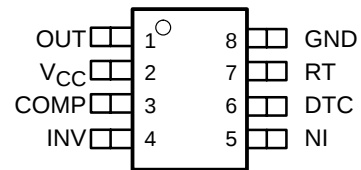


# TL5002 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

SLVS304A – SEPTEMBER 2000 – REVISED AUGUST 2002

- 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<sub>CC</sub> conditions, the UVLO circuit turns the output off until V<sub>CC</sub> recovers to its normal operating range.

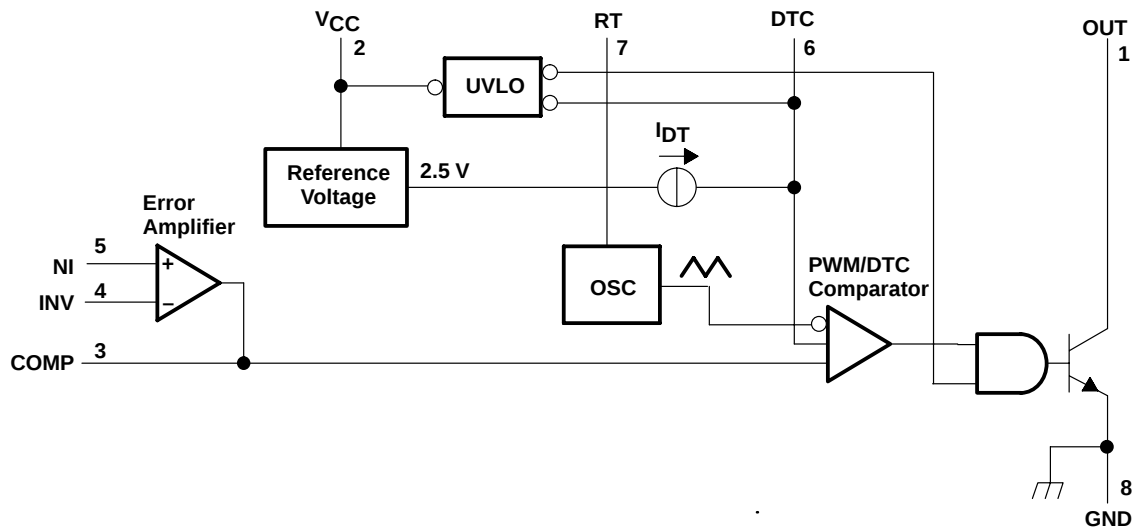
The TL5002 is characterized for operation from –40°C to 85°C.

AVAILABLE OPTIONS

| T <sub>A</sub> | 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



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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.

**TEXAS  
INSTRUMENTS**

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# TL5002

## PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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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:

$$V_O = (1 + R_1/R_2) (1 \text{ V})$$

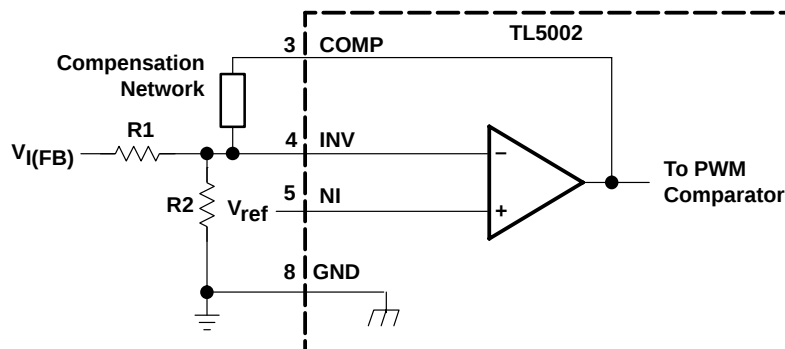


Figure 1. Error-Amplifier Gain Setting

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  $\mu$ A, the total dc load resistance should be 100 k $\Omega$  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 k $\Omega$  to 250 k $\Omega$ . 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  $\Omega$ ), 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 ( $V_{OSCmax}$  and  $V_{OSCmin}$  are the maximum and minimum oscillator levels):

### dead-time control (DTC) (continued)

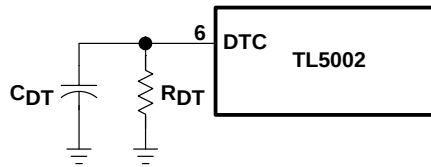
$$R_{DT} = (R_t + 1250) [D(V_{oscmax} - V_{oscmin}) + V_{oscmin}]$$

