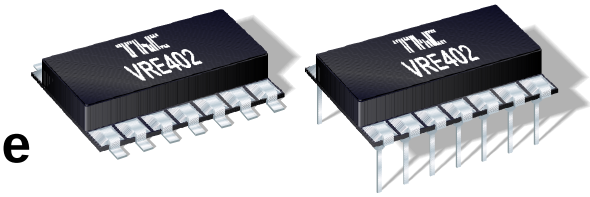
# VRE402
# Precision
# Dual Reference




**THALER CORPORATION • 2015 N. FORBES BOULEVARD • TUCSON, AZ. 85745 • (520) 882-4000**

## FEATURES

- **±2.500 V OUTPUT ± 0.250 mV (.01%)**
- **TEMPERATURE DRIFT: 0.6 ppm/°C**
- **LOW NOISE: 1.5µ$V_{pp}$ (0.1-10Hz)**
- **TRACKING ERROR: 0.2 mV max.**
- **EXCELLENT LINE REGULATION: 6ppm/V Typ.**
- **SURFACE MOUNT AND DIP PACKAGES**

## PIN CONFIGURATION

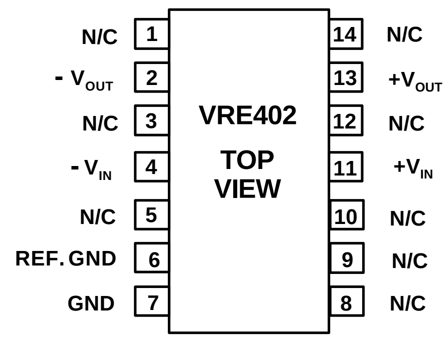



**FIGURE 1**

## DESCRIPTION

The VRE402 is a low cost, high precision, ±2.5V reference. Packaged in 14 pin DIP or SMT packages, the device is ideal for new designs that need a high performance reference.

The device provides ultrastable ±2.500V output with ±0.250 mV (.01%) initial accuracy and a temperature coefficient of 0.6 ppm/°C. This improvement in accuracy is made possible by a unique, patented multipoint laser compensation technique developed by Thaler Corporation.

Another key feature of this reference is the 0.3 mV maximum tracking error between the positive and negative output voltages over the operating temperature range. This is extremely important in high performance systems for reducing overall system errors.

For designs which use the DIP package in a socket, there is a reference ground pin to eliminate reference ground errors.

The VRE402 is recommended for use as a reference for high precision A/D and D/A converters which require an external precision reference. The device is ideal for calibrating scale factor on high resolution A/D converters. The VRE402 offers superior performance over monolithic references.

### SELECTION GUIDE

| Model | Initial Error mV | Temp. Coeff. ppm/°C | Temp. Range °C |
|---|---|---|---|
| VRE402A | 0.25 | 0.6 | 0°C to +70°C |
| VRE402B | 0.40 | 1.0 | 0°C to +70°C |
| VRE402C | 0.50 | 2.0 | 0°C to +70°C |
| VRE402J | 0.25 | 0.6 | -40°C to +85°C |
| VRE402K | 0.40 | 1.0 | -40°C to +85°C |
| VRE402L | 0.50 | 2.0 | -40°C to +85°C |

For package option add D for DIP or S for Surface Mount to end of model number.

VRE402DS REV. A MAY 1996

## ELECTRICAL SPECIFICATIONS

**VRE402**

Vps =±15V, T = 25°C, RL = 10KΩ unless otherwise noted.

| MODEL | A/J | | | B/K | | | C/L | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **UNITS** |
| **ABSOLUTE RATINGS** | | | | | | | | | | |
| Power Supply | ±13.5 | ±15 | ±22 | * | * | * | * | * | * | V |
| Operating Temp. (A,B,C) | 0 | | +70 | * | | * | * | | * | °C |
| Operating Temp. (J,K,L) | -40 | | +85 | * | | * | * | | * | °C |
| Storage Temperature | -65 | | +150 | * | | * | * | | * | °C |
| Short Circuit Protection | | Continuous | | | * | | | * | | |
| **OUTPUT VOLTAGE** | | | | | | | | | | |
| VRE402 | | ±2.5 | | | * | | | * | | V |
| **OUTPUT VOLTAGE ERRORS** | | | | | | | | | | |
| Initial Error (1) | | | 0.25 | | | 0.40 | | | 0.50 | mV |
| Warmup Drift | | 1 | | | 2 | | | 3 | | ppm |
| $T_{min}$ - $T_{max}$ (2) | | | 0.6 | | | 1.0 | | | 2.0 | ppm/ °C |
| Tracking Error (3) | | | 0.2 | | | 0.3 | | | 0.4 | mV |
| Long-Term Stability | | 6 | | | * | | | * | | ppm/1000hrs |
| Noise (.1-10Hz) | | 1.5 | | | * | | | * | | µVpp |
| **OUTPUT CURRENT** | | | | | | | | | | |
| Range | ±10 | | | * | | | * | | | mA |
| **REGULATION** | | | | | | | | | | |
| Line | | 3 | 10 | | * | * | | * | * | ppm/V |
| Load | | 3 | | | * | | | * | | ppm/mA |
| **POWER SUPPLY CURRENTS (4)** | | | | | | | | | | |
| +PS | | 7 | 9 | | * | * | | * | * | mA |
| -PS | | 4 | 6 | | * | * | | * | * | mA |

NOTES: *Same as A/J Models.

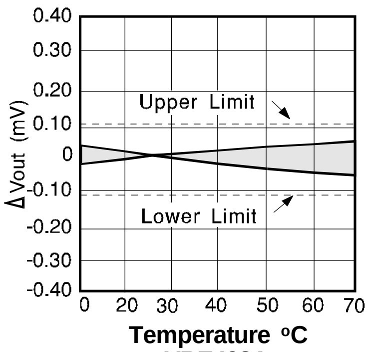
1. The specified values are without external trim.
2. The temperature coefficient (tc) is determined by the box method using the following formula:

$$tc = \frac{V_{max} - V_{min}}{V_{nominal} \times (T_{max} - T_{min})} \times 10^6$$

3. The tracking error is the deviation between the positive and negative output over the operating temp. range.
4. The specified values are unloaded.

