures from DUT2 with  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$  on the OUT signal with a  $\pm 20\%$  pulse-width trigger, minimum pulse-width low



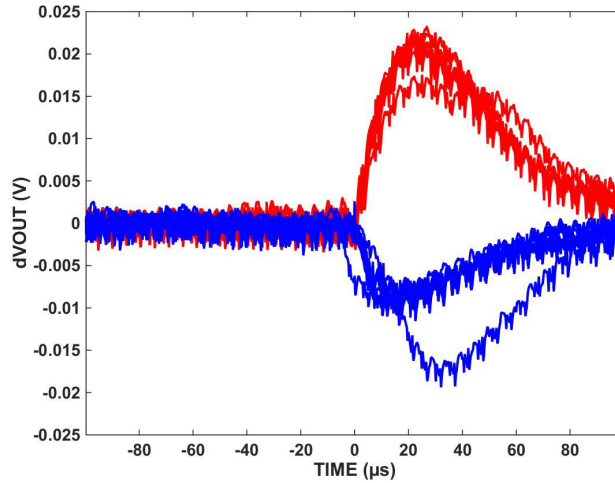


Figure 32. Composite of Ten Greatest Positive and Negative  $V_{OUT}$  Transients

### 6.2.5 Conclusion

The device is sensitive to soft errors with a LET of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ . No soft error was observed which caused more than one missing PWM output pulse at LET value of  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ .

Test <sup>[1]</sup>	Missed Pulses (Typical)	Missed Pulses (Maximum)	Temp	LET (MeV·cm <sup>2</sup> /mg)	Remarks
SEB/L <sup>[2][3][4]</sup>	-	-	+125	43	No destructive single event burnouts or latch-up events occurred at $V_{DD} = 14.7\text{V}$ at $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ and $0^\circ$ incidence at a fluence of $4\times 10^7$ particles/cm <sup>2</sup>
SET	-	1	+25	43	

- SEE tests performed at a switching frequency of 200kHz, RT = 17.8k, CT = 390pF. SEB/L tests are done in a standalone open loop configuration and the SET tests are done in a closed loop configuration.
- SEB occurs if an increase in the  $I_{DD}$  of greater than 5% is measured after exposure to the beam. A 0.22μF capacitor was connected from the VREF pin to GND for the purpose of bypass.
- SEL results: No latch-up conditions were observed, a SEL is categorized by an increase in the  $I_{DD}$  current greater than 5% during exposure. A 0.22μF capacitor was used from VREF pin to GND for bypass.
- The recommended highest operating  $V_{DD}$  for the device is 13.2V, which is below the single event breakdown survival voltage of 14.7V for normal incidence LET =  $43\text{MeV}\cdot\text{cm}^2/\text{mg}$ .

