# PULSE-WIDTH-MODULATION CONTROL CIRCUITS

SLVS053D – FEBRUARY 1988 – REVISED NOVEMBER 2003

- **Complete PWM Power-Control Function**
- **Totem-Pole Outputs for 200-mA Sink or Source Current**
- **Output Control Selects Parallel or Push-Pull Operation**
- **Internal Circuitry Prohibits Double Pulse at Either Output**
- **Variable Dead-Time Provides Control Over Total Range**
- **Internal Regulator Provides a Stable 5-V Reference Supply, Trimmed to 1% Tolerance**
- **On-Board Output Current-Limiting Protection**
- **Undervoltage Lockout for Low-$V_{CC}$ Conditions**
- **Separate Power and Signal Grounds**

**D OR N PACKAGE**
**(TOP VIEW)**

```
              ┌────∪────┐
ERROR  1IN+ [ 1       16 ] 2IN+   ERROR
AMP 1  1IN− [ 2       15 ] 2IN−   AMP 2
    FEEDBACK [ 3       14 ] REF
        DTC [ 4       13 ] OUTPUT CTRL
         CT [ 5       12 ] VCC
         RT [ 6       11 ] VC
 SIGNAL GND [ 7       10 ] POWER GND
       OUT1 [ 8        9 ] OUT2
              └─────────┘
```
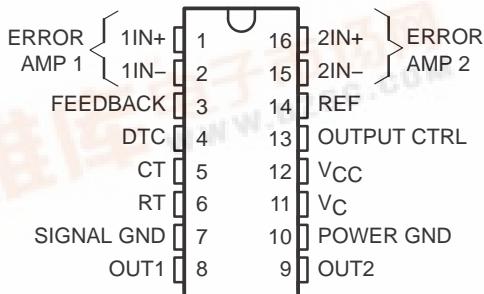
## description/ordering information

The TL598 incorporates all the functions required in the construction of pulse-width-modulated (PWM) controlled systems on a single chip. Designed primarily for power-supply control, the TL598 provides the systems engineer with the flexibility to tailor the power-supply control circuits to a specific application.

The TL598 contains two error amplifiers, an internal oscillator (externally adjustable), a dead-time control (DTC) comparator, a pulse-steering flip-flop, a 5-V precision reference, undervoltage lockout control, and output control circuits. Two totem-pole outputs provide exceptional rise- and fall-time performance for power FET control. The outputs share a common source supply and common power ground terminals, which allow system designers to eliminate errors caused by high current-induced voltage drops and common-mode noise.

The error amplifier has a common-mode voltage range of 0 V to $V_{CC}$ – 2 V. The DTC comparator has a fixed offset that prevents overlap of the outputs during push-pull operation. A synchronous multiple supply operation can be achieved by connecting RT to the reference output and providing a sawtooth input to CT.

The TL598 device provides an output control function to select either push-pull or parallel operation. Circuit architecture prevents either output from being pulsed twice during push-pull operation. The output frequency for push-pull applications is one-half the oscillator frequency $\left( f_O = \dfrac{1}{2\ RT\ CT} \right)$. For single-ended applications:

$$f_O = \frac{1}{RT\ CT}.$$

## ORDERING INFORMATION

| $T_A$ | PACKAGE† | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|
| 0°C to 70°C | PDIP (N) | Tube of 25 | TL598CN | TL598CN |
| | SOIC (D) | Tube of 40 | TL598CD | TL598C |
| | | Reel of 2500 | TL598CDR | |

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

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.

Copyright © 2003, Texas Instruments Incorporated

**TEXAS INSTRUMENTS**

# TL598
# PULSE-WIDTH-MODULATION CONTROL CIRCUITS

**FUNCTION TABLE**

| INPUT/OUTPUT CTRL | OUTPUT FUNCTION |
|---|---|
| $V_I$ = GND | Single-ended or parallel output |
| $V_I$ = REF | Normal push-pull operation |