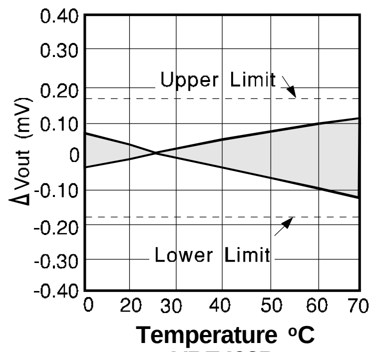
# TYPICAL PERFORMANCE CURVES

**$V_{OUT}$ vs. TEMPERATURE**



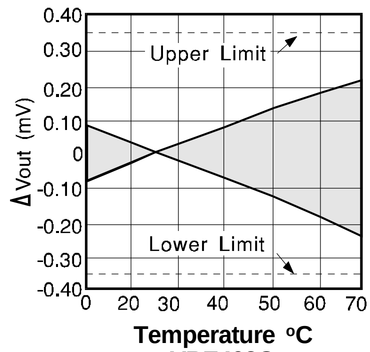

**VRE402A**

**$V_{OUT}$ vs. TEMPERATURE**



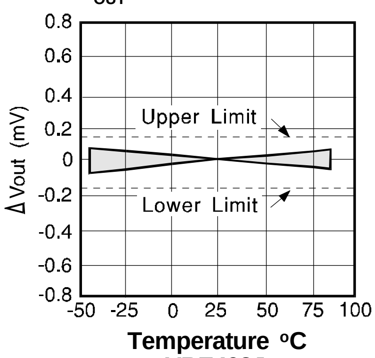

**VRE402B**

**$V_{OUT}$ vs. TEMPERATURE**



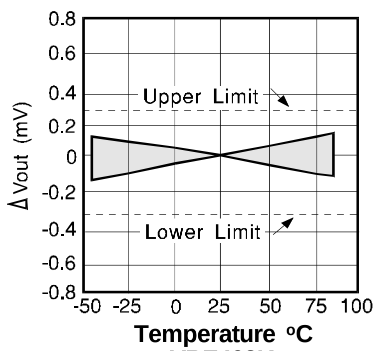

**VRE402C**

**$V_{OUT}$ vs. TEMPERATURE**



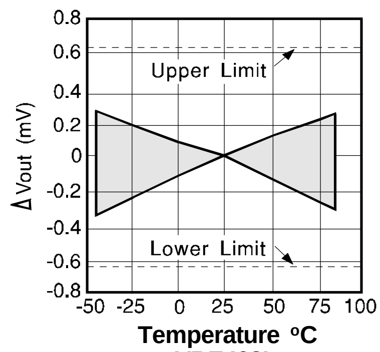

**VRE402J**

**$V_{OUT}$ vs. TEMPERATURE**




**VRE402K**

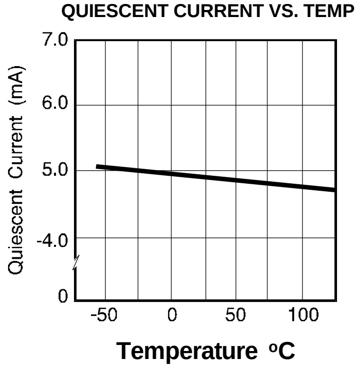
**$V_{OUT}$ vs. TEMPERATURE**



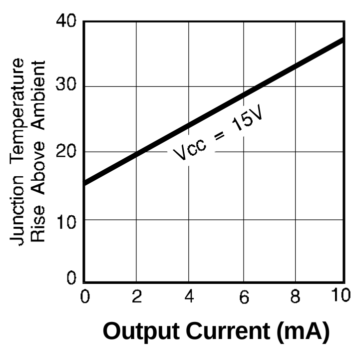

**VRE402L**

***POSITIVE OUTPUT (TYP)***

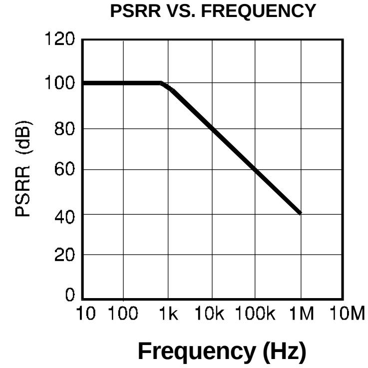
**QUIESCENT CURRENT VS. TEMP**




**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**

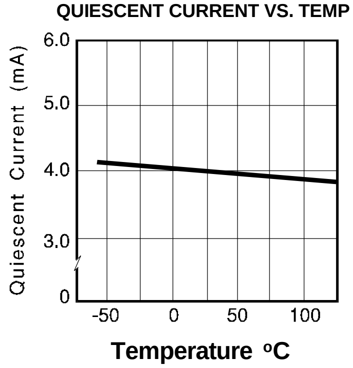



**PSRR VS. FREQUENCY**

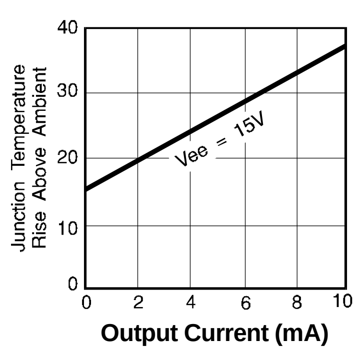



***NEGATIVE OUTPUT (TYP)***

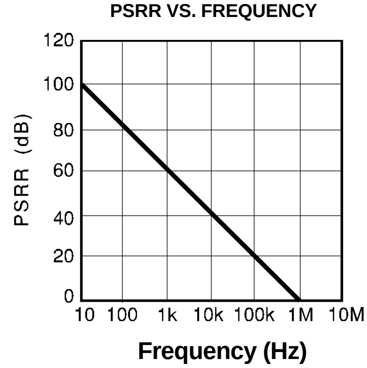
**QUIESCENT CURRENT VS. TEMP**




**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**PSRR VS. FREQUENCY**



# DISCUSSION OF PERFORMANCE

## THEORY OF OPERATION

The following discussion refers to the schematic in figure 2 below. A FET current source is used to bias a 6.3V zener diode. The zener voltage is divided by the resistor network R1 and R2. This voltage is then applied to the noninverting input of the operational amplifier which amplifies the voltage to produce a 2.500V output. The gain is determined by the resistor networks R3 and R4: G=1 + R4/R3. The 6.3V zener diode is used because it is the most stable diode over time and temperature.

The current source provides a closely regulated zener current, which determines the slope of the references' voltage vs. temperature function. By trimming the zener current a lower drift over temperature can be achieved. But since the voltage vs. temperature function is nonlinear this compensation technique is not well suited for wide temperature ranges.

Thaler Corporation has developed a nonlinear compensation network of thermistors and resistors that is used in the VRE series voltage references. This proprietary network eliminates most of the nonlinearity in the voltage vs. temperature function. By adjusting the slope, Thaler Corporation produces a very stable voltage over wide temperature ranges. This network is less than 2% of the overall network resistance so it has a negligible effect on long term stability.

The VRE402 reference has it's ground brought out on two pins (pin 6 and 7) which are connected internally. This allows the user to achieve greater accuracy when using a socket. Voltage references have a voltage drop across their power supply ground pin due to quiescent current flowing through the contact resistance. If the contact resistance was constant with time and temperature, this voltage drop could be trimmed out. When the reference is plugged into a socket, this source of error can be as high as 20ppm. By connecting pin 7 to the power supply ground and pin 6 to a high impedance ground point in the measurement circuit, the error due to the contact resistance can be eliminated. If the unit is soldered into place, the contact resistance is sufficiently small that it does not effect performance.

## VRE402

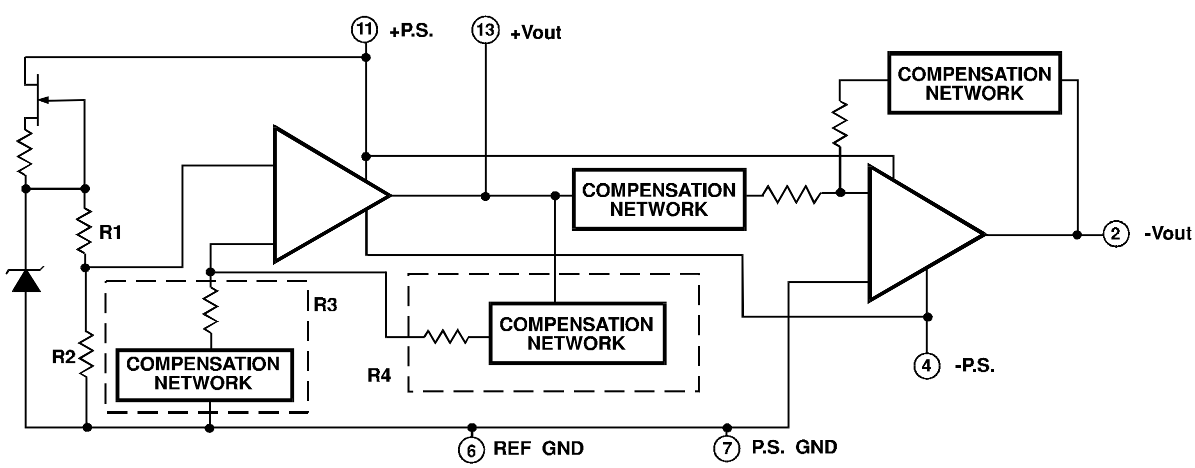
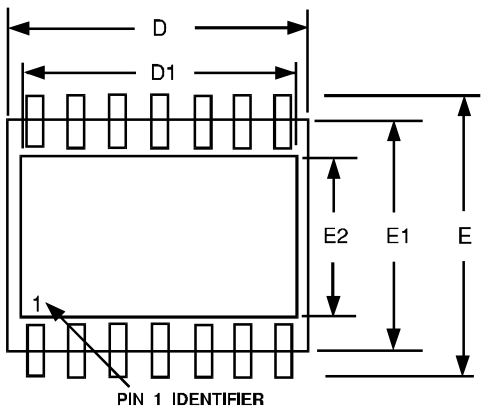