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:

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



**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.

# TL5002

## PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

|                                                              |                              |
|--------------------------------------------------------------|------------------------------|
| 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                        |

<sup>†</sup> 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 | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>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   |

# TL5002 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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

## undervoltage lockout

| PARAMETER               | TEST CONDITIONS          | TL5002C |                  |     | UNIT |
|-------------------------|--------------------------|---------|------------------|-----|------|
|                         |                          | MIN     | TYP <sup>†</sup> | MAX |      |
| Upper threshold voltage | $T_A = 25^\circ\text{C}$ |         | 3                |     | V    |
| Lower threshold voltage | $T_A = 25^\circ\text{C}$ |         | 2.8              |     | V    |
| Hysteresis              | $T_A = 25^\circ\text{C}$ | 100     | 200              |     | mV   |

<sup>†</sup> All typical values are at  $T_A = 25^\circ\text{C}$ .

## oscillator

| PARAMETER                         | TEST CONDITIONS                               | TL5002C |                  |     | UNIT |
|-----------------------------------|-----------------------------------------------|---------|------------------|-----|------|
|                                   |                                               | MIN     | TYP <sup>†</sup> | MAX |      |
| Frequency                         | $R_t = 100\text{ k}\Omega$                    |         | 100              |     | kHz  |
| Standard deviation of frequency   |                                               |         | 15               |     | kHz  |
| Frequency change with voltage     | $V_{CC} = 3.6\text{ V to }40\text{ V}$        |         | 1                |     | kHz  |
| Frequency change with temperature | $T_A = -40^\circ\text{C to }25^\circ\text{C}$ | -4      | -0.4             | 4   | kHz  |
|                                   | $T_A = -20^\circ\text{C to }25^\circ\text{C}$ | -4      | -0.4             | 4   | kHz  |
|                                   | $T_A = 25^\circ\text{C to }85^\circ\text{C}$  | -4      | -0.2             | 4   | kHz  |
| Voltage at RT                     |                                               |         | 1                |     | V    |

<sup>†</sup> All typical values are at  $T_A = 25^\circ\text{C}$ .

## dead-time control

| PARAMETER               |        | TEST CONDITIONS           | TL5002C                                          |                  |     | UNIT          |
|-------------------------|--------|---------------------------|--------------------------------------------------|------------------|-----|---------------|
|                         |        |                           | MIN                                              | TYP <sup>†</sup> | MAX |               |
| Output (source) current | TL5002 | $V_{(DT)} = 1.5\text{ V}$ | $0.9 \times I_{RT}^\ddagger$ $1.2 \times I_{RT}$ |                  |     | $\mu\text{A}$ |
| Input threshold voltage |        | Duty cycle = 0%           | 0.5                                              | 0.7              |     | V             |
|                         |        | Duty cycle = 100%         |                                                  | 1.3              | 1.5 |               |

<sup>†</sup> All typical values are at  $T_A = 25^\circ\text{C}$ .

<sup>‡</sup> Output source current at RT

## error amplifier

| PARAMETER                       |          | TEST CONDITIONS                                        | TL5002C |                  |      | UNIT          |
|---------------------------------|----------|--------------------------------------------------------|---------|------------------|------|---------------|
|                                 |          |                                                        | MIN     | TYP <sup>†</sup> | MAX  |               |
| Input voltage                   |          | $V_{CC} = 3.6\text{ V to }40\text{ V}$                 | 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           |          | $V_{I(INV)} = 1.2\text{ V}, \text{ COMP} = 1\text{ V}$ | 100     | 600              |      | $\mu\text{A}$ |
| Output (source) current         |          | $V_{I(INV)} = 0.8\text{ V}, \text{ COMP} = 1\text{ V}$ | -45     | -70              |      | $\mu\text{A}$ |

<sup>†</sup> All typical values are at  $T_A = 25^\circ\text{C}$ .



TL5002  
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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

output

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

† All typical values are at  $T_A = 25^\circ\text{C}$ .

total device

| PARAMETER              |           | TEST CONDITIONS            | TL5002C |      |     | UNIT |
|------------------------|-----------|----------------------------|---------|------|-----|------|
|                        |           |                            | MIN     | TYP† | MAX |      |
| Standby supply current | Off state |                            |         | 1    | 1.5 | mA   |
| Average supply current |           | $R_t = 100\text{ k}\Omega$ |         | 1.4  | 2.1 | mA   |

† All typical values are at  $T_A = 25^\circ\text{C}$ .