## functional block diagram
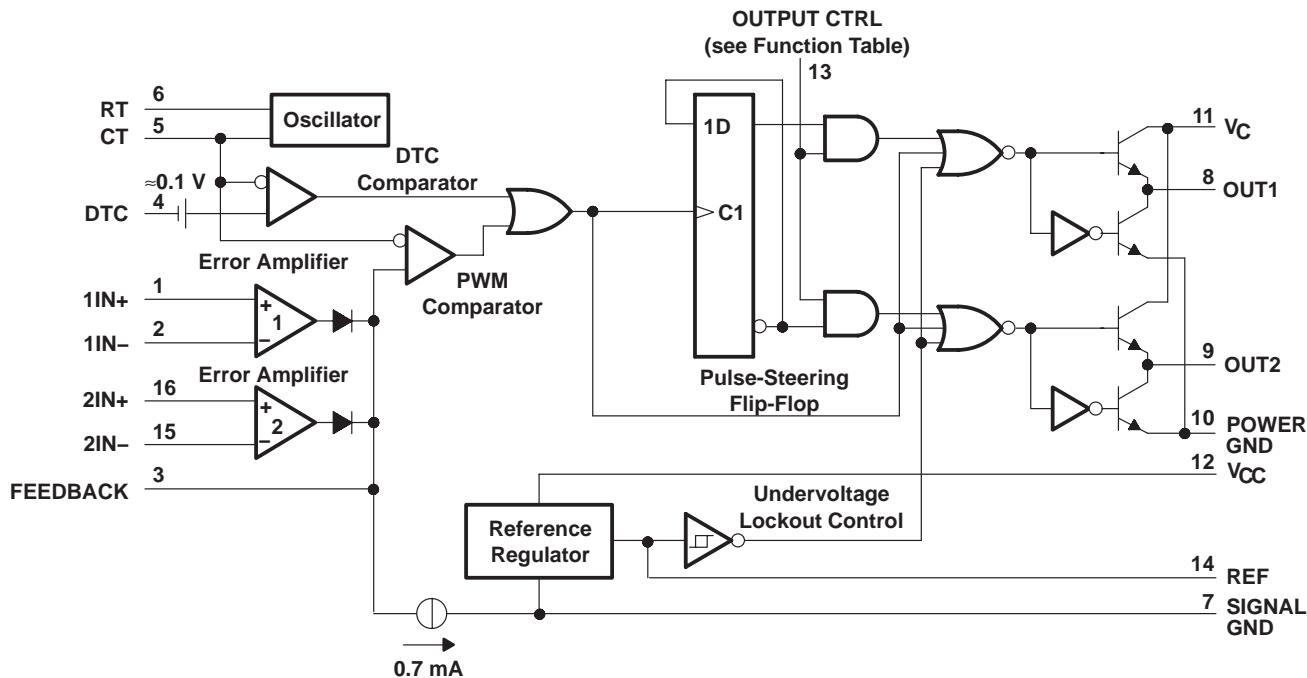


## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

| | |
|---|---|
| Supply voltage, $V_{CC}$ (see Note 1) | 41 V |
| Amplifier input voltage, $V_I$ | $V_{CC}$ + 0.3 V |
| Collector voltage | 41 V |
| Output current (each output), sink or source, $I_O$ | 250 mA |
| Package thermal impedance, $\theta_{JA}$ (see Notes 2 and 3): D package | 73°C/W |
| N package | 67°C/W |
| Operating virtual junction temperature, $T_J$ | 150°C |
| Storage temperature range, $T_{stg}$ | −65°C to 150°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.

NOTES: 1. All voltage values, except differential voltages, are with respect to the signal ground terminal.
2. Maximum power dissipation is a function of $T_J$(max), $\theta_{JA}$, and $T_A$. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J$(max) − $T_A)/\theta_{JA}$. Operating at the absolute maximum $T_J$ of 150°C can impact reliability.
3. The package thermal impedance is calculated in accordance with JESD 51-7.

## recommended operating conditions

|  |  | MIN | MAX | UNIT |
|---|---|---|---|---|
| $V_{CC}$ | Supply voltage | 7 | 40 | V |
| $V_I$ | Amplifier input voltage | 0 | $V_{CC}-2$ | V |
| $I_O$ | Collector voltage |  | 40 | V |
| $I_{IL}$ | Output current (each output), sink or source |  | 200 | mA |
|  | Current into feedback terminal |  | 0.3 | mA |
| $C_T$ | Timing capacitor | 0.00047 | 10 | μF |
| $R_T$ | Timing resistor | 1.8 | 500 | kΩ |
| $f_{osc}$ | Oscillator frequency | 1 | 300 | kHz |
| $T_A$ | Operating free-air temperature | 0 | 70 | °C |

## electrical characteristics over recommended operating free-air temperature range, $V_{CC}$ = 15 V (unless otherwise noted)

### reference section (see Note 4)

| PARAMETER | TEST CONDITIONS† |  | MIN | TYP‡ | MAX | UNIT |
|---|---|---|---|---|---|---|
| Output voltage (REF) | $I_O$ = 1 mA | $T_A$ = 25°C | 4.95 | 5 | 5.05 | V |
|  |  | $T_A$ = full range | 4.9 |  | 5.1 |  |
| Input regulation | $V_{CC}$ = 7 V to 40 V | $T_A$ = 25°C |  | 2 | 25 | mV |
| Output regulation | $I_O$ = 1 mA to 10 mA | $T_A$ = 25°C |  | 1 | 15 | mV |
|  |  | $T_A$ = full range |  |  | 50 |  |
| Output voltage change with temperature | $\Delta T_A$ = MIN to MAX |  |  | 2 | 10 | mV/V |
| Short-circuit output current§ | REF = 0 V |  | −10 | −48 |  | mA |

† Full range is 0°C to 70°C.
‡ All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
§ Duration of the short circuit should not exceed one second.
NOTE 4: Pulse-testing techniques that maintain the junction temperature as close to the ambient temperature as possible must be used.