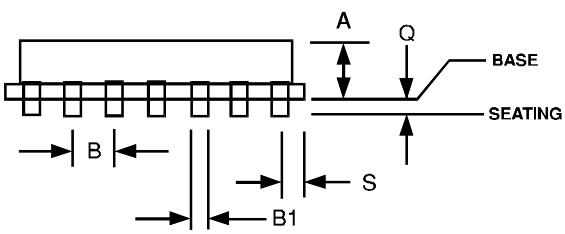

FIGURE 2

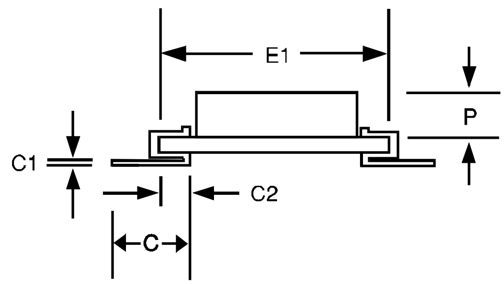
# MECHANICAL

## FIGURE 3

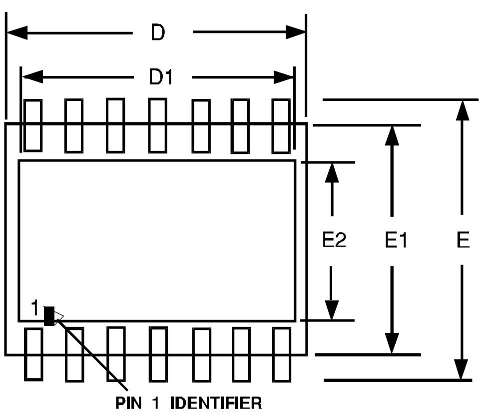



| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .495 | .526 | 12.5 | 13.3 |
| B | .098 | .103 | 2.48 | 2.62 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| C | .103 | .118 | 2.62 | 3.00 | P | .090 | .110 | 2.29 | 2.79 |
| C1 | .009 | .020 | 0.22 | 0.51 | Q | .024 | .035 | 0.61 | .890 |
| C2 | .054 | .062 | 1.37 | 1.57 | S | .040 | .060 | 1.02 | 1.52 |
| D | .690 | .715 | 17.5 | 18.1 | | | | | |
| D1 | .666 | .680 | 16.9 | 17.2 | | | | | |

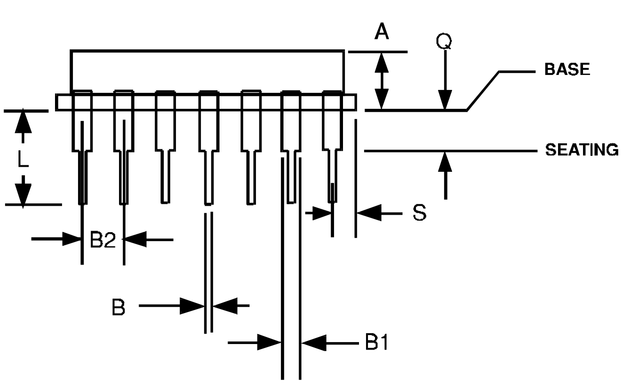


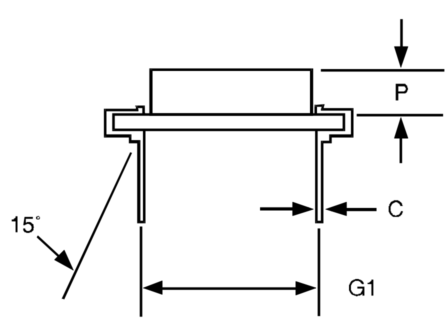




## FIGURE 4

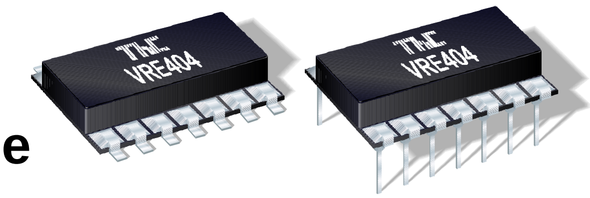



| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .410 | .435 | 10.4 | 11.0 |
| B | .018 | .027 | .460 | .690 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| B2 | .097 | .103 | 2.46 | 2.62 | G1 | .285 | .315 | 7.24 | 8.00 |
| C | .009 | .020 | 0.22 | 0.51 | L | .195 | .225 | 4.95 | 5.72 |
| D | .690 | .715 | 17.5 | 18.1 | P | .090 | .110 | 2.29 | 2.79 |
| D 1 | .666 | .680 | 16.9 | 17.2 | Q | .050 | .070 | 1.27 | 1.79 |
| | | | | | S | .040 | .060 | 1.02 | 1.52 |



# VRE404
# Precision
# Dual Reference

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## FEATURES

- **±4.500 V OUTPUT ± 0.400 mV (.01%)**
- **TEMPERATURE DRIFT: 0.6 ppm/°C**
- **LOW NOISE: $3\mu V_{pp}$ (0.1-10Hz)**
- **TRACKING ERROR: 0.3 mV max.**
- **EXCELLENT LINE REGULATION: 6ppm/V Typ.**
- **SURFACE MOUNT AND DIP PACKAGES**

## PIN CONFIGURATION

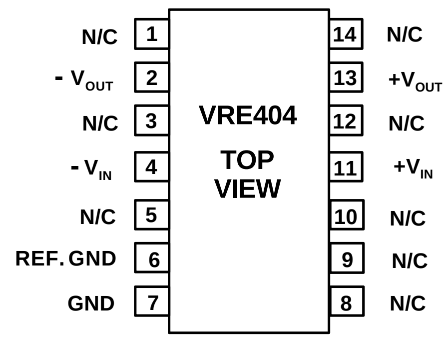



**FIGURE 1**

## DESCRIPTION

The VRE404 is a low cost, high precision, ±4.5V reference. Packaged in 14 pin DIP or SMT packages, the device is ideal for new designs that need a high performance reference.

The device provides ultrastable ±4.500V output with ±0.450 mV (.01%) initial accuracy and a temperature coefficient of 0.6 ppm/°C. This improvement in accuracy is made possible by a unique, patented multipoint laser compensation technique developed by Thaler Corporation.

Another key feature of this reference is the 0.3 mV maximum tracking error between the positive and negative output voltages over the operating temperature range. This is extremely important in high performance systems for reducing overall system errors.

For designs which use the DIP package in a socket, there is a reference ground pin to eliminate reference ground errors.