PARAMETER MEASUREMENT INFORMATION

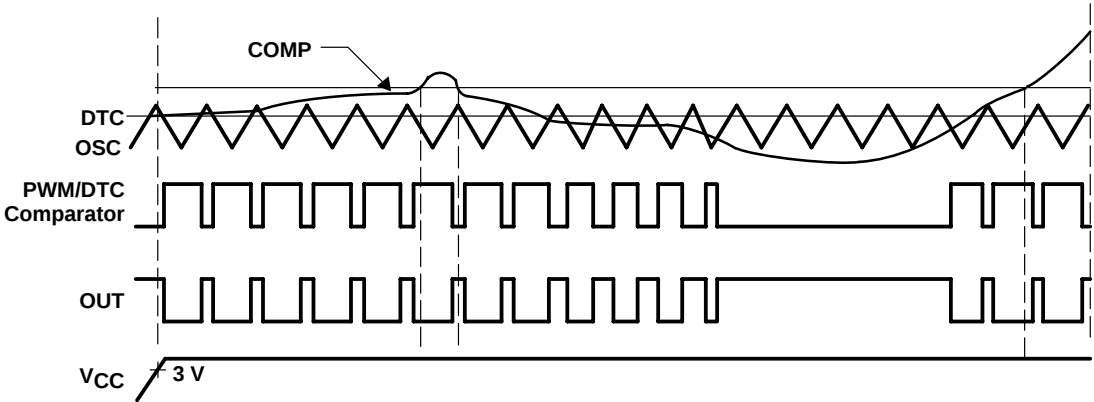


Figure 3. PWM Timing Diagram

## TYPICAL CHARACTERISTICS

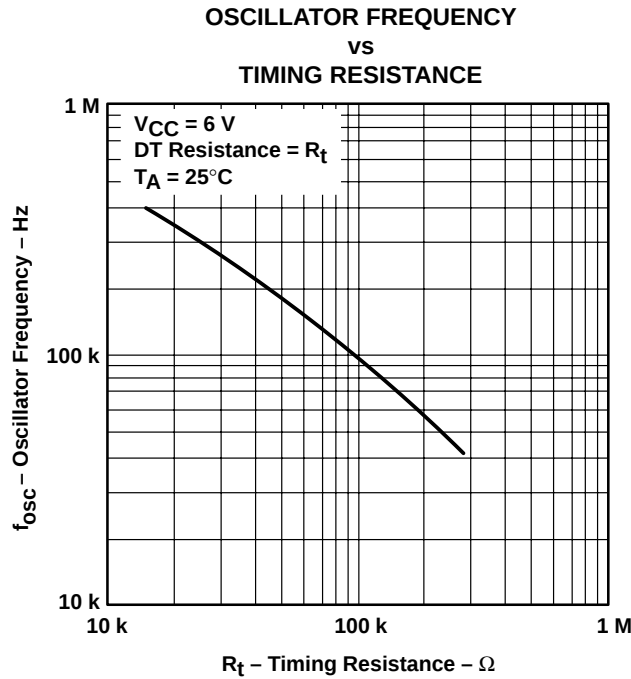


Figure 4

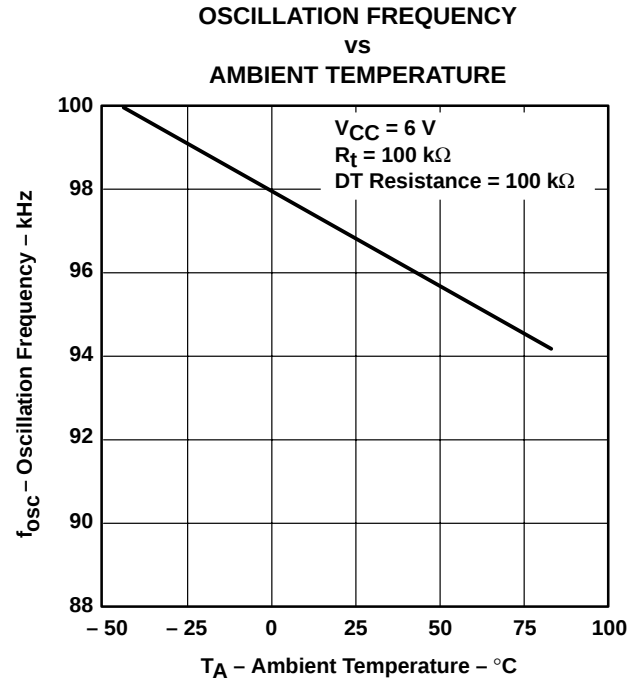


Figure 5