### oscillator section, $C_T$ = 0.001 μF, $R_T$ = 12 kΩ (see Figure 1) (see Note 4)

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|---|---|---|---|---|---|
| Frequency |  |  | 100 |  | kHz |
| Standard deviation of frequency¶ | All values of $V_{CC}$, $C_T$, $R_T$, $T_A$ constant |  | 100 |  | Hz/kHz |
| Frequency change with voltage | $V_{CC}$ = 7 V to 40 V,     $T_A$ = 25°C |  | 1 | 10 | Hz/kHz |
| Frequency change with temperature# | $\Delta T_A$ = full range |  | 70 | 120 | Hz/kHz |
|  | $\Delta T_A$ = full range,     $C_T$ = 0.01 μF |  | 50 | 80 |  |

† Full range is 0°C to 70°C.
‡ All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
¶ Standard deviation is a measure of the statistical distribution about the mean, as derived from the formula:

$$\sigma = \sqrt{\frac{\sum\limits_{n=1}^{N} (x_n - \overline{x})^2}{N-1}}$$

# Effects of temperature on external $R_T$ and $C_T$ are not taken into account.
NOTE 4. Pulse-testing techniques that maintain the junction temperature as close to the ambient temperature as possible must be used.

## electrical characteristics over recommended operating free-air temperature range, $V_{CC}$ = 15 V (unless otherwise noted) (continued)

### error amplifier section (see Note 4)

| PARAMETER | TEST CONDITIONS | MIN | TYP[†] | MAX | UNIT |
|---|---|---|---|---|---|
| Input offset voltage | FEEDBACK = 2.5 V | | 2 | 10 | mV |
| Input offset current | FEEDBACK = 2.5 V | | 25 | 250 | nA |
| Input bias current | FEEDBACK = 2.5 V | | 0.2 | 1 | µA |
| Common-mode input voltage range | $V_{CC}$ = 7 V to 40 V | 0 to $V_{CC}-2$ | | | V |
| Open-loop voltage amplification | $\Delta V_O$ (FEEDBACK) = 3 V,    $V_O$ (FEEDBACK) = 0.5 V to 3.5 V | 70 | 95 | | dB |
| Unity-gain bandwidth | | | 800 | | kHz |
| Common-mode rejection ratio | $V_{CC}$ = 40 V,         $\Delta V_{IC}$ = 6.5 V,       $T_A$ = 25°C | 65 | 80 | | dB |
| Output sink current (FEEDBACK) | FEEDBACK = 0.5 V | 0.3 | 0.7 | | mA |
| Output source current (FEEDBACK) | FEEDBACK = 3.5 V | −2 | | | mA |
| Phase margin at unity gain | FEEDBACK = 0.5 V to 3.5 V,            $R_L$ = 2 kΩ | | 65° | | |
| Supply-voltage rejection ratio | FEEDBACK = 2.5 V,       $\Delta V_{CC}$ = 33 V,       $R_L$ = 2 kΩ | | 100 | | dB |

[†] All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
NOTE 4.  Pulse-testing techniques that maintain the junction temperature as close to the ambient temperature as possible must be used.

## electrical characteristics over recommended operating free-air temperature range, $V_{CC}$ = 15 V (unless otherwise noted)

### undervoltage lockout section (see Note 4)

| PARAMETER | TEST CONDITIONS[‡] | MIN | MAX | UNIT |
|---|---|---|---|---|
| Threshold voltage | $T_A$ = 25°C | 4 | 6 | V |
| | $\Delta T_A$ = full range | 3.5 | 6.9 | |
| Hysteresis[§] | $T_A$ = 25°C | 100 | | mV |
| | $T_A$ = full range | 50 | | |

[‡] Full range is 0°C to 70°C.
[§] Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.
NOTE 4.  Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

### output section (see Note 4)

| PARAMETER | TEST CONDITIONS | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| High-level output voltage | $V_{CC}$ = 15 V, $V_C$ = 15 V | $I_O$ = −200 mA | 12 | | V |
| | | $I_O$ = −20 mA | 13 | | |
| Low-level output voltage | $V_{CC}$ = 15 V, $V_C$ = 15 V | $I_O$ = 200 mA | | 2 | V |
| | | $I_O$ = 20 mA | | 0.4 | |
| Output-control input current | $V_I$ = $V_{ref}$ | | | 3.5 | mA |
| | $V_I$ = 0.4 V | | | 100 | µA |

NOTE 4.  Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

## electrical characteristics over recommended operating free-air temperature range, $V_{CC}$ = 15 V (unless otherwise noted) (continued)

### dead-time control section (see Figure 1) (see Note 4)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|
| Input bias current (DTC) | $V_I$ = 0 to 5.25 V | | −2 | −10 | µA |
| Maximum duty cycle, each output | DTC = 0 V | 0.45 | | | |
| Input threshold voltage (DTC) | Zero duty cycle | | 3 | 3.3 | V |
| | Maximum duty cycle | 0 | | | |

† All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
NOTE 4. Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

### pwm comparator section (see Note 4)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|
| Input threshold voltage (FEEDBACK) | DTC = 0 V | | 3.75 | 4.5 | V |
| Input sink current (FEEDBACK) | $V_{(FEEDBACK)}$ = 0.5 V | 0.3 | 0.7 | | mA |