The VRE404 is recommended for use as a reference for high precision D/A and A/D converters which require an external precision reference. The device is ideal for calibrating scale factor on high resolution A/D converters. The VRE404 offers superior performance over monolithic references.

**SELECTION GUIDE**

| Model | Initial Error mV | Temp. Coeff. ppm/°C | Temp. Range °C |
|---|---|---|---|
| VRE404A | 0.45 | 0.6 | 0°C to +70°C |
| VRE404B | 0.70 | 1.0 | 0°C to +70°C |
| VRE404C | 0.90 | 2.0 | 0°C to +70°C |
| VRE404J | 0.45 | 0.6 | -40°C to +85°C |
| VRE404K | 0.70 | 1.0 | -40°C to +85°C |
| VRE404L | 0.90 | 2.0 | -40°C to +85°C |

For package option add D for DIP or S for Surface Mount to end of model number.

## ELECTRICAL SPECIFICATIONS

**VRE404**

Vps =±15V, T = 25°C, RL = 10KΩ unless otherwise noted.

| MODEL | A/J | | | B/K | | | C/L | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| **ABSOLUTE RATINGS** | | | | | | | | | | |
| Power Supply | ±13.5 | ±15 | ±22 | * | * | * | * | * | * | V |
| Operating Temp. (A,B,C) | 0 | | +70 | * | | * | * | | * | °C |
| Operating Temp. (J,K,L) | -40 | | +85 | * | | * | * | | * | °C |
| Storage Temperature | -65 | | +150 | * | | * | * | | * | °C |
| Short Circuit Protection | Continuous | | | | * | | | * | | |
| **OUTPUT VOLTAGE** | | | | | | | | | | |
| VRE404 | | ±4.5 | | | * | | | * | | V |
| **OUTPUT VOLTAGE ERRORS** | | | | | | | | | | |
| Initial Error (1) | | | 0.45 | | | 0.70 | | | 0.90 | mV |
| Warmup Drift | | 1 | | | 2 | | | 3 | | ppm |
| $T_{min}$ - $T_{max}$ (2) | | | 0.6 | | | 1.0 | | | 2.0 | ppm/ °C |
| Tracking Error (3) | | | 0.3 | | | 0.4 | | | 0.5 | mV |
| Long-Term Stability | | 6 | | | * | | | * | | ppm/1000hrs |
| Noise (.1-10Hz) | | 3 | | | * | | | * | | µVpp |
| **OUTPUT CURRENT** | | | | | | | | | | |
| Range | ±10 | | | * | | | * | | | mA |
| **REGULATION** | | | | | | | | | | |
| Line | | 3 | 10 | | * | * | | * | * | ppm/V |
| Load | | 3 | | | * | | | * | | ppm/mA |
| **POWER SUPPLY CURRENTS (4)** | | | | | | | | | | |
| +PS | | 7 | 9 | | * | * | | * | * | mA |
| -PS | | 4 | 6 | | * | * | | * | * | mA |

NOTES: *Same as A/J Models.

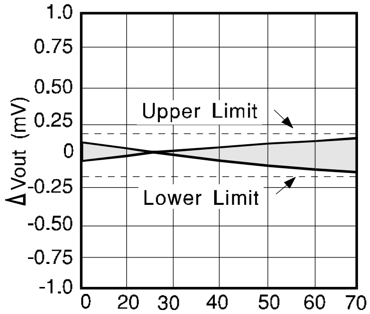
1. The specified values are without external trim.
2. The temperature coefficient (tc) is determined by the box method using the following formula:

$$tc = \frac{V_{max} - V_{min}}{V_{nominal} \times (T_{max} - T_{min})} \times 10^6$$

3. The tracking error is the deviation between the positive and negative output over the operating temp. range.
4. The specified values are unloaded.

