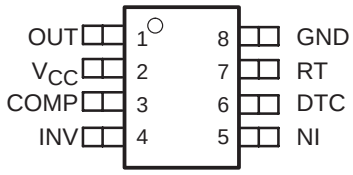
- **Complete PWM Power Control**
- **3.6-V to 40-V Operation**
- **Internal Undervoltage-Lockout Circuit**
- **Oscillator Frequency . . . 20 kHz to 500 kHz**
- **Variable Dead Time Provides Control Over Total Range**
- **Ideal Controller for DDR Memory Application**
- **Uncommitted Error Amplifier Inputs**

D PACKAGE
(TOP VIEW)



description

The TL5002 incorporates on a single monolithic chip all the functions required for a pulse-width-modulation (PWM) control circuit. Designed primarily for power-supply control, the TL5002 contains an error amplifier, a regulator, an oscillator, a PWM comparator with a dead-time-control input, undervoltage lockout (UVLO), and an open-collector output transistor.

The error-amplifier input common-mode voltage ranges from 0.9 V to 1.5 V. Dead-time control (DTC) can be set to provide 0% to 100% dead time by connecting an external resistor between DTC and GND. The oscillator frequency is set by terminating RT with an external resistor to GND. During low V_{CC} conditions, the UVLO circuit turns the output off until V_{CC} recovers to its normal operating range.

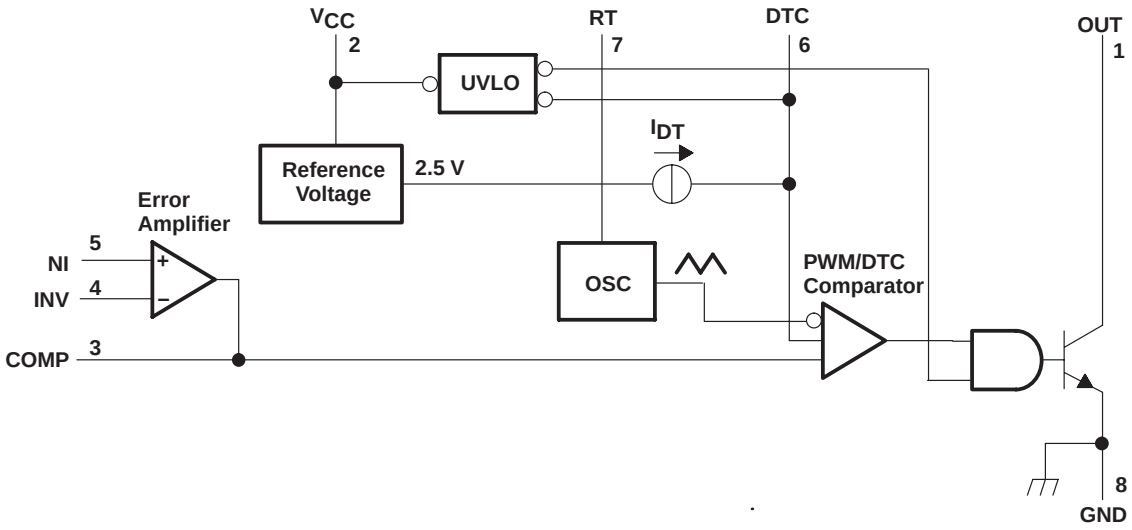
The TL5002 is characterized for operation from −40°C to 85°C.

AVAILABLE OPTIONS

T_A	SMALL OUTLINE (D)
−20°C to 85°C	TL5002CD
−40°C to 85°C	TL5002ID

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL5002CDR).

functional block diagram



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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detailed description

voltage reference

A 2.5-V regulator operating from V_{CC} is used to power the internal circuitry of the TL5002.

error amplifier

The error amplifier compares a sample of the dc-to-dc converter output voltage to an external reference voltage and generates an error signal for the PWM comparator. The dc-to-dc converter output voltage is set by selecting the error-amplifier gain (see Figure 1), using the following expression:

$$V_O = (1 + R1/R2)\ (1\ V)$$

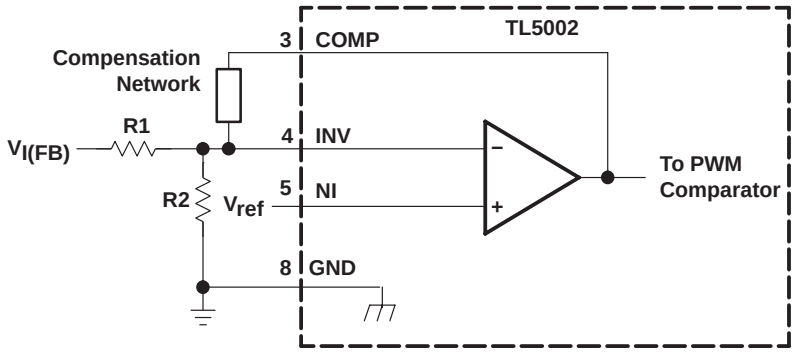


Figure 1. Error-Amplifier Gain Setting

The error-amplifier output is brought out as COMP for use in compensating the dc-to-dc converter control loop for stability. Because the amplifier can only source 45 μA, the total dc load resistance should be 100 kΩ or more.

oscillator/PWM

The oscillator frequency (f_{osc}) can be set between 20 kHz and 500 kHz by connecting a resistor between RT and GND. Acceptable resistor values range from 15 kΩ to 250 kΩ. The oscillator frequency can be determined by using the graph shown in Figure 5.