† All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
NOTE Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

### total device (see Figure 1) (see Note 4)

| PARAMETER | TEST CONDITIONS | | MIN | TYP† | MAX | UNIT |
|---|---|---|---|---|---|---|
| Standby supply current | RT = $V_{ref}$, All other inputs and outputs open | $V_{CC}$ = 15 V | | 15 | 21 | mA |
| | | $V_{CC}$ = 40 V | | 20 | 26 | |
| Average supply current | DTC = 2 V | | | 15 | | mA |

† All typical values, except for parameter changes with temperature, are at $T_A$ = 25°C.
NOTE 4. Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

## switching characteristics, $T_A$ = 25°C (see Note 4)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Output-voltage rise time | CL = 1500 pF,   VC = 15 V,   VCC = 15 V, See Figure 2 | | 60 | 150 | ns |
| Output-voltage fall time | | | 35 | 75 | |

NOTE 4. Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

## PARAMETER MEASUREMENT INFORMATION

**MAIN DEVICE TEST CIRCUIT**
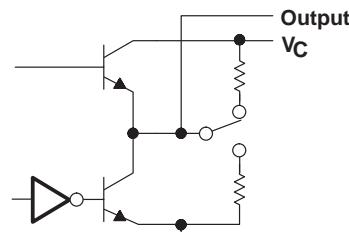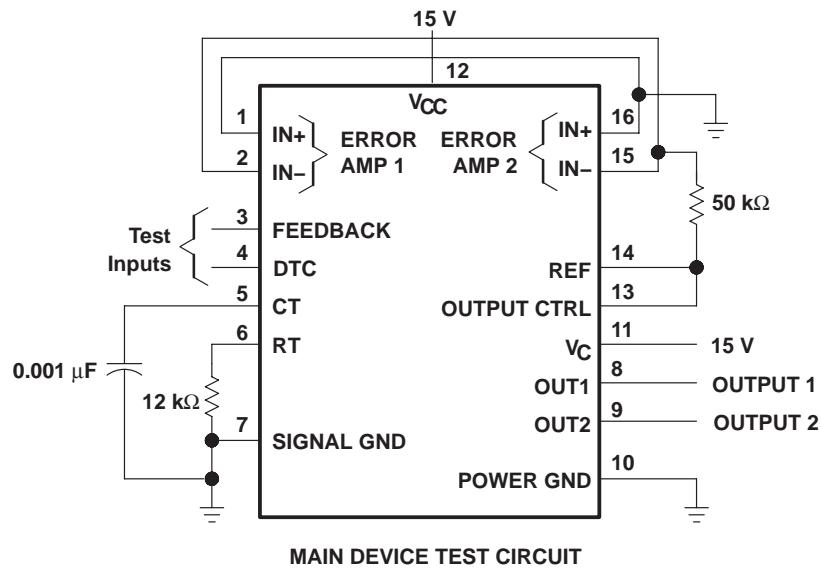
**OUTPUT CONFIGURATION**
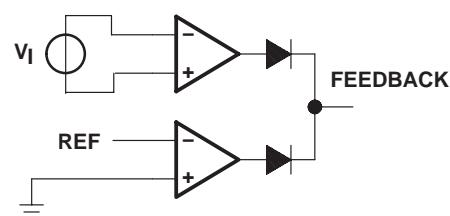
**ERROR-AMPLIFIER TEST CIRCUIT**

**Figure 1. Test Circuits**
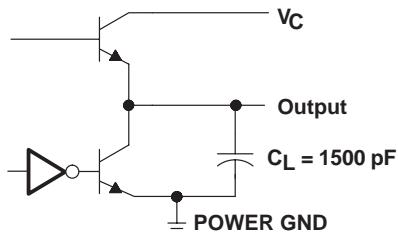
**OUTPUT CONFIGURATION**
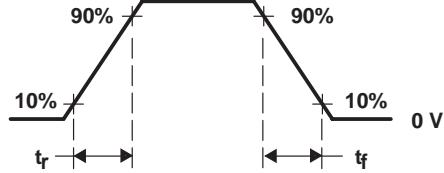
**OUTPUT-VOLTAGE WAVEFORM**

**Figure 2. Switching Output Configuration and Voltage Waveform**

## TYPICAL CHARACTERISTICS

**OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION†
vs
TIMING RESISTANCE**
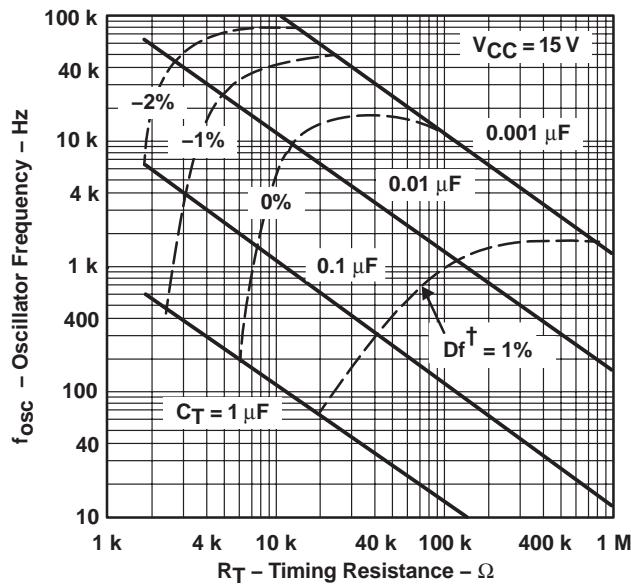


† Frequency variation (Δf) is the change in predicted oscillator
frequency that occurs over the full temperature range.