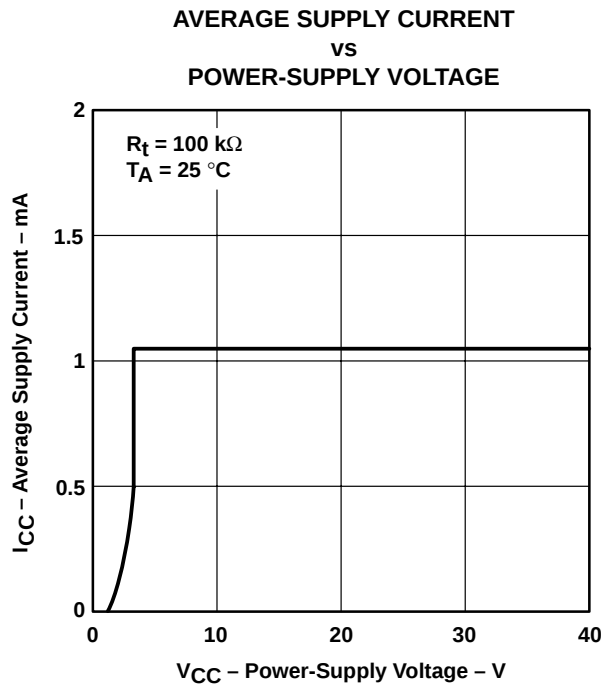


Figure 6

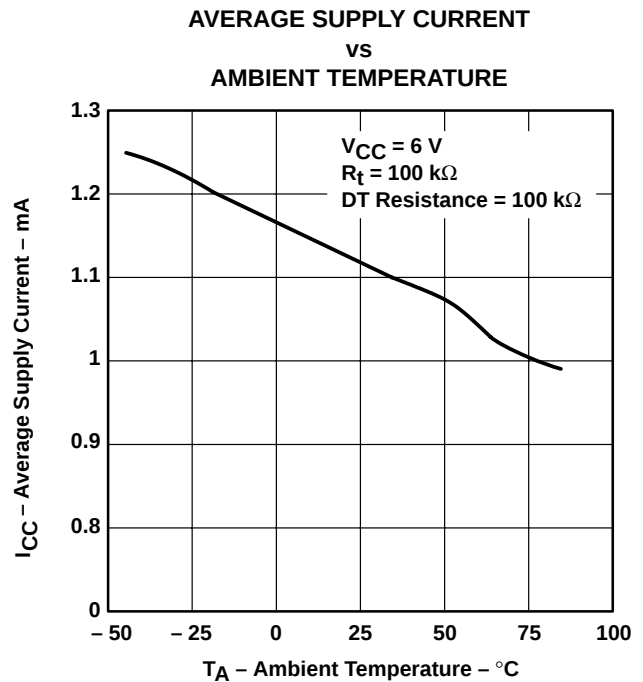


Figure 7

# TL5002

## PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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### TYPICAL CHARACTERISTICS