The oscillator output is a triangular wave with a minimum value of approximately 0.7 V and a maximum value of approximately 1.3 V. The PWM comparator compares the error-amplifier output voltage and the DTC input voltage to the triangular wave and turns the output transistor off whenever the triangular wave is greater than the lesser of the two inputs.

dead-time control (DTC)

DTC provides a means of limiting the output-switch duty cycle to a value less than 100%, which is critical for boost and flyback converters. A current source generates a reference current (I_{DT}) at DTC that is nominally equal to the current at the oscillator timing terminal, RT. Connecting a resistor between DTC and GND generates a dead-time reference voltage (V_{DT}), which the PWM/DTC comparator compares to the oscillator triangle wave as described in the previous section. Nominally, the maximum duty cycle is 0% when V_{DT} is 0.7 V or less and 100% when V_{DT} is 1.3 V or greater. Because the triangle wave amplitude is a function of frequency and the source impedance of RT is relatively high (1250 Ω), choosing R_{DT} for a specific maximum duty cycle, D, is accomplished using the following equation and the voltage limits for the frequency in question as found in Figure 11 (V_{osc}max and V_{osc}min are the maximum and minimum oscillator levels):

dead-time control (DTC) (continued)

$$R_{DT} = \left(R_t + 1250\right)\left[D\left(V_{osc}max - V_{osc}min\right) + V_{osc}min\right]$$

Where

R_{DT} and R_t are in ohms, D in decimal

Soft start can be implemented by paralleling the DTC resistor with a capacitor (C_{DT}) as shown in Figure 2. During soft start, the voltage at DTC is derived by the following equation:

$$V_{DT} \approx I_{DT}R_{DT}\left(1 - e^{\left(-t/R_{DT}C_{DT}\right)}\right)$$

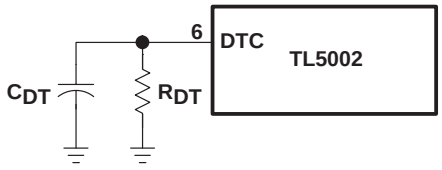


Figure 2. Soft-Start Circuit

If the dc-to-dc converter must be in regulation within a specified period of time, the time constant, $R_{DT}C_{DT}$, should be $t_0/3$ to $t_0/5$. The TL5002 remains off until $V_{DT} \approx 0.7$ V, the minimum ramp value. C_{DT} is discharged every time UVLO becomes active.

undervoltage-lockout (UVLO) protection

The undervoltage-lockout circuit turns the output transistor off whenever the supply voltage drops too low (approximately 3 V at 25°C) for proper operation. A hysteresis voltage of 200 mV eliminates false triggering on noise and chattering.

output transistor

The output of the TL5002 is an open-collector transistor with a maximum collector current rating of 21 mA and a voltage rating of 51 V. The output is turned on under the following conditions: the oscillator triangle wave is lower than both the DTC voltage and the error-amplifier output voltage, and the UVLO circuit is inactive.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{CC} (see Note 1) . . . . . 41 V
Amplifier input voltage, $V_{I(INV)}$, $V_{I(NI)}$ . . . . . 20 V
Output voltage, V_O, OUT . . . . . 51 V
Output current, I_O, OUT . . . . . 21 mA
Output peak current, $I_{O(peak)}$, OUT . . . . . 100 mA
Continuous total power dissipation . . . . . See Dissipation Rating Table
Operating ambient temperature range, T_A . . . . . −40°C to 85°C
Storage temperature range, T_{stg} . . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . . 260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V_{CC}	3.6	40	V
Amplifier input voltage, $V_{I(INV)}$, $V_{I(NI)}$	0.9	1.5	V
Output voltage, V_O, OUT		50	V
Output current, I_O, OUT		20	mA
COMP source current		45	μA
COMP dc load resistance	100		kΩ
Oscillator timing resistor, R_t	15	250	kΩ
Oscillator frequency, f_{osc}	20	500	kHz
Operating ambient temperature, T_A	−40	85	°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 6 V, f_{osc} = 100 kHz (unless otherwise noted)

undervoltage lockout

PARAMETER	TEST CONDITIONS	TL5002C			UNIT
		MIN	TYP†	MAX	
Upper threshold voltage	T_A = 25°C		3		V
Lower threshold voltage	T_A = 25°C		2.8		V
Hysteresis	T_A = 25°C	100	200		mV

† All typical values are at T_A = 25°C.

oscillator

PARAMETER	TEST CONDITIONS	TL5002C			UNIT
		MIN	TYP†	MAX	
Frequency	R_t = 100 kΩ		100		kHz
Standard deviation of frequency			15		kHz
Frequency change with voltage	V_{CC} = 3.6 V to 40 V		1		kHz
Frequency change with temperature	T_A = −40°C to 25°C	−4	−0.4	4	kHz
	T_A = −20°C to 25°C	−4	−0.4	4	kHz
	T_A = 25°C to 85°C	−4	−0.2	4	kHz
Voltage at RT			1		V

† All typical values are at T_A = 25°C.