**Figure 3**

**AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY**
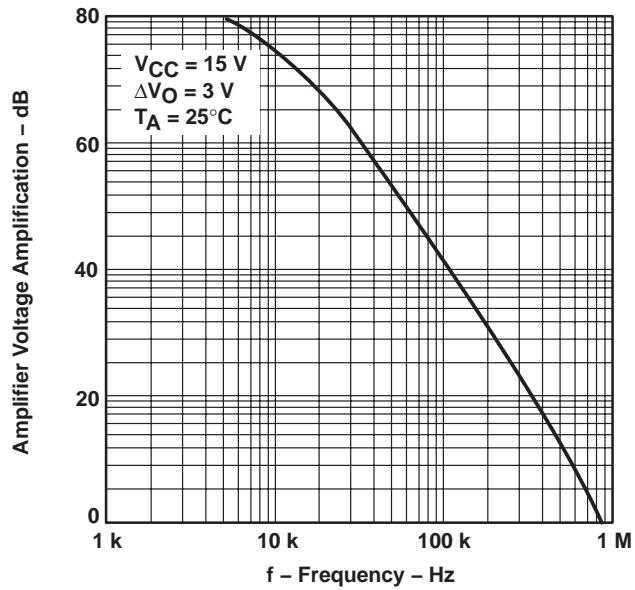


**Figure 4**

## PACKAGING INFORMATION

| Orderable Device | Status [1] | Package Type | Package Drawing | Pins | Package Qty | Eco Plan [2] | Lead/Ball Finish | MSL Peak Temp [3] |
|---|---|---|---|---|---|---|---|---|
| 5962-9166801QEA | OBSOLETE | CDIP | J | 16 | | TBD | Call TI | Call TI |
| TL598CD | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TL598CDE4 | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TL598CDR | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TL598CDRE4 | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TL598CN | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TL598CNE4 | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TL598MFKB | OBSOLETE | LCCC | FK | 20 | | TBD | Call TI | Call TI |
| TL598MJB | OBSOLETE | CDIP | J | 16 | | TBD | Call TI | Call TI |
| TL598QD | OBSOLETE | SOIC | D | 16 | | TBD | Call TI | Call TI |
| TL598QDR | OBSOLETE | SOIC | D | 16 | | TBD | Call TI | Call TI |
| TL598QN | OBSOLETE | PDIP | N | 16 | | TBD | Call TI | Call TI |

[1] The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

J (R−GDIP−T**)　　　　　　　　　CERAMIC DUAL IN−LINE PACKAGE

14 LEADS SHOWN
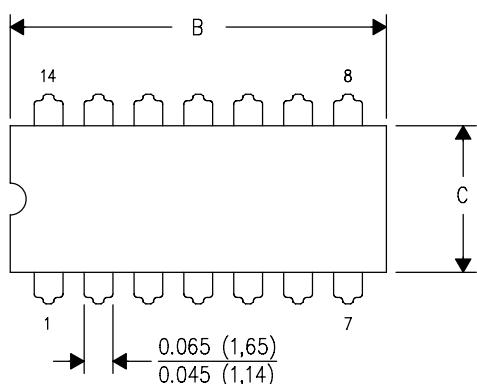
| DIM \ PINS ** | 14 | 16 | 18 | 20 |
|---|---|---|---|---|
| A | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC |
| B MAX | 0.785 (19,94) | .840 (21,34) | 0.960 (24,38) | 1.060 (26,92) |
| B MIN | —— | —— | —— | —— |
| C MAX | 0.300 (7,62) | 0.300 (7,62) | 0.310 (7,87) | 0.300 (7,62) |
| C MIN | 0.245 (6,22) | 0.245 (6,22) | 0.220 (5,59) | 0.245 (6,22) |

B

14    8

$\dfrac{0.065\ (1,65)}{0.045\ (1,14)}$

1    7

C

0.005 (0,13) MIN

$\dfrac{0.060\ (1,52)}{0.015\ (0,38)}$

0.200 (5,08) MAX

Seating Plane

0.130 (3,30) MIN

$\dfrac{0.026\ (0,66)}{0.014\ (0,36)}$

0.100 (2,54)