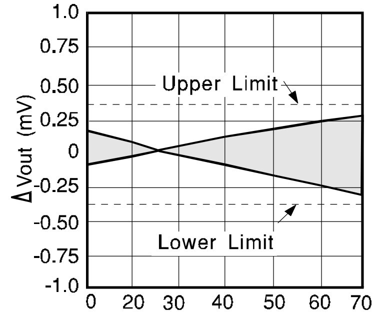
# TYPICAL PERFORMANCE CURVES

### $V_{OUT}$ vs. TEMPERATURE



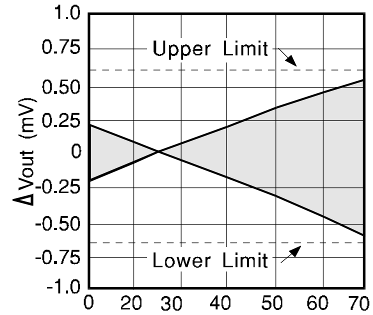

**Temperature °C**
**VRE404A**

### $V_{OUT}$ vs. TEMPERATURE



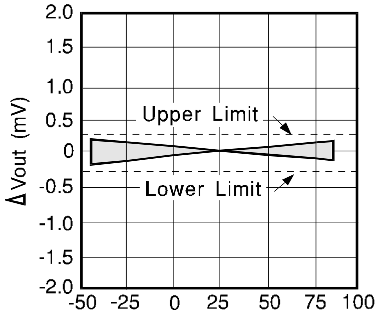

**Temperature °C**
**VRE404B**

### $V_{OUT}$ vs. TEMPERATURE



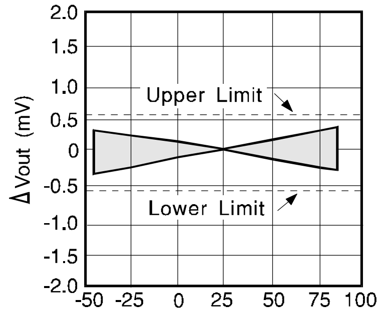

**Temperature °C**
**VRE404C**

### $V_{OUT}$ vs. TEMPERATURE



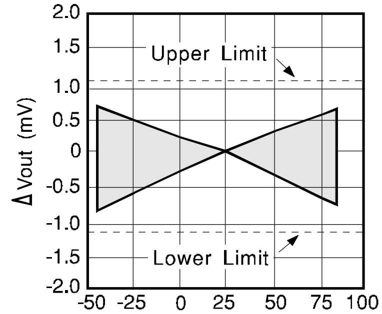

**Temperature °C**
**VRE404J**

### $V_{OUT}$ vs. TEMPERATURE




**Temperature °C**
**VRE404K**

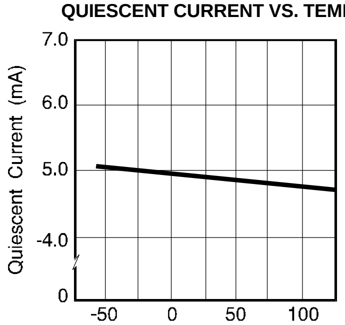
### $V_{OUT}$ vs. TEMPERATURE




**Temperature °C**
**VRE404L**

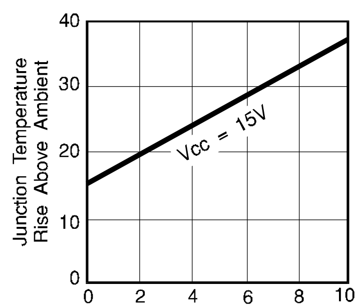
***POSITIVE OUTPUT (TYP)***

**QUIESCENT CURRENT VS. TEMP**



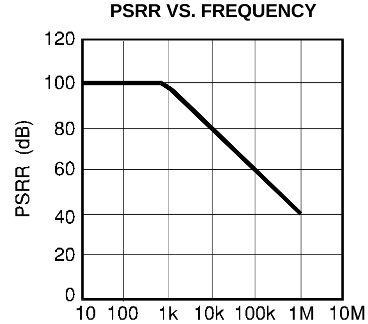

**Temperature °C**

**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**Output Current (mA)**

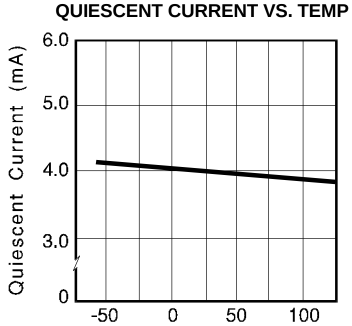
**PSRR VS. FREQUENCY**




**Frequency (Hz)**

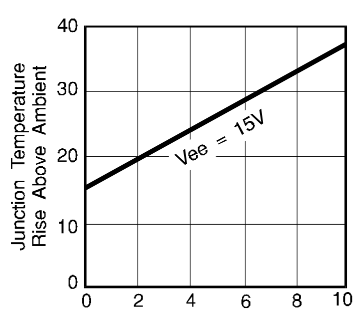
***NEGATIVE OUTPUT (TYP)***

**QUIESCENT CURRENT VS. TEMP**



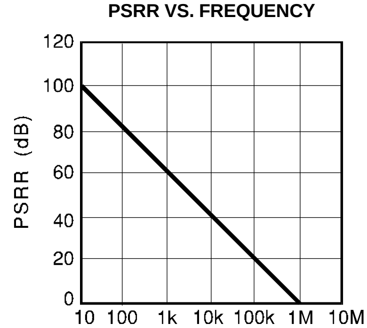

**Temperature °C**

**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**Output Current (mA)**

**PSRR VS. FREQUENCY**




**Frequency (Hz)**

# DISCUSSION OF PERFORMANCE

### THEORY OF OPERATION

The following discussion refers to the schematic in figure 2 below. A FET current source is used to bias a 6.3V zener diode. The zener voltage is divided by the resistor network R1 and R2. This voltage is then applied to the noninverting input of the operational amplifier which amplifies the voltage to produce a 4.500V output. The gain is determined by the resistor networks R3 and R4: G=1 + R4/R3. The 6.3V zener diode is used because it is the most stable diode over time and temperature.

The current source provides a closely regulated zener current, which determines the slope of the references' voltage vs. temperature function. By trimming the zener current a lower drift over temperature can be achieved. But since the voltage vs. temperature function is nonlinear this compensation technique is not well suited for wide temperature ranges.

Thaler Corporation has developed a nonlinear compensation network of thermistors and resistors that is used in the VRE series voltage references. This proprietary network eliminates most of the nonlinearity in the voltage vs. temperature function. By adjusting the slope, Thaler Corporation produces a very stable voltage over wide temperature ranges. This network is less than 2% of the overall network resistance so it has a negligible effect on long term stability.

The VRE404 reference has it's ground brought out on two pins (pin 6 and 7) which are connected internally. This allows the user to achieve greater accuracy when using a socket. Voltage references have a voltage drop across their power supply ground pin due to quiescent current flowing through the contact resistance. If the contact resistance was constant with time and temperature, this voltage drop could be trimmed out. When the reference is plugged into a socket, this source of error can be as high as 20ppm. By connecting pin 7 to the power supply ground and pin 6 to a high impedance ground point in the measurement circuit, the error due to the contact resistance can be eliminated. If the unit is soldered into place, the contact resistance is sufficiently small that it does not effect performance.

## VRE404

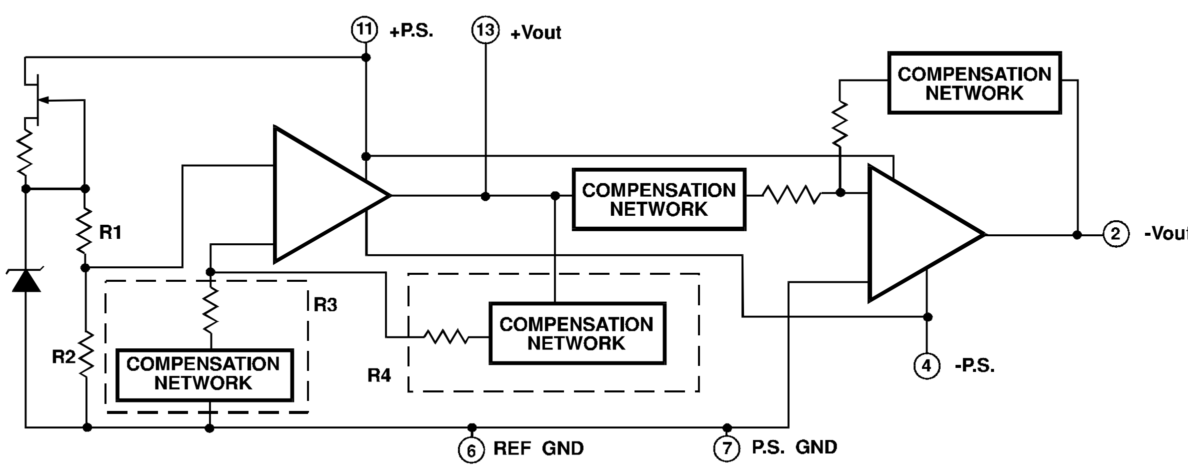
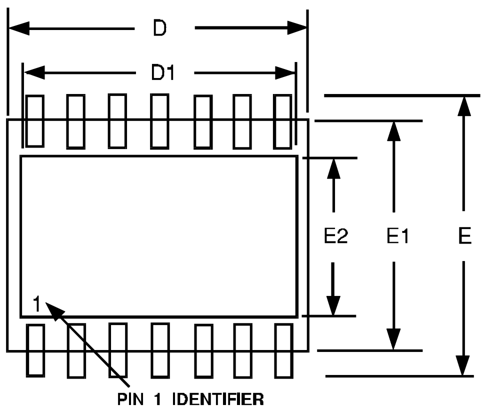


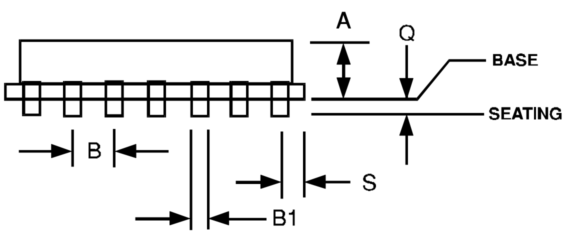

FIGURE 2

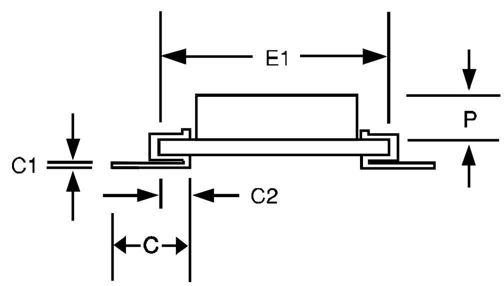
# MECHANICAL

## FIGURE 3

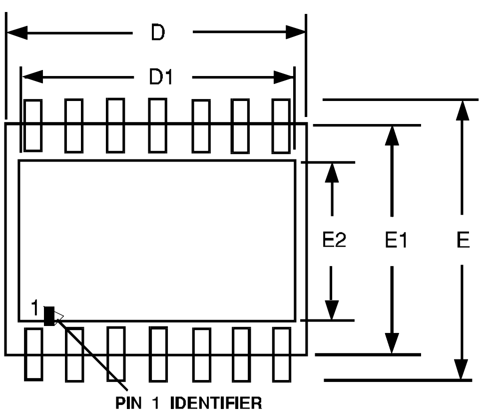



| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .495 | .526 | 12.5 | 13.3 |
| B | .098 | .103 | 2.48 | 2.62 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| C | .103 | .118 | 2.62 | 3.00 | P | .090 | .110 | 2.29 | 2.79 |
| C1 | .009 | .020 | 0.22 | 0.51 | Q | .024 | .035 | 0.61 | .890 |
| C2 | .054 | .062 | 1.37 | 1.57 | S | .040 | .060 | 1.02 | 1.52 |
| D | .690 | .715 | 17.5 | 18.1 | | | | | |
| D1 | .666 | .680 | 16.9 | 17.2 | | | | | |