dead-time control

PARAMETER		TEST CONDITIONS	TL5002C			UNIT
			MIN	TYP†	MAX	
Output (source) current	TL5002	$V_{(DT)}$ = 1.5 V	0.9 × I_{RT}‡		1.2 × I_{RT}	μA
Input threshold voltage		Duty cycle = 0%	0.5	0.7		V
		Duty cycle = 100%		1.3	1.5	

† All typical values are at T_A = 25°C.
‡ Output source current at RT

error amplifier

PARAMETER		TEST CONDITIONS	TL5002C			UNIT
			MIN	TYP†	MAX	
Input voltage		V_{CC} = 3.6 V to 40 V	0.3		1.5	V
Input bias current				−160	−500	nA
Output voltage swing	Positive		1.5	2.3		V
	Negative			0.3	0.4	V
Open-loop voltage amplification				80		dB
Unity-gain bandwidth				1.5		MHz
Output (sink) current		$V_{I(INV)}$ = 1.2 V, COMP = 1 V	100	600		μA
Output (source) current		$V_{I(INV)}$ = 0.8 V, COMP = 1 V	−45	−70		μA

† All typical values are at T_A = 25°C.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 6 V, f_{osc} = 100 kHz (unless otherwise noted) (continued)

output

PARAMETER	TEST CONDITIONS	TL5002C			UNIT
		MIN	TYP†	MAX	
Output saturation voltage	I_O = 10 mA		1.5	2	V
Off-state current	V_O = 50 V, V_{CC} = 0			10	μA
	V_O = 50 V			10	
Short-circuit output current	V_O = 6 V		40		mA

† All typical values are at T_A = 25°C.

total device

PARAMETER		TEST CONDITIONS	TL5002C			UNIT
			MIN	TYP†	MAX	
Standby supply current	Off state			1	1.5	mA
Average supply current		R_t = 100 kΩ		1.4	2.1	mA