A

0°−15°

$\dfrac{0.014\ (0,36)}{0.008\ (0,20)}$
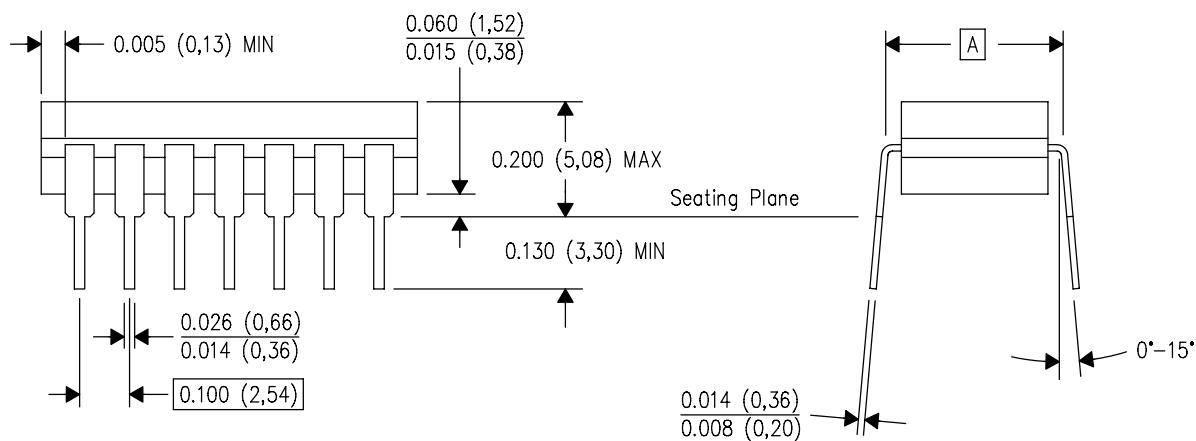
4040083/F 03/03

NOTES:　A.　All linear dimensions are in inches (millimeters).

B.　This drawing is subject to change without notice.

C.　This package is hermetically sealed with a ceramic lid using glass frit.

D.　Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.

E.　Falls within MIL STD 1835 GDIP1−T14, GDIP1−T16, GDIP1−T18 and GDIP1−T20.

# MECHANICAL DATA

## FK (S-CQCC-N**)

**28 TERMINAL SHOWN**

### LEADLESS CERAMIC CHIP CARRIER

| NO. OF TERMINALS ** | A | | B | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| 20 | 0.342 (8,69) | 0.358 (9,09) | 0.307 (7,80) | 0.358 (9,09) |
| 28 | 0.442 (11,23) | 0.458 (11,63) | 0.406 (10,31) | 0.458 (11,63) |
| 44 | 0.640 (16,26) | 0.660 (16,76) | 0.495 (12,58) | 0.560 (14,22) |
| 52 | 0.739 (18,78) | 0.761 (19,32) | 0.495 (12,58) | 0.560 (14,22) |
| 68 | 0.938 (23,83) | 0.962 (24,43) | 0.850 (21,6) | 0.858 (21,8) |
| 84 | 1.141 (28,99) | 1.165 (29,59) | 1.047 (26,6) | 1.063 (27,0) |

B SQ

A SQ

$\frac{0.020\ (0,51)}{0.010\ (0,25)}$

$\frac{0.020\ (0,51)}{0.010\ (0,25)}$

$\frac{0.080\ (2,03)}{0.064\ (1,63)}$

$\frac{0.055\ (1,40)}{0.045\ (1,14)}$

$\frac{0.045\ (1,14)}{0.035\ (0,89)}$

$\frac{0.028\ (0,71)}{0.022\ (0,54)}$

$\frac{0.045\ (1,14)}{0.035\ (0,89)}$

0.050 (1,27)

**4040140 / D 10/96**

NOTES:  A.  All linear dimensions are in inches (millimeters).
B.  This drawing is subject to change without notice.
C.  This package can be hermetically sealed with a metal lid.
D.  The terminals are gold plated.
E.  Falls within JEDEC MS-004