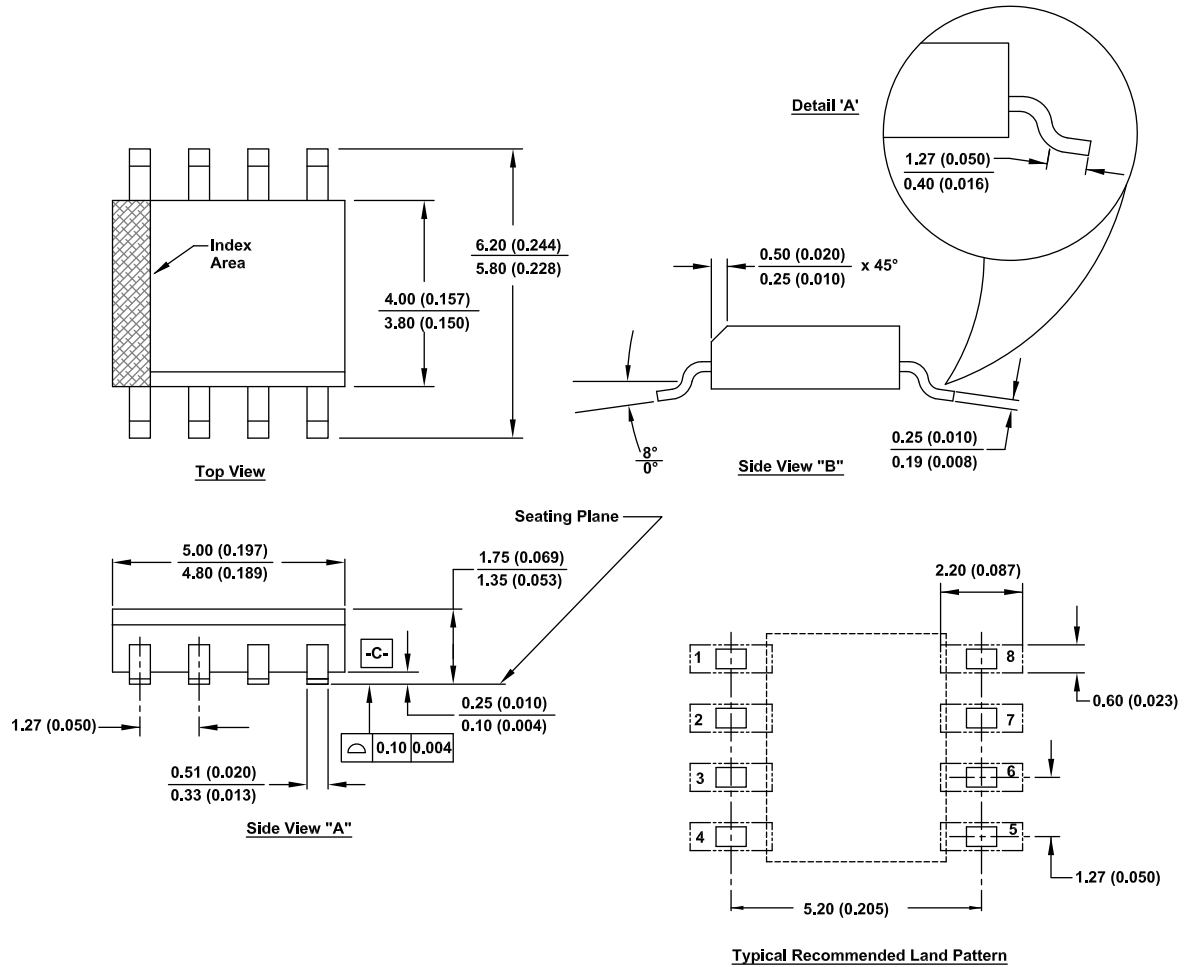
## 7. Package Outline Drawings

For the most recent package outline drawing, see [M8.15](#).

M8.15

8 Lead Narrow Body Small Outline Plastic Package

Rev 7, 9/2023



Notes:

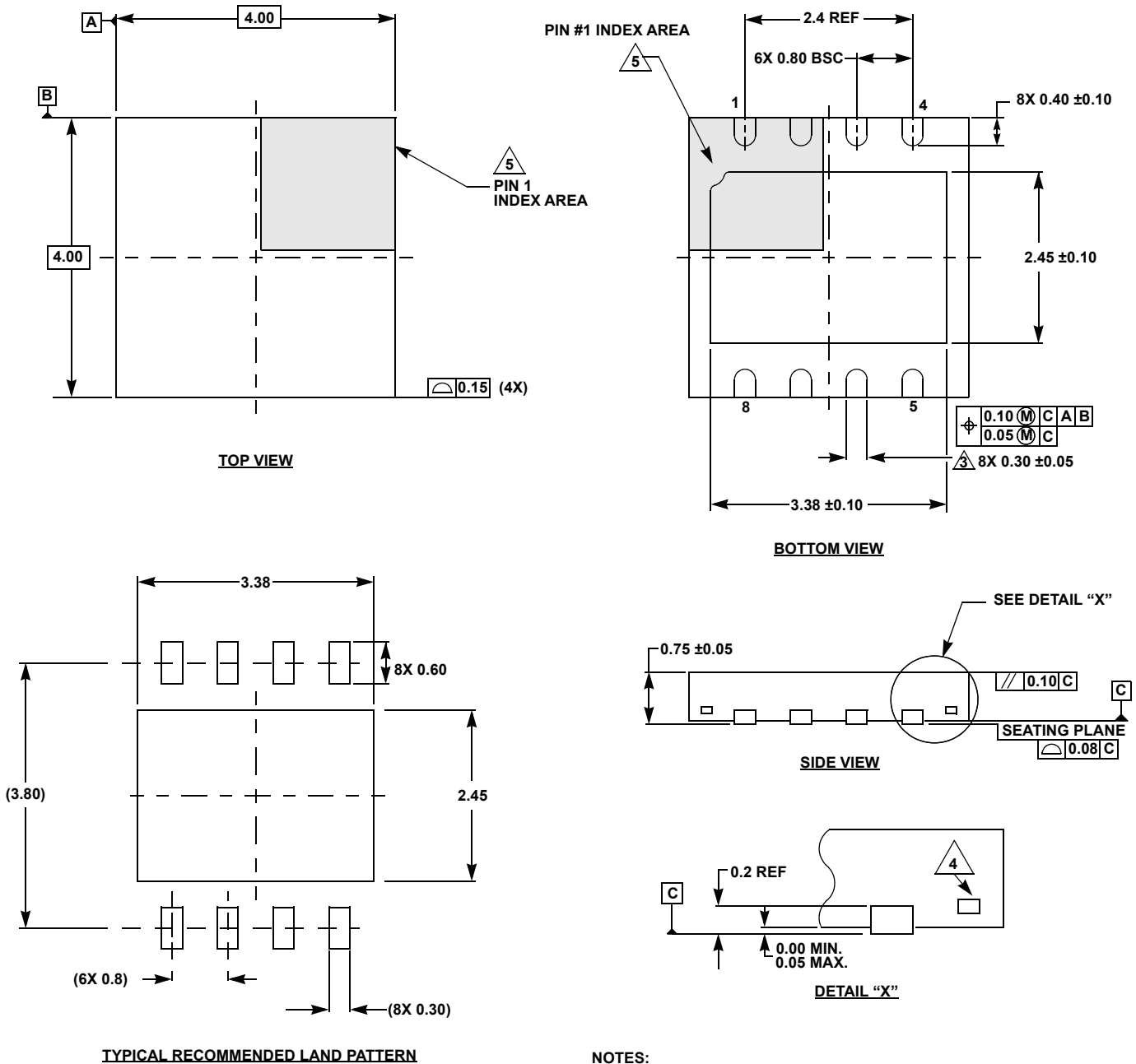
1. Dimensioning and tolerancing conform to ASME Y14.5M-1994.
2. Package length does not include mold flash, protrusion or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
3. Package width does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
4. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
5. Terminal numbers are shown for reference only.
6. The lead width as measured 0.36mm (0.014 Inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
7. Controlling dimension: MILLIMETER. Converted inch dimension are not necessarily exact.
8. This outline conforms to JEDEC publication MS-012-AA ISSUE C.