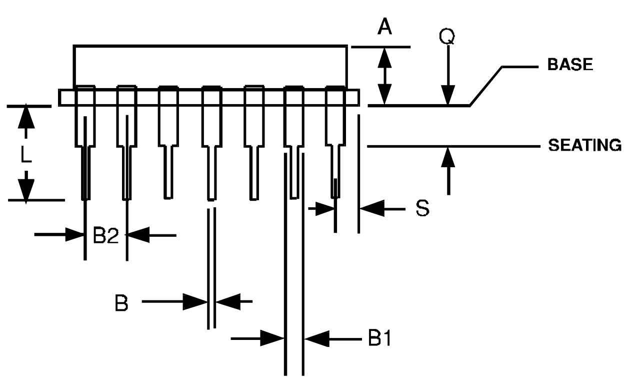


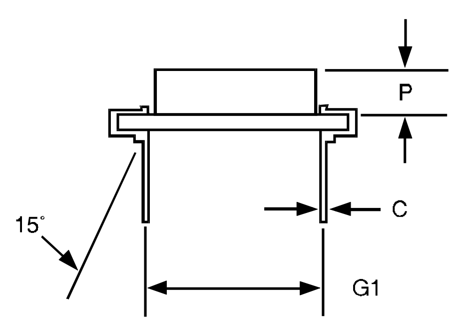




## FIGURE 4

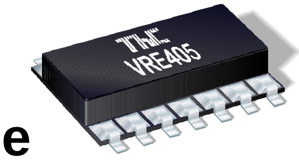


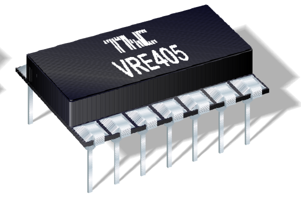

| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .410 | .435 | 10.4 | 11.0 |
| B | .018 | .027 | .460 | .690 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| B2 | .097 | .103 | 2.46 | 2.62 | G1 | .285 | .315 | 7.24 | 8.00 |
| C | .009 | .020 | 0.22 | 0.51 | L | .195 | .225 | 4.95 | 5.72 |
| D | .690 | .715 | 17.5 | 18.1 | P | .090 | .110 | 2.29 | 2.79 |
| D 1 | .666 | .680 | 16.9 | 17.2 | Q | .050 | .070 | 1.27 | 1.79 |
| | | | | | S | .040 | .060 | 1.02 | 1.52 |



# VRE405
# Precision
# Dual Reference

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## FEATURES

- **±5.000 V OUTPUT ± 0.500 mV (.01%)**
- **TEMPERATURE DRIFT: 0.6 ppm/°C**
- **LOW NOISE: 3µV$_{pp}$ (0.1-10Hz)**
- **TRACKING ERROR: 0.3 mV max.**
- **EXCELLENT LINE REGULATION: 6ppm/V Typ.**
- **SURFACE MOUNT AND DIP PACKAGES**

### PIN CONFIGURATION

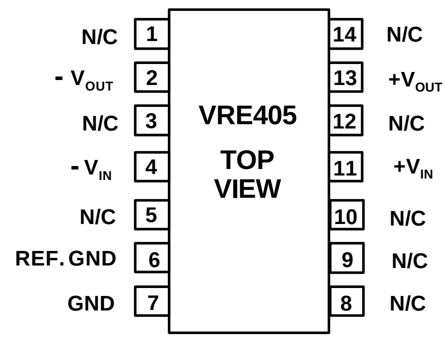



**FIGURE 1**

## DESCRIPTION

The VRE405 is a low cost, high precision, ±5.0V reference. Packaged in 14 pin DIP or SMT packages, the device is ideal for new designs that need a high performance reference.

The device provides ultrastable ±5.000V output with ±0.500 mV (.01%) initial accuracy and a temperature coefficient of 0.6 ppm/°C. This improvement in accuracy is made possible by a unique, patented multipoint laser compensation technique developed by Thaler Corporation.

Another key feature of this reference is the 0.3 mV maximum tracking error between the positive and negative output voltages over the operating temperature range. This is extremely important in high performance systems for reducing overall system errors.

For designs which use the DIP package in a socket, there is a reference ground pin to eliminate the reference ground errors.

The VRE405 is recommended for use as a reference for high precision D/A and A/D converters which require an external precision reference. The device is ideal for calibrating scale factor on high resolution A/D converters. The VRE405 offers superior performance over monolithic references.

### SELECTION GUIDE

| Model | Initial Error mV | Temp. Coeff. ppm/°C | Temp. Range °C |
|---|---|---|---|
| VRE405A | 0.5 | 0.6 | 0°C to +70°C |
| VRE405B | 0.8 | 1.0 | 0°C to +70°C |
| VRE405C | 1.0 | 2.0 | 0°C to +70°C |
| VRE405J | 0.5 | 0.6 | -40°C to +85°C |
| VRE405K | 0.8 | 1.0 | -40°C to +85°C |
| VRE405L | 1.0 | 2.0 | -40°C to +85°C |

For package option add D for DIP or S for Surface Mount to end of model number.

## ELECTRICAL SPECIFICATIONS

**VRE405**

Vps =±15V, T = 25°C, RL = 10KΩ unless otherwise noted.

| MODEL | A/J | | | B/K | | | C/L | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| **ABSOLUTE RATINGS** | | | | | | | | | | |
| Power Supply | ±13.5 | ±15 | ±22 | * | * | * | * | * | * | V |
| Operating Temp. (A,B,C) | 0 | | +70 | * | | * | * | | * | °C |
| Operating Temp. (J,K,L) | -40 | | +85 | * | | * | * | | * | °C |
| Storage Temperature | -65 | | +150 | * | | * | * | | * | °C |
| Short Circuit Protection | | Continuous | | | * | | | * | | |
| **OUTPUT VOLTAGE** | | | | | | | | | | |
| VRE405 | | ±5.00 | | | * | | | * | | V |
| **OUTPUT VOLTAGE ERRORS** | | | | | | | | | | |
| Initial Error (1) | | | 0.50 | | | 0.80 | | | 1.00 | mV |
| Warmup Drift | | 1 | | | 2 | | | 3 | | ppm |
| $T_{min}$ - $T_{max}$ (2) | | | 0.6 | | | 1.0 | | | 2.0 | ppm/ °C |
| Tracking Error (3) | | | 0.3 | | | 0.4 | | | 0.5 | mV |
| Long-Term Stability | | 6 | | | * | | | * | | ppm/1000hrs |
| Noise (.1-10Hz) | | 3 | | | * | | | * | | µVpp |
| **OUTPUT CURRENT** | | | | | | | | | | |
| Range | ±10 | | | * | | | * | | | mA |
| **REGULATION** | | | | | | | | | | |
| Line | | 3 | 10 | | * | * | | * | * | ppm/V |
| Load | | 3 | | | * | | | * | | ppm/mA |
| **POWER SUPPLY CURRENTS** (4) | | | | | | | | | | |
| +PS | | 7 | 9 | | * | * | | * | * | mA |
| -PS | | 4 | 6 | | * | * | | * | * | mA |

NOTES: *Same as A/J Models.