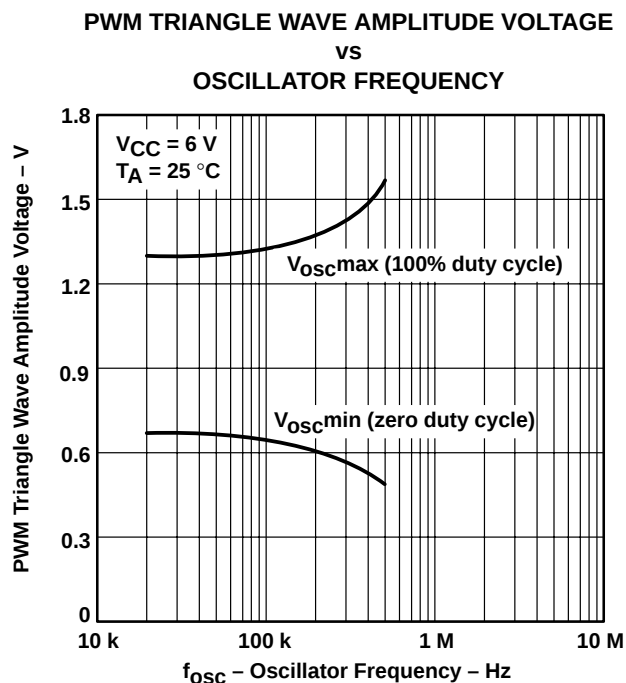


Figure 8

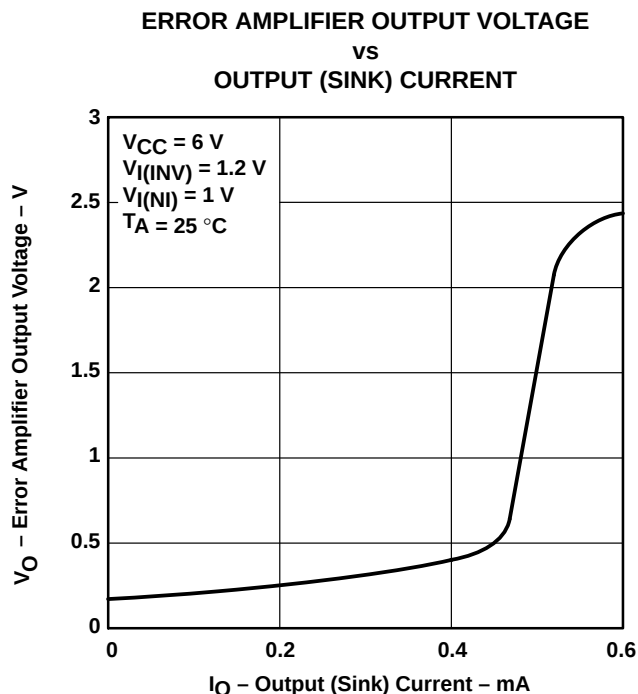


Figure 9

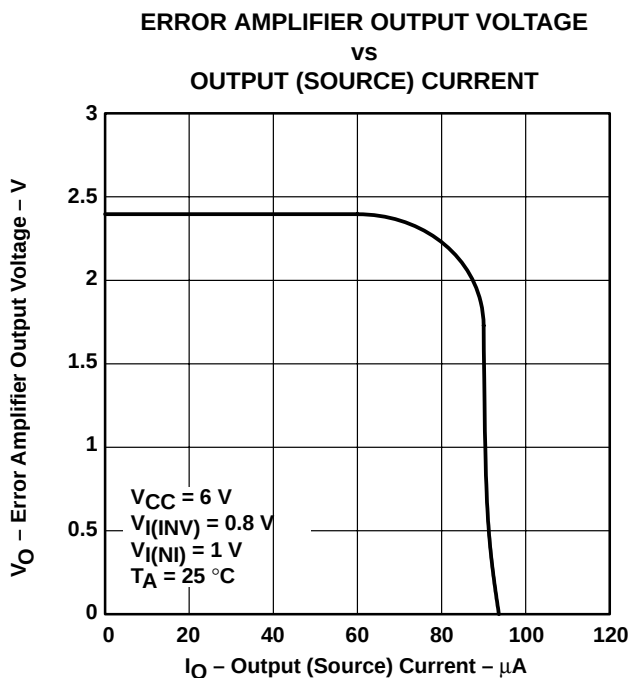


Figure 10

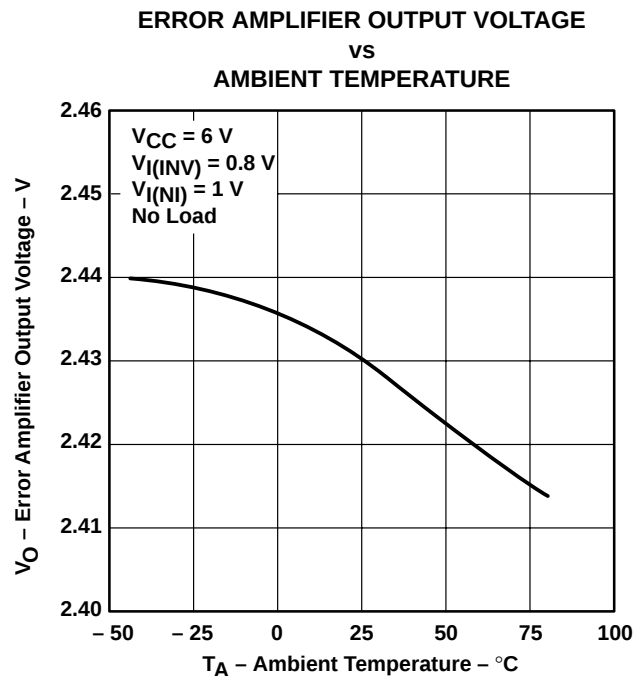


Figure 11

## TYPICAL CHARACTERISTICS

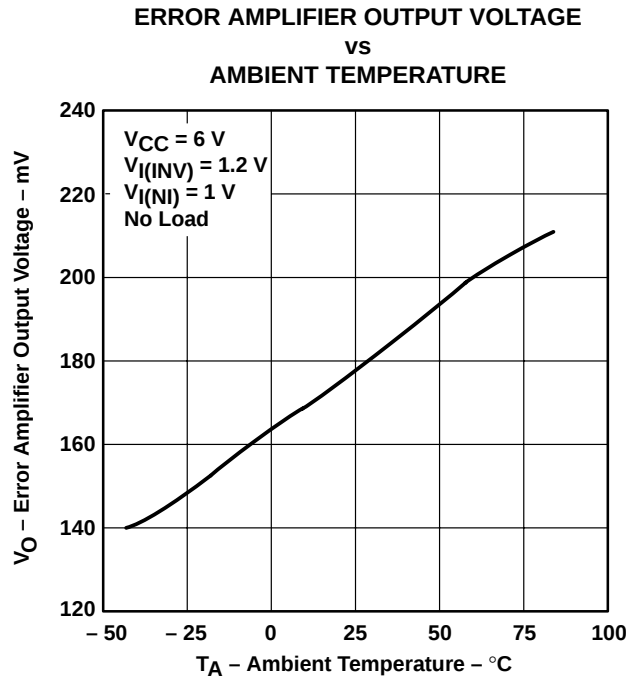