† All typical values are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION

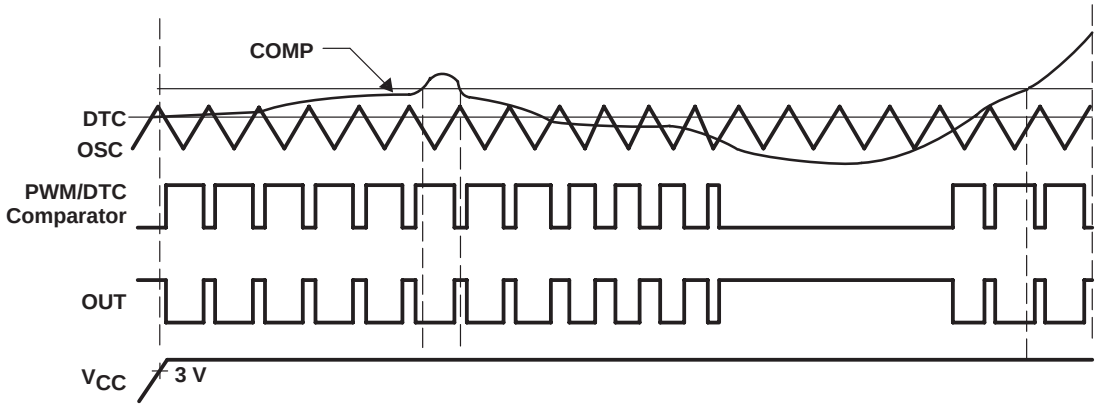


Figure 3. PWM Timing Diagram

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY vs TIMING RESISTANCE

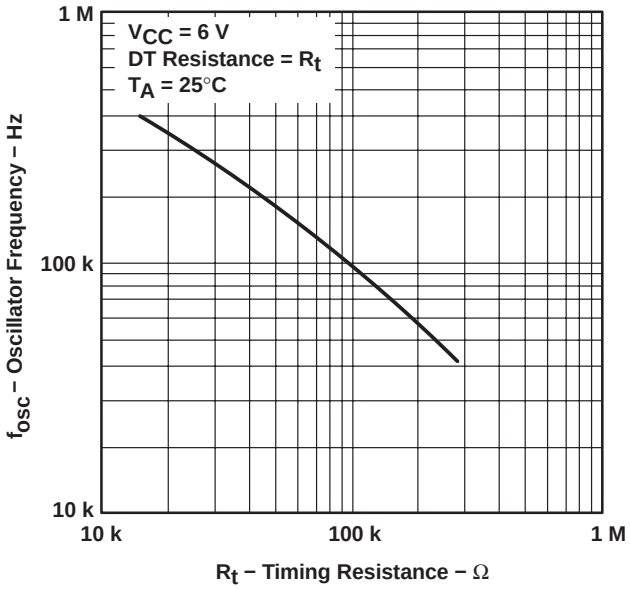


Figure 4

OSCILLATION FREQUENCY vs AMBIENT TEMPERATURE

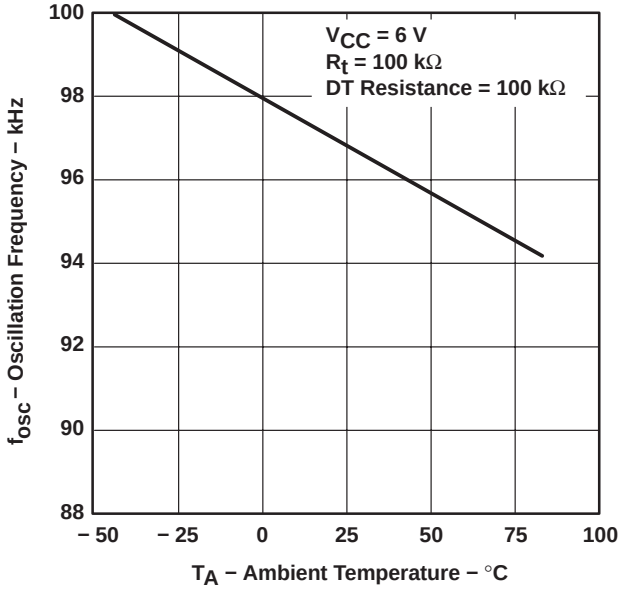


Figure 5

AVERAGE SUPPLY CURRENT vs POWER-SUPPLY VOLTAGE

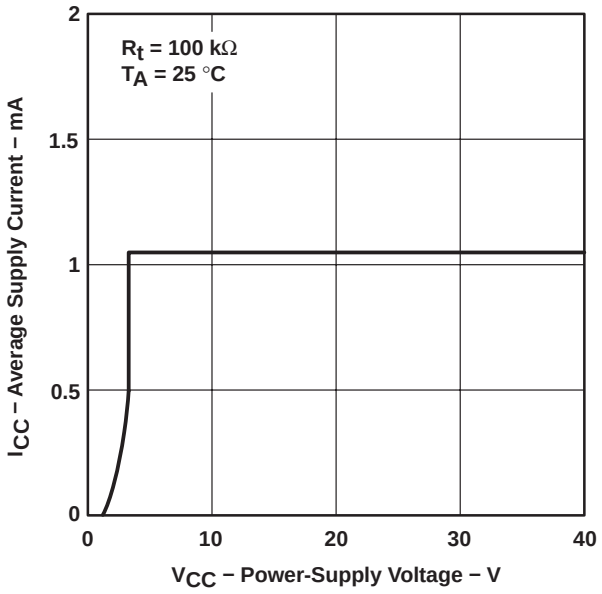


Figure 6

AVERAGE SUPPLY CURRENT vs AMBIENT TEMPERATURE

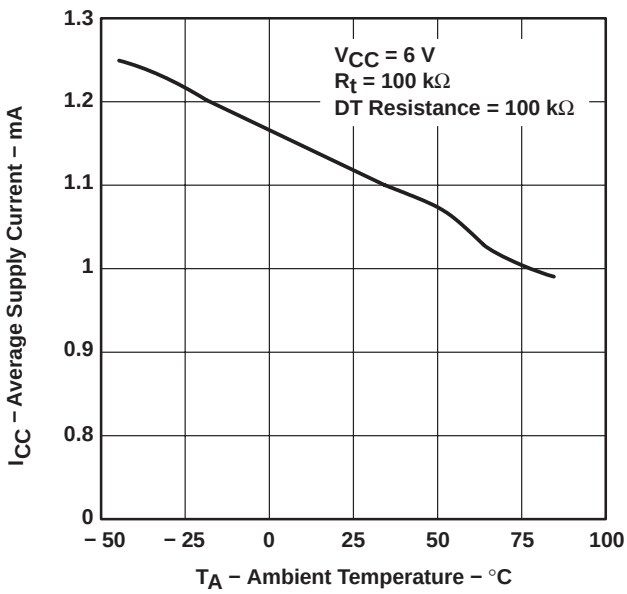


Figure 7

TYPICAL CHARACTERISTICS

PWM TRIANGLE WAVE AMPLITUDE VOLTAGE vs OSCILLATOR FREQUENCY

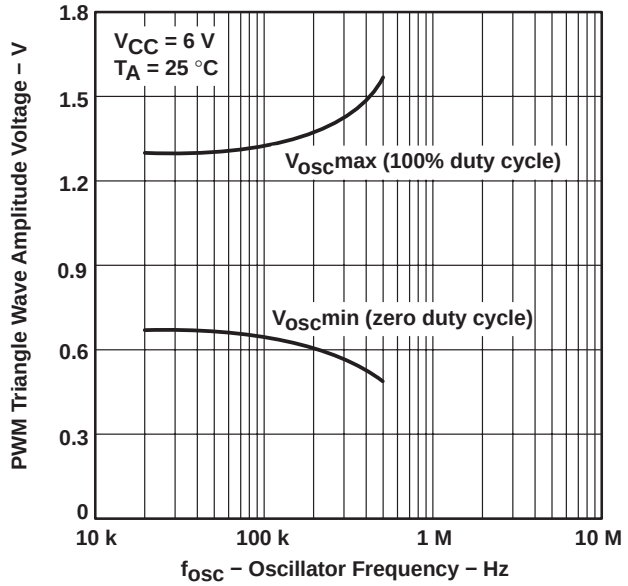


Figure 8