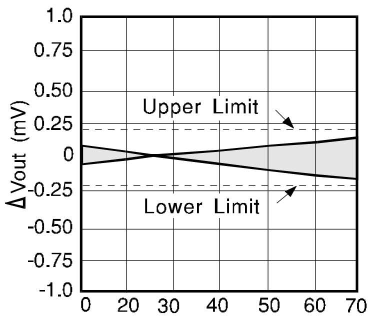
1. The specified values are without external trim.
2. The temperature coefficient (tc) is determined by the box method using the following formula:

$$tc = \frac{V_{max} - V_{min}}{V_{nominal} \times (T_{max} - T_{min})} \times 10^6$$

3. The tracking error is the deviation between the positive and negative output over the operating temp. range.
4. The specified values are unloaded.

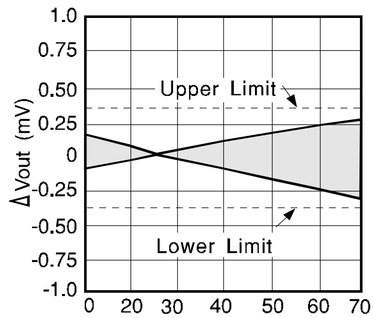
# TYPICAL PERFORMANCE CURVES

**$V_{OUT}$ vs. TEMPERATURE**



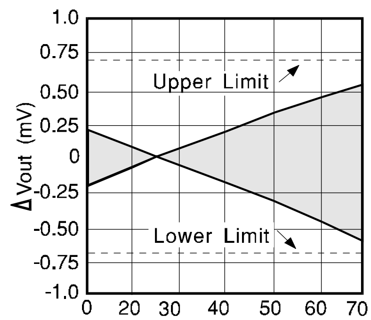

**Temperature °C**
**VRE405A**

**$V_{OUT}$ vs. TEMPERATURE**



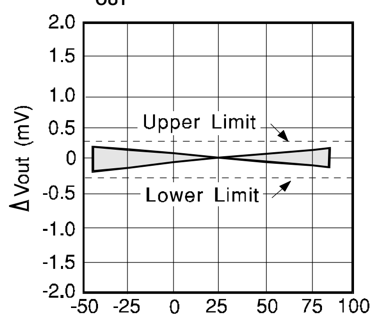

**Temperature °C**
**VRE405B**

**$V_{OUT}$ vs. TEMPERATURE**



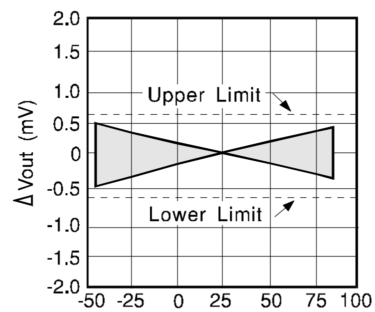

**Temperature °C**
**VRE405C**

**$V_{OUT}$ vs. TEMPERATURE**



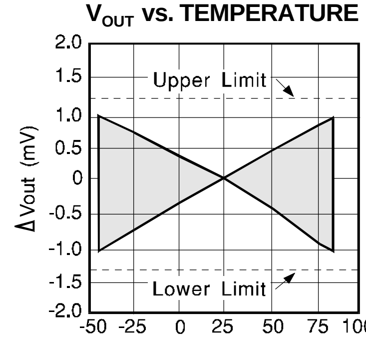

**Temperature °C**
**VRE405J**

**$V_{OUT}$ vs. TEMPERATURE**




**Temperature °C**
**VRE405K**

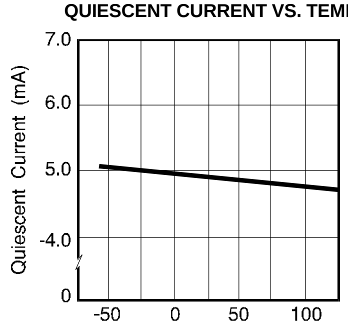
**$V_{OUT}$ vs. TEMPERATURE**




**Temperature °C**
**VRE405L**

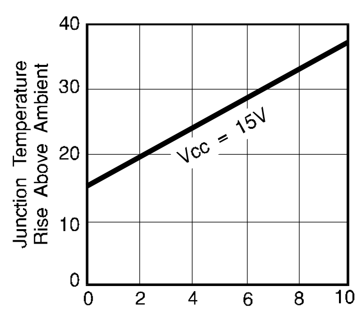
***POSITIVE OUTPUT (TYP)***

**QUIESCENT CURRENT VS. TEMP**



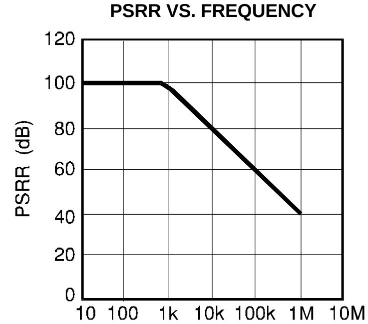

**Temperature °C**

**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**Output Current (mA)**

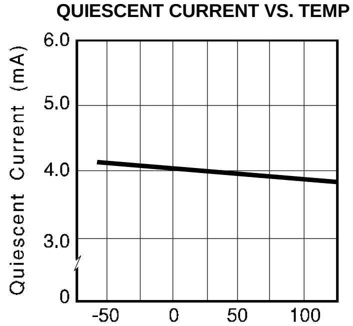
**PSRR VS. FREQUENCY**




**Frequency (Hz)**

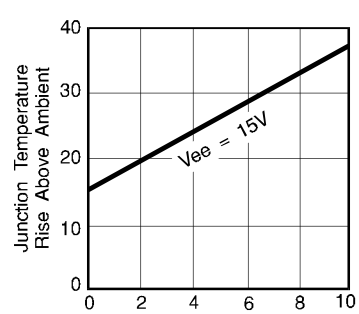
***NEGATIVE OUTPUT (TYP)***

**QUIESCENT CURRENT VS. TEMP**



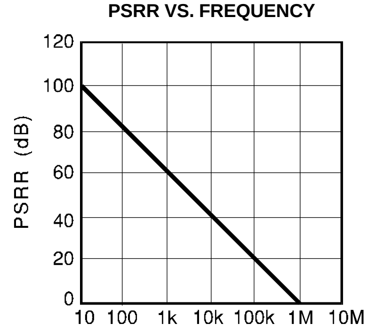

**Temperature °C**

**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**Output Current (mA)**

**PSRR VS. FREQUENCY**




**Frequency (Hz)**

# DISCUSSION OF PERFORMANCE

**THEORY OF OPERATION**

The following discussion refers to the schematic in figure 2 below. A FET current source is used to bias a 6.3V zener diode. The zener voltage is divided by the resistor network R1 and R2. This voltage is then applied to the noninverting input of the operational amplifier which amplifies the voltage to produce a 5.000V output. The gain is determined by the resistor networks R3 and R4: G=1 + R4/R3. The 6.3V zener diode is used because it is the most stable diode over time and temperature.

The current source provides a closely regulated zener current, which determines the slope of the references' voltage vs. temperature function. By trimming the zener current a lower drift over temperature can be achieved. But since the voltage vs. temperature function is nonlinear this compensation technique is not well suited for wide temperature ranges.

Thaler Corporation has developed a nonlinear compensation network of thermistors and resistors that is used in the VRE series voltage references. This proprietary network eliminates most of the nonlinearity in the voltage vs. temperature function. By adjusting the slope, Thaler Corporation produces a very stable voltage over wide temperature ranges.

This network is less than 2% of the overall network resistance so it has a negligible effect on long term stability.