Figure 12

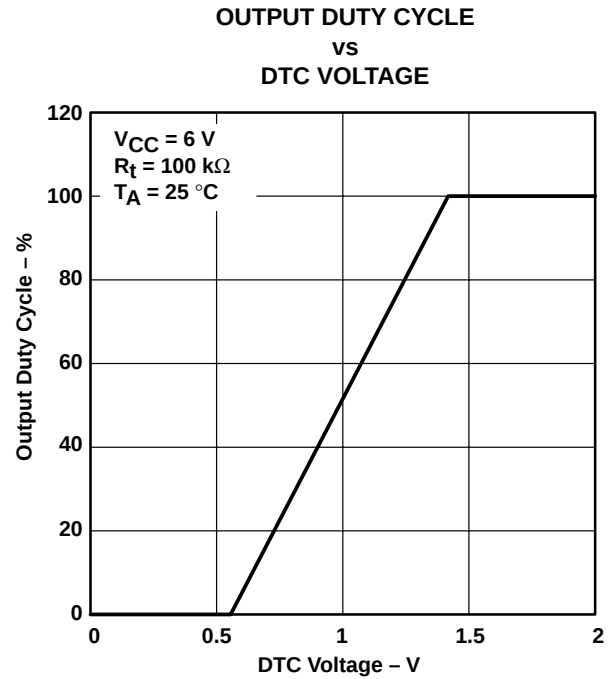


Figure 13

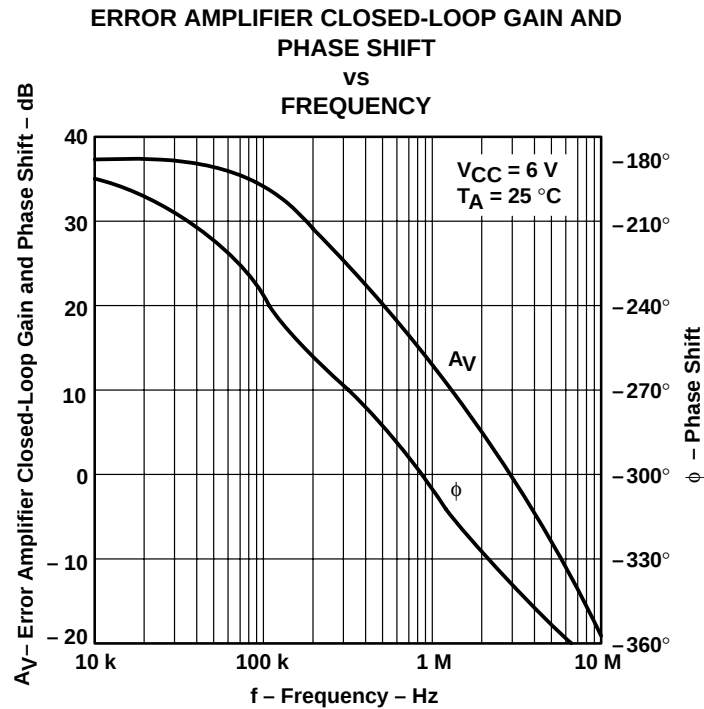


Figure 14

TL5002  
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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TYPICAL CHARACTERISTICS