### TEXAS INSTRUMENTS

## N (R−PDIP−T**)
16 PINS SHOWN

**PLASTIC DUAL−IN−LINE PACKAGE**
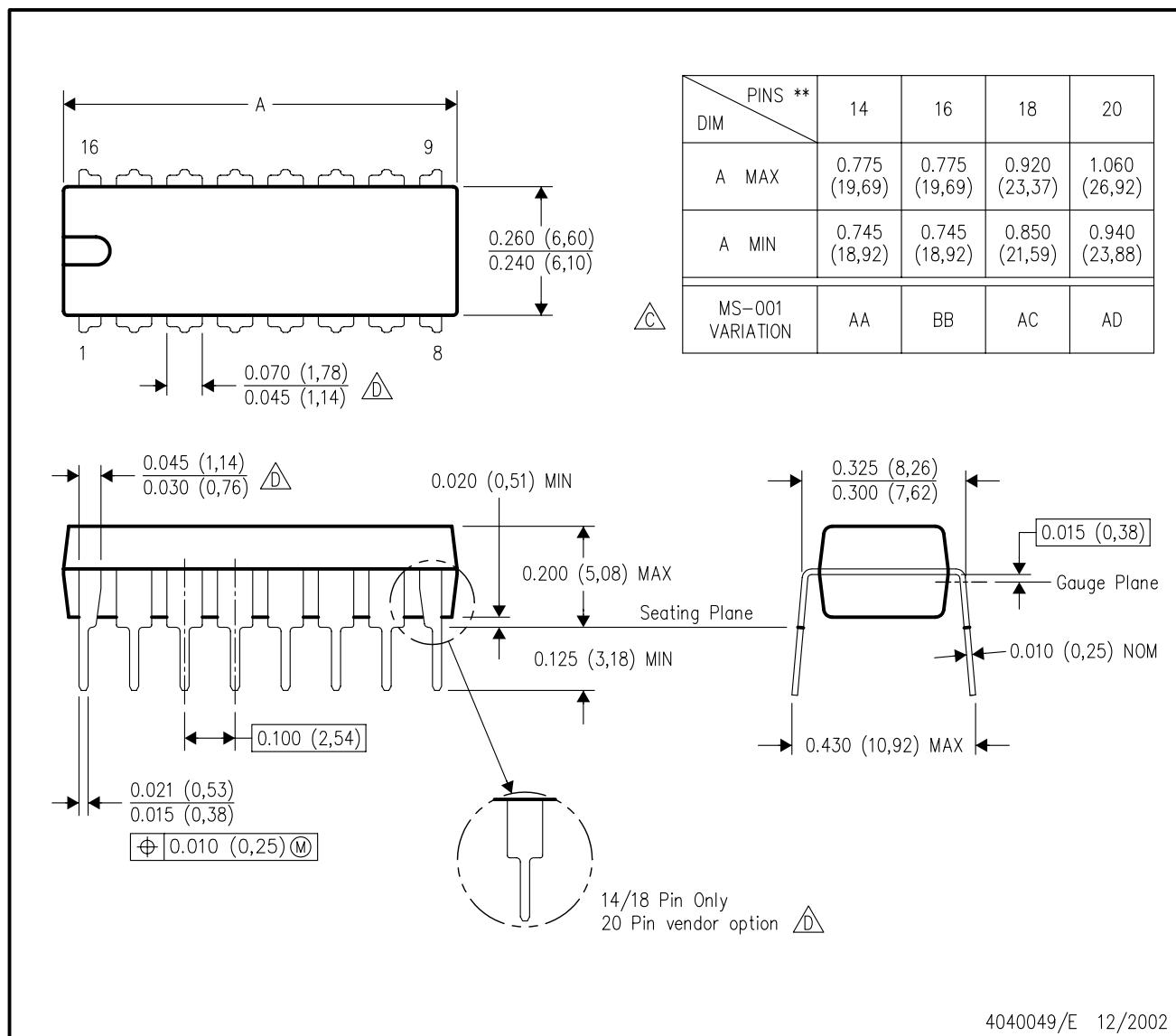
| DIM | PINS ** | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|
| A MAX | | 0.775 (19,69) | 0.775 (19,69) | 0.920 (23,37) | 1.060 (26,92) |
| A MIN | | 0.745 (18,92) | 0.745 (18,92) | 0.850 (21,59) | 0.940 (23,88) |
| MS−001 VARIATION | △C | AA | BB | AC | AD |

$\frac{0.260\ (6,60)}{0.240\ (6,10)}$

$\frac{0.070\ (1,78)}{0.045\ (1,14)}$ △D

$\frac{0.045\ (1,14)}{0.030\ (0,76)}$ △D

0.020 (0,51) MIN

0.200 (5,08) MAX

Seating Plane

0.125 (3,18) MIN

0.100 (2,54)

$\frac{0.021\ (0,53)}{0.015\ (0,38)}$

⊕ | 0.010 (0,25) Ⓜ

14/18 Pin Only
20 Pin vendor option △D

$\frac{0.325\ (8,26)}{0.300\ (7,62)}$

0.015 (0,38)

Gauge Plane

0.010 (0,25) NOM

0.430 (10,92) MAX

4040049/E   12/2002

NOTES:  A.  All linear dimensions are in inches (millimeters).
        B.  This drawing is subject to change without notice.
    △C  Falls within JEDEC MS−001, except 18 and 20 pin minimum body length (Dim A).
    △D  The 20 pin end lead shoulder width is a vendor option, either half or full width.

**D (R−PDSO−G16)**                    **PLASTIC SMALL−OUTLINE PACKAGE**



0.394 (10,00)
0.386 (9,80)
△C

16                                  9

0.244 (6,20)
0.228 (5,80)

0.157 (4,00)
0.150 (3,80)  △D

Pin 1
Index Area

1                                   8

0.050 (1,27)

0.020 (0,51)
0.012 (0,31)

⊕ 0.010 (0,25) Ⓜ

0.069 (1,75) Max

0.010 (0,25)
0.004 (0,10)

0.010 (0,25)
0.007 (0,17)

0.004 (0,10)