The VRE405 reference has it's ground terminal brought out on two pins (pin 6 and 7) which are connected internally. This allows the user to achieve greater accuracy when using a socket. Voltage references have a voltage drop across their power supply ground pin due to quiescent current flowing through the contact resistance. If the contact resistance was constant with time and temperature, this voltage drop could be trimmed out. When the reference is plugged into a socket, this source of error can be as high as 20ppm. By connecting pin 7 to the power supply ground and pin 6 to a high impedance ground point in the measurement circuit, the error due to the contact resistance can be eliminated. If the unit is soldered into place, the contact resistance is sufficiently small that it does not effect performance.



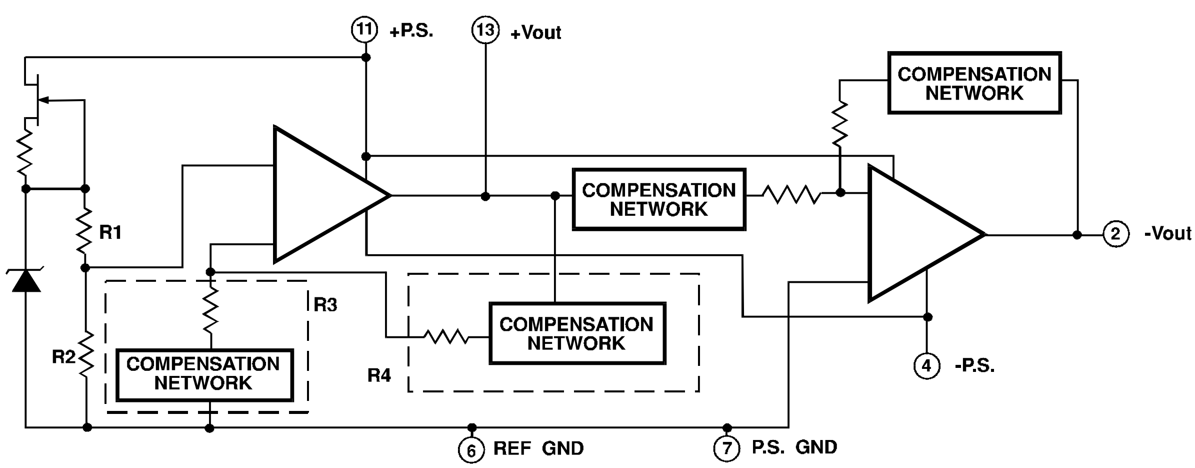
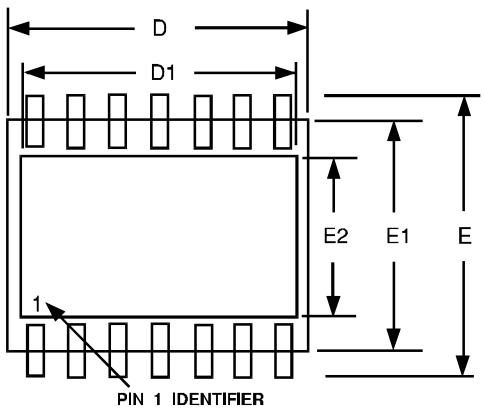


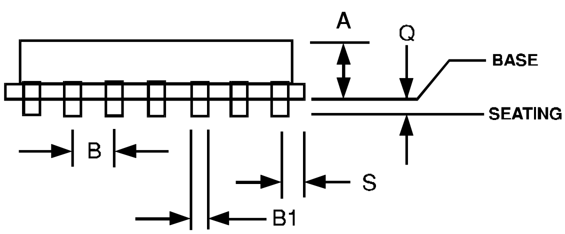

**FIGURE 2**

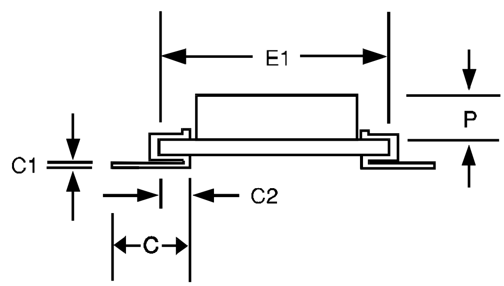
# MECHANICAL

## FIGURE 3

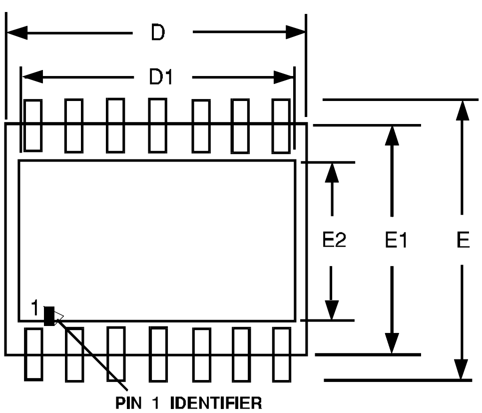



| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .495 | .526 | 12.5 | 13.3 |
| B | .098 | .103 | 2.48 | 2.62 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| C | .103 | .118 | 2.62 | 3.00 | P | .090 | .110 | 2.29 | 2.79 |
| C1 | .009 | .020 | 0.22 | 0.51 | Q | .024 | .035 | 0.61 | .890 |
| C2 | .054 | .062 | 1.37 | 1.57 | S | .040 | .060 | 1.02 | 1.52 |
| D | .690 | .715 | 17.5 | 18.1 | | | | | |
| D1 | .666 | .680 | 16.9 | 17.2 | | | | | |

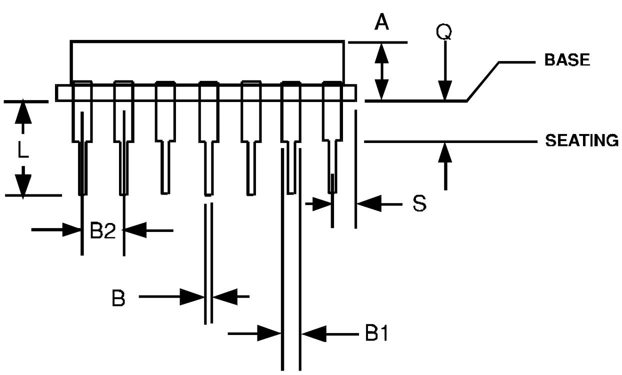


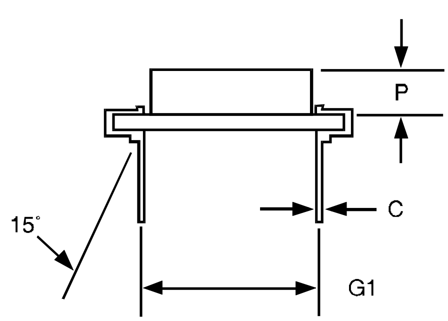




## FIGURE 4

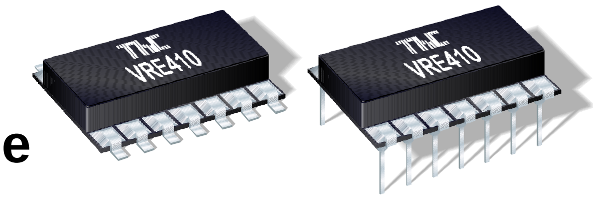



| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .410 | .435 | 10.4 | 11.0 |
| B | .018 | .027 | .460 | .690 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| B2 | .097 | .103 | 2.46 | 2.62 | G1 | .285 | .315 | 7.24 | 8.00 |
| C | .009 | .020 | 0.22 | 0.51 | L | .195 | .225 | 4.95 | 5.72 |
| D | .690 | .715 | 17.5 | 18.1 | P | .090 | .110 | 2.29 | 2.79 |
| D 1 