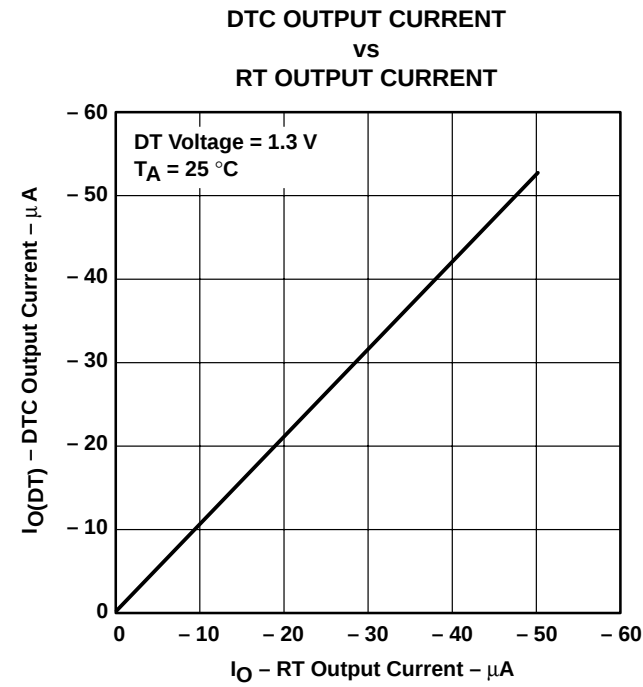


Figure 15

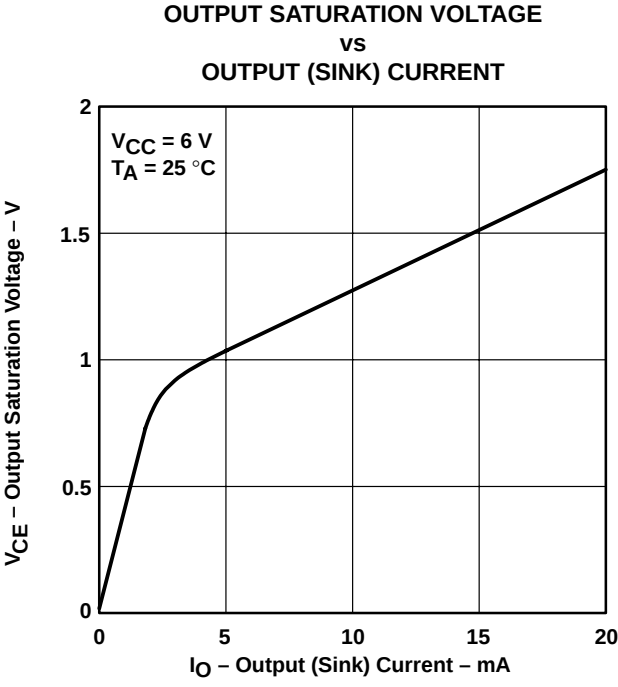


Figure 16

**MODE #1**  
VIN: 5V  
VB: SHORT  
U1: OPEN  
POS#1: OPEN  
POS#2: C7  
D1: OPEN

**MODE #2**  
VIN: 2.5V~3.3V  
VB: 5V OPEN  
U1: OPEN  
POS#1: OPEN  
POS#2: C7  
D1: OPEN

**MODE #3**  
VIN: 12V  
VB: OPEN  
U1: OPEN  
POS#1: OPEN  
POS#2: C7  
D1: INSTALL



# TL5002

## PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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### 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 $\Omega$    | Std               | 603           |
| 1        | R3             | Std                        | Resistor, chip, 2.49 K $\Omega$ | Std               | 603           |
| 2        | R5, R6         | Std                        | Resistor, chip, 0 $\Omega$      | Std               | 603           |
| 1        | R7             | Std                        | Resistor, chip, 20 K $\Omega$   | Std               | 603           |
| 1        | R8             | Std                        | Resistor, chip, 162 K $\Omega$  | Std               | 603           |
| 1        | R9             | Std                        | Resistor, chip, 1.74 K $\Omega$ | Std               | 603           |
| 1        | R10            | Std                        | Resistor, chip, 7.32 K $\Omega$ | Std               | 603           |
| 1        | R11            | Std                        | Open                            | Std               | 603           |
| 1        | R12            | Std                        | Resistor, chip, 15 K $\Omega$   | Std               | 603           |
| 1        | R13            | Std                        | Resistor, chip, 10 $\Omega$     | Std               | 603           |
| 1        | R14            | Std                        | Resistor, chip, 10 K $\Omega$   | 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           |