Gauge Plane

Seating Plane

0.010 (0,25)          0°–8°

0.050 (1,27)
0.016 (0,40)
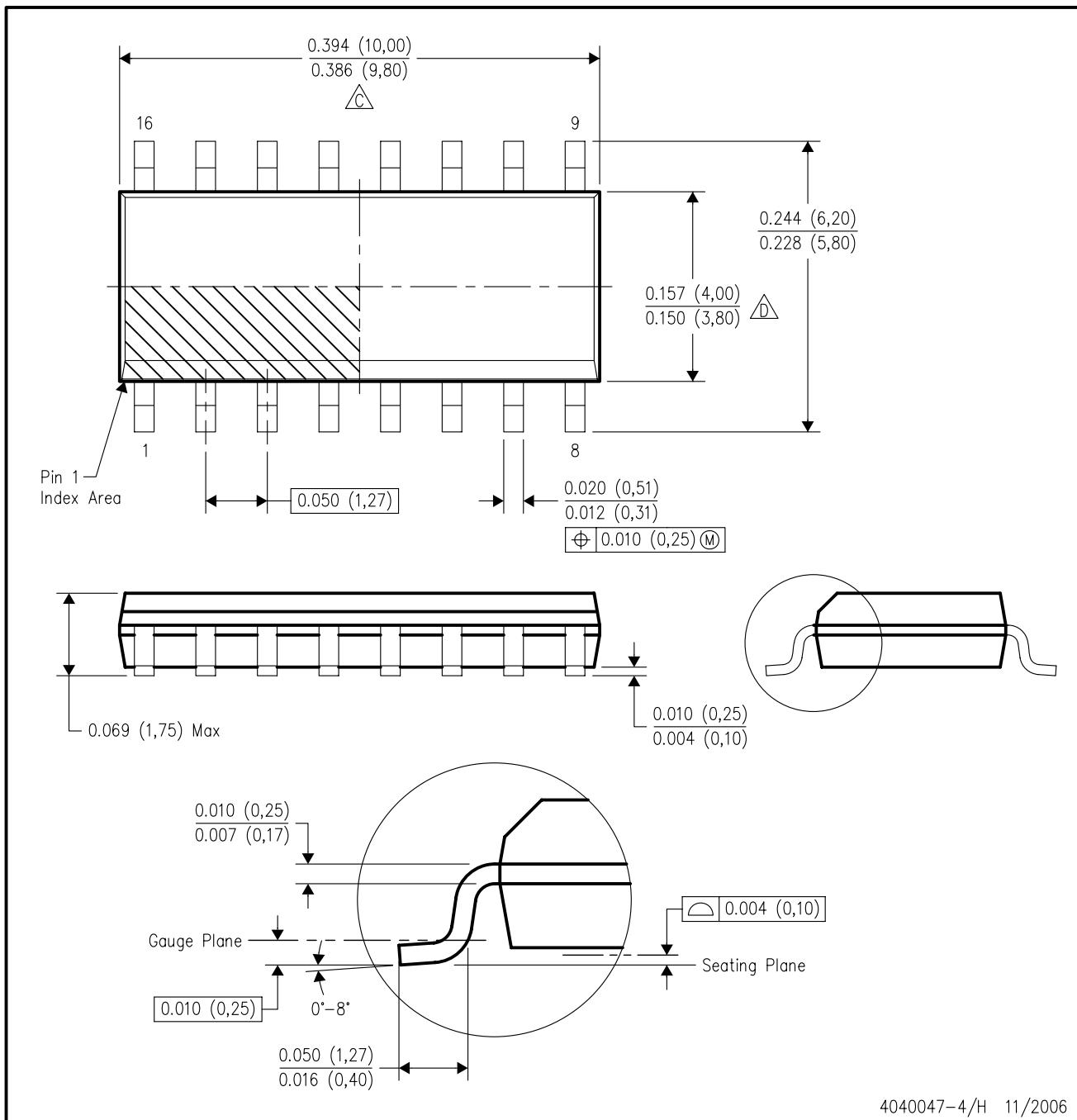
4040047−4/H  11/2006

NOTES:    A.  All linear dimensions are in inches (millimeters).
          B.  This drawing is subject to change without notice.
          △C  Body length does not include mold flash, protrusions, or gate burrs.  Mold flash, protrusions, or gate burrs shall
              not exceed .006 (0,15) per end.
          △D  Body width does not include interlead flash.  Interlead flash shall not exceed .017 (0,43) per side.
          E.  Reference JEDEC MS−012 variation AC.

**IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| **Products** | | **Applications** | |
|---|---|---|---|
| Amplifiers | amplifier.ti.com | Audio | www.ti.com/audio |
| Data Converters | dataconverter.ti.com | Automotive | www.ti.com/automotive |
| DSP | dsp.ti.com | Broadband | www.ti.com/broadband |
| Interface | interface.ti.com | Digital Control | www.ti.com/digitalcontrol |
| Logic | logic.ti.com | Military | www.ti.com/military |
| Power Mgmt | power.ti.com | Optical Networking | www.ti.com/opticalnetwork |
| Microcontrollers | microcontroller.ti.com | Security | www.ti.com/security |
| Low Power Wireless | www.ti.com/lpw | Telephony | www.ti.com/telephony |
| | | Video & Imaging | www.ti.com/video |
| | | Wireless | www.ti.com/wireless |

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