For the most recent package outline drawing, see [L8.4x4B](#).

L8.4x4B

8 Lead Thin Dual Flat No-Lead Plastic Package (TDFN)

Rev 0, 05/16



NOTES:

1. Dimensions are in millimeters.  
Dimensions in ( ) for Reference Only.
2. Dimensioning and tolerancing conform to ASME Y14.5M-1994.
3. Dimension applies to the metallized terminal and is measured between 0.015mm and 0.30mm from the terminal tip.
4. Tiebar shown (if present) is a non-functional feature, and may be located on any of the 4 sides (or ends).
5. The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.

## 8. Ordering Information

Part Number <sup>[1][2]</sup>	Part Marking	Package Description <sup>[3]</sup> (RoHS Compliant)	Pkg. Dwg. #	Carrier Type <sup>[4]</sup>	Temp Range
ISL71043MBZ	71043 MBZ	8 Ld NSOIC	M8.15	Tube	-55 to +125°C
ISL71043MBZ-T				Reel, 1k	
ISL71043MBZ-T7A				Reel, 250	
ISL71043MRTZ	710 43MRTZ	8 Ld TDFN	L8.4x4B	Tube	
ISL71043MRTZ-T				Reel, 1k	
ISL71043MRTZ-T7A				Reel, 250	
ISL71041MRTZ	710 41MRTZ	8 Ld TDFN	L8.4x4B	Tube	
ISL71041MRTZ-T				Reel, 1k	
ISL71041MRTZ-T7A				Reel, 250	
ISL71043MEVAL1Z	Flyback Power Supply Evaluation Board using the ISL71043M and ISL71040M.				

1. These Pb-free plastic packaged products employ special Pb-free material sets; molding compounds/die attach materials and NiPdAu-Ag plate - e4 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J-STD-020.
2. For Moisture Sensitivity Level (MSL), see the [ISL71043M](#) and [ISL71041M](#) device pages. For more information about MSL, see [TB363](#).
3. For the Pb-Free Reflow Profile, see [TB493](#).
4. See [TB347](#) for details about reel specifications.

## 9. Revision History

Rev.	Date	Description
5.03	Sep 29, 2023	Updated M8.15 POD to the latest revision (corrected typo).
5.02	Aug 11, 2023	Applied the latest template throughout. Updated Features bullets. Updated block diagram. Added Maximum Duty Cycle minimum specification. Added ISL71043M Radiation Acceptance Test Limits section. Added Table 6. Updated Tables 4 and 5. Updated Figures 18 through 23. Added Figures 24 and 25. Removed Reference section as reference is now a footnote on the applicable page.
5.01	Feb 23, 2023	Added EPAD description to the Pin Descriptions table. Removed Related Literature section. Updated ordering information table formatting. Updated POD M8.15 to the latest revision, changes are as follows: <ul style="list-style-type: none"> <li>▪ Added the coplanarity spec into the drawing.</li> </ul>
5.00	Sep 30, 2020	Added ISL71041 throughout
4.00	Nov 19, 2019	Updated $V_{OH}$ and $V_{OL}$ limits on page 9.
3.00	Oct 18, 2019	Added TDFN package information throughout document.

Rev.	Date	Description
2.00	Jun 14, 2019	Applied new formatting throughout. Updated the rise and fall time bullet in the Features section. Updated the Reference Voltage Overall Accuracy minimum (from 4.9 to 4.925) and maximum (from 5.1 to 5.050) specifications Updated the Error Amplifier Reference Voltage minimum (from 2.4 to 2.475) and maximum (from 2.6 to 2.530) specifications Updated Table 2 (13.2V condition only). Updated Single-Event Effects Testing sections.
1.00	Jan 21, 2019	Initial release

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