ERROR AMPLIFIER OUTPUT VOLTAGE vs OUTPUT (SINK) CURRENT

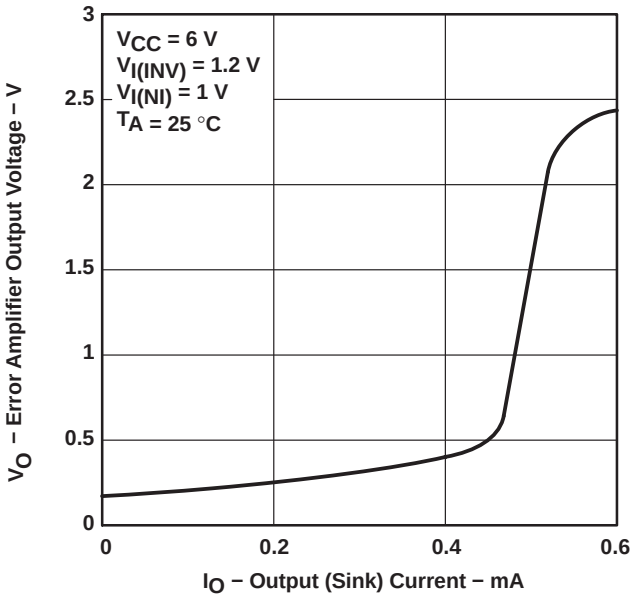


Figure 9

ERROR AMPLIFIER OUTPUT VOLTAGE vs OUTPUT (SOURCE) CURRENT

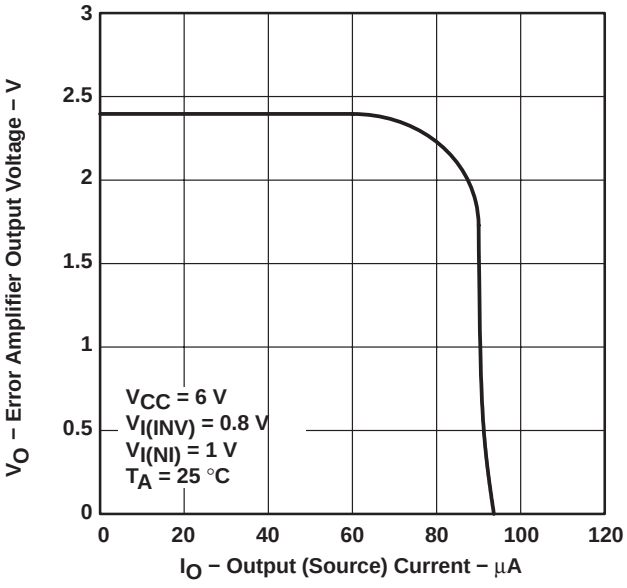


Figure 10

ERROR AMPLIFIER OUTPUT VOLTAGE vs AMBIENT TEMPERATURE

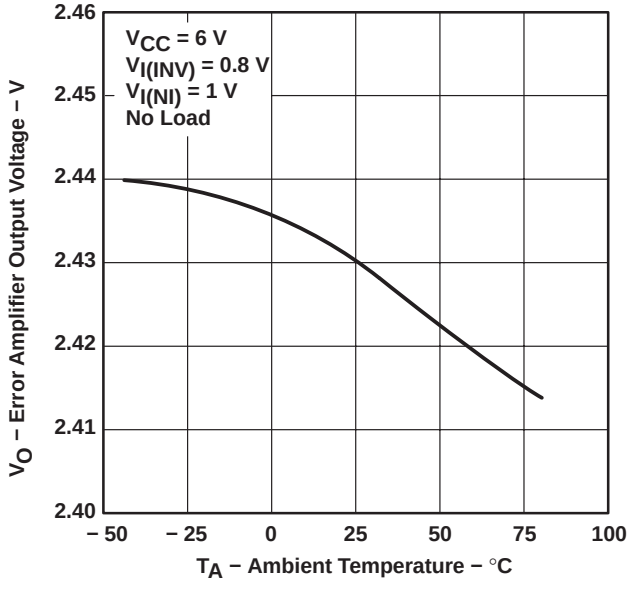


Figure 11

TYPICAL CHARACTERISTICS

ERROR AMPLIFIER OUTPUT VOLTAGE vs AMBIENT TEMPERATURE

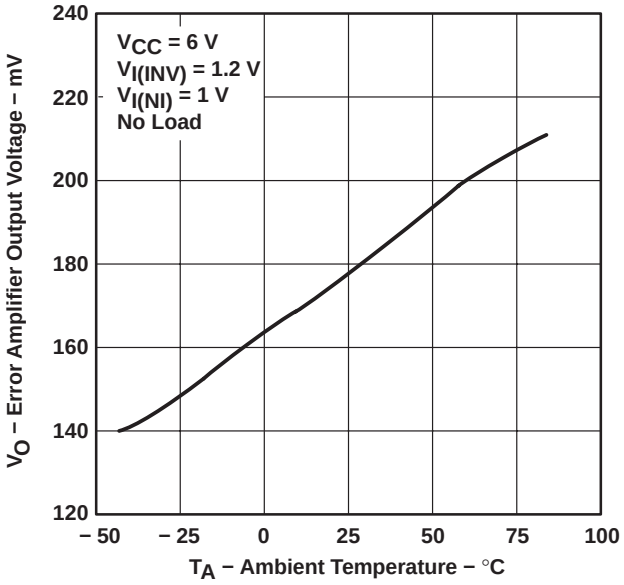


Figure 12

OUTPUT DUTY CYCLE vs DTC VOLTAGE

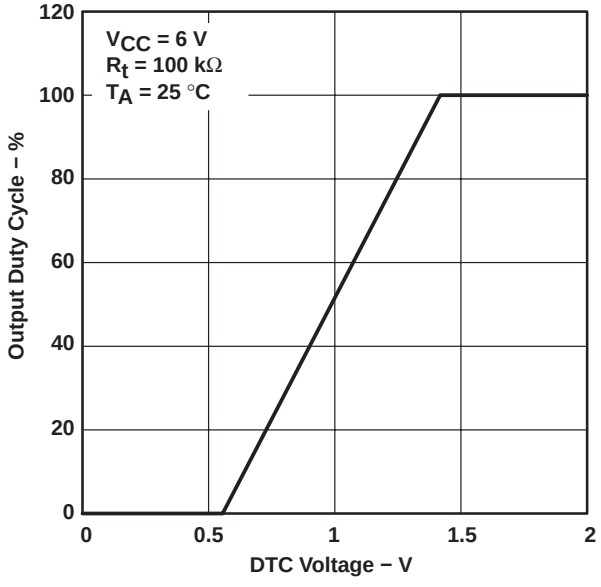


Figure 13

ERROR AMPLIFIER CLOSED-LOOP GAIN AND PHASE SHIFT vs FREQUENCY

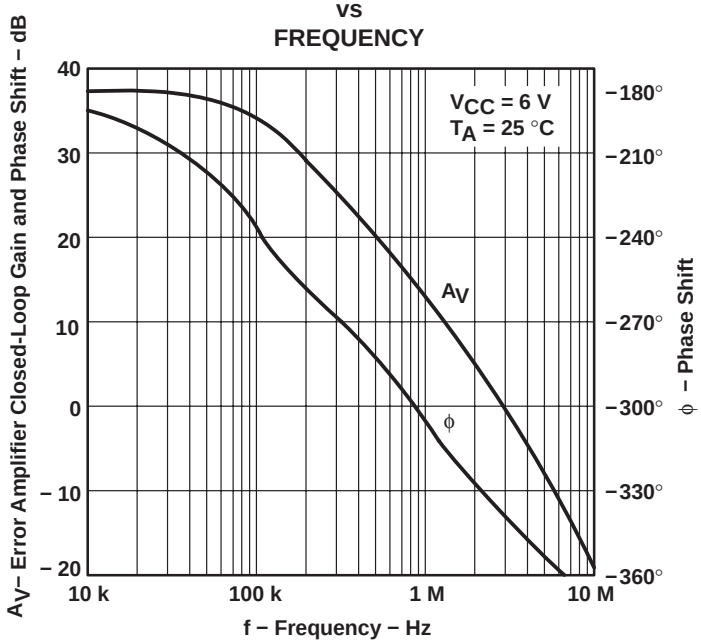


Figure 14

TYPICAL CHARACTERISTICS

DTC OUTPUT CURRENT vs RT OUTPUT CURRENT