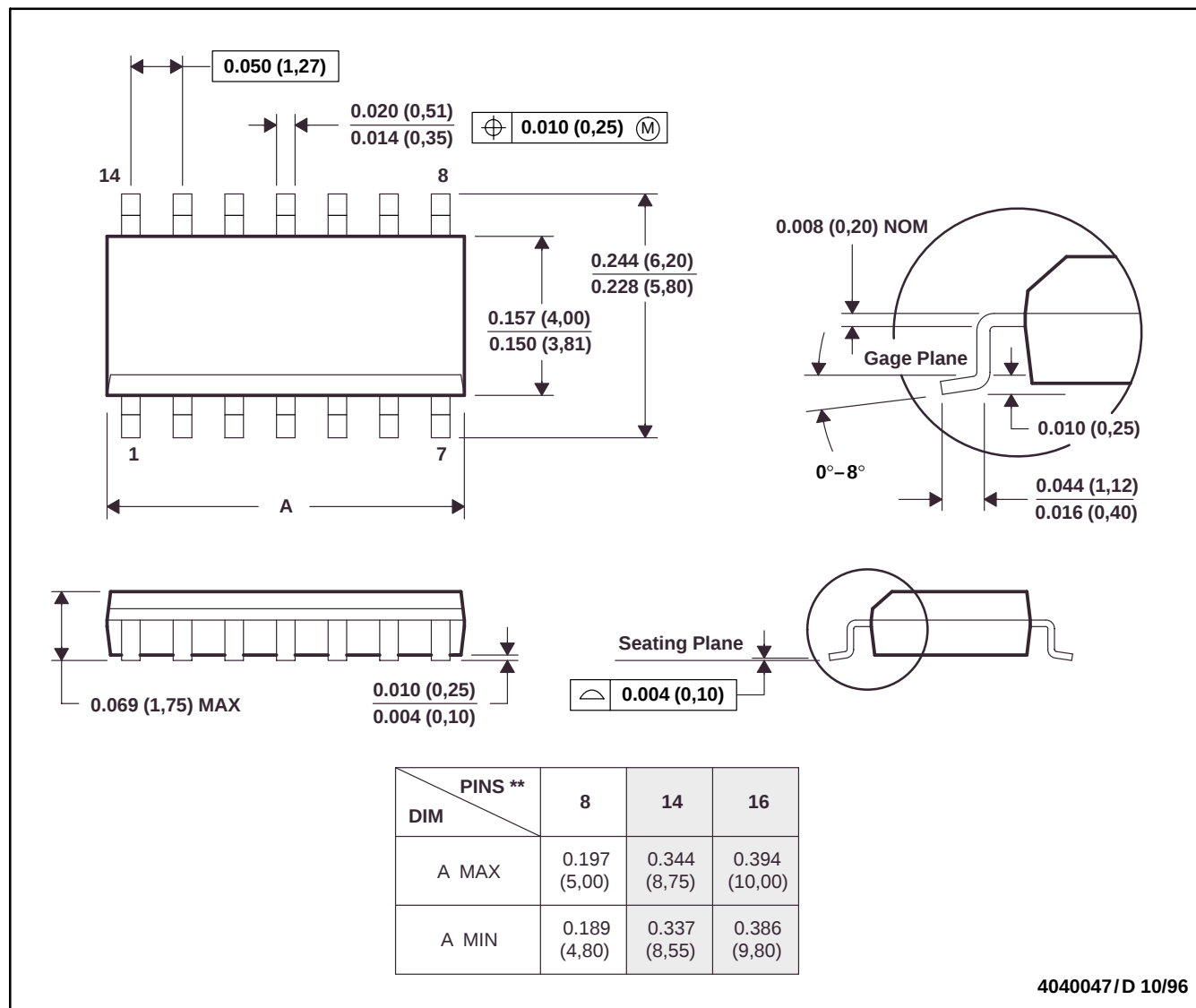
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## MECHANICAL DATA

**D (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

**14 PIN SHOWN**



- 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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