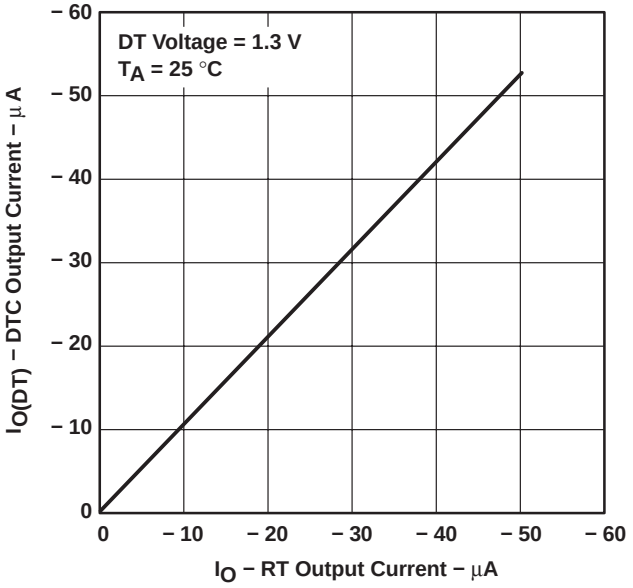


Figure 15

OUTPUT SATURATION VOLTAGE vs OUTPUT (SINK) CURRENT

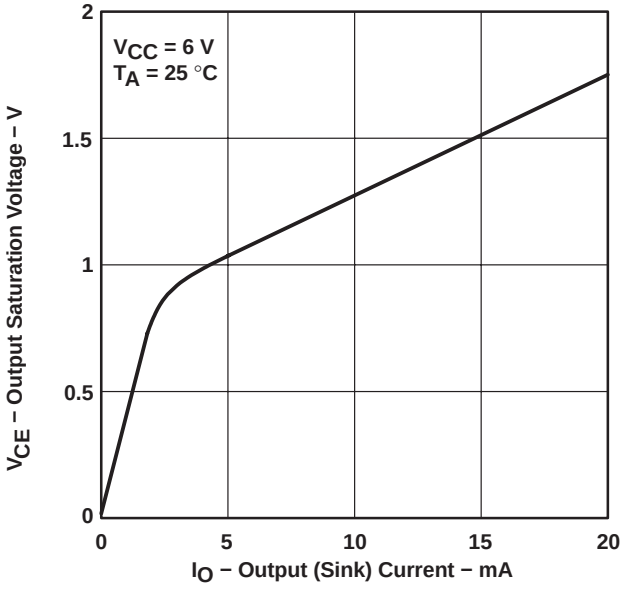


Figure 16

APPLICATION INFORMATION

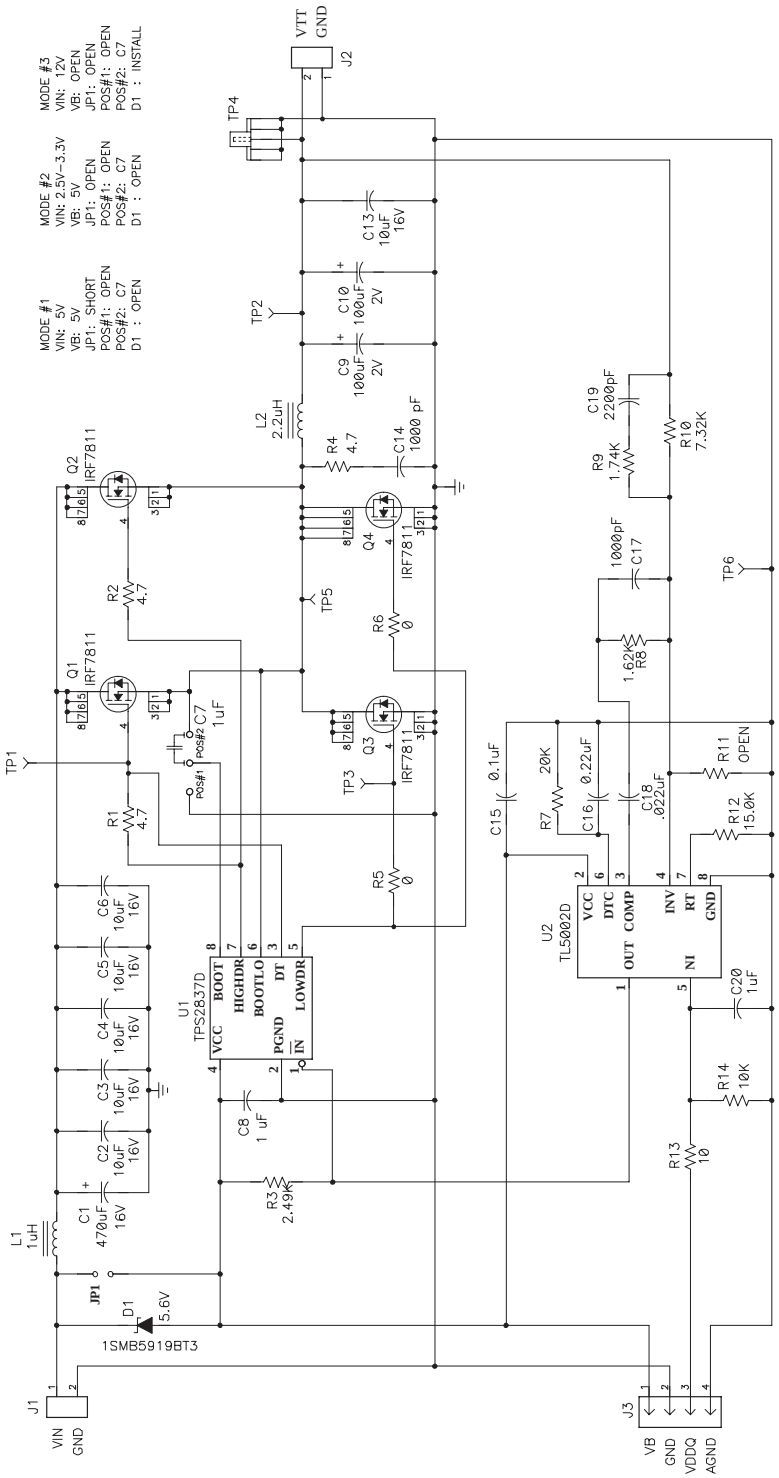


Figure 17. DDRI Application

APPLICATION INFORMATION

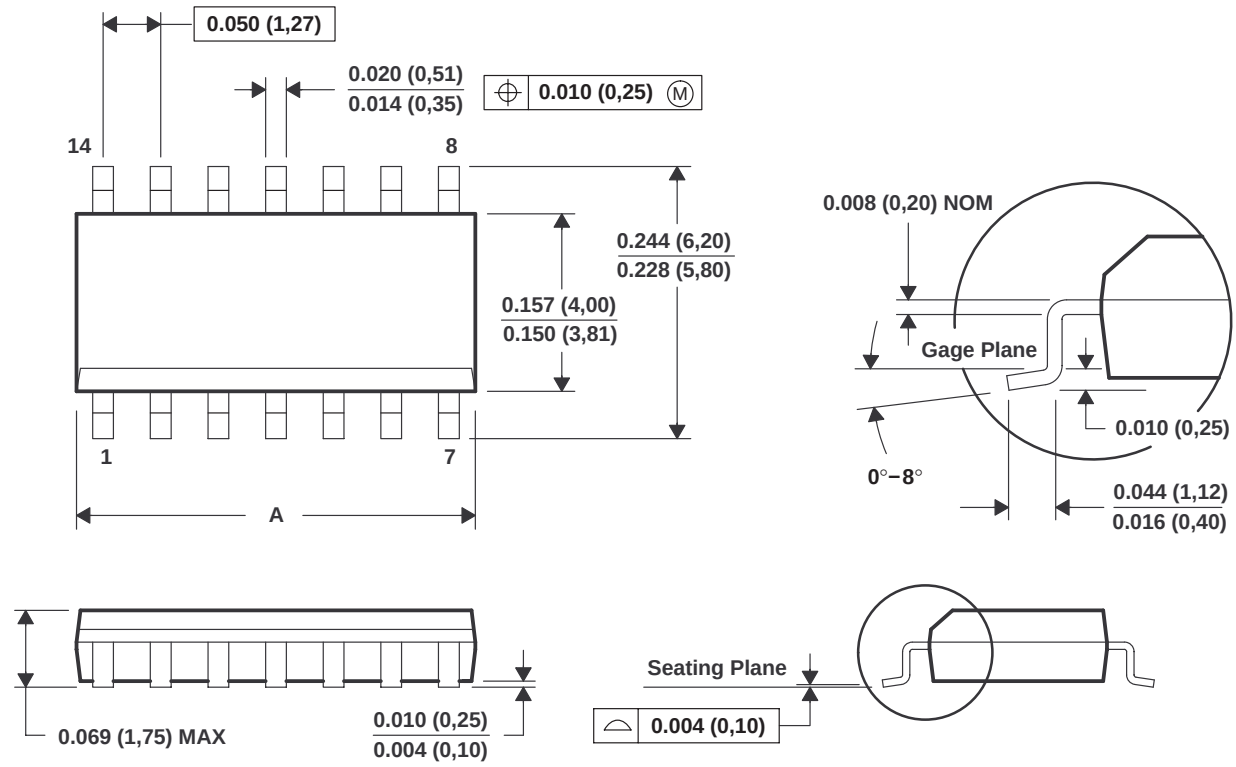
PARTIAL BILL OF MATERIALS

QUANTITY	REF DES	PART NUMBER	DESCRIPTION	MANUFACTURER	SIZE
1	C1	UUD1C471MNR1GS	Capacitor, aluminum	Nichicon	0.327 x 0.327
6	C2 − C6, C13	EMK325BJ106MN−B	Capacitor, ceramic	Taiyo Yuden	1210
3	C7, C8, C20	GRM40X7R105K16PT	Capacitor, ceramic, jumper	Murata	805
2	C9, C10	EEF−CD0D101R	Capacitor, aluminum	Panasonic	7343
1	C14	08055A102JAT2A	Capacitor, ceramic	AVX	805
1	C15	GRM39X7R104K016D	Capacitor, ceramic	Murata	603
1	C16	NMC0805X7R224K16TR	Capacitor, ceramic	NIP	603
1	C17	VJ0603Y222KXANT	Capacitor, ceramic	Murata	603
1	C18	C0603C223J3RACTU	Capacitor, ceramic	Kemet	603
1	C19	GRM39X7R223K16	Capacitor, ceramic	Murata	603
1	D1	1SMB5919BT3	Diode, zener, 5.6 V	On Semi	SMB
2	J1, J2	ED1609	Terminal block, 2-pin	OST	
1	J3	PTC36SAAN	Header, 4-pin	Sullins	
1	JP1	PTC36SAAN	Header, 2-pin	Sullins	
1	L1	UP2B−1R0	Inductor, SMT	Coiltronics	0.55 x 0.41
1	L2	UP4B−2R2	Inductor, SMT	Coiltronics	
4	Q1 − Q4	IRF7811	MOSFET, N−ch, 30 V	IR	SO8
3	R1, R2, R4	Std	Resistor, chip, 4.7 Ω	Std	603
1	R3	Std	Resistor, chip, 2.49 KΩ	Std	603
2	R5, R6	Std	Resistor, chip, 0 Ω	Std	603
1	R7	Std	Resistor, chip, 20 KΩ	Std	603
1	R8	Std	Resistor, chip, 162 KΩ	Std	603
1	R9	Std	Resistor, chip, 1.74 KΩ	Std	603
1	R10	Std	Resistor, chip, 7.32 KΩ	Std	603
1	R11	Std	Open	Std	603
1	R12	Std	Resistor, chip, 15 KΩ	Std	603
1	R13	Std	Resistor, chip, 10 Ω	Std	603
1	R14	Std	Resistor, chip, 10 KΩ	Std	603
4	TP1 − TP3, TP5	240-345	Test point, red, 1 mm	Farnell	0.038
1	TP4	131-4244-00 or 131-5031-00	Adaptor, 3.5 mm probe	Tektronix	0.200
1	TP6	1045-3-17-15-30-14-02-0	Post, wirewrap	Mill-Max	0.043
1	U1	TPS2837D	IC, MOSFET driver	Texas Instruments	SO8
1	U2	TL5002D	IC, low-cost PMW	Texas Instruments	SO8

MECHANICAL DATA

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/D 10/96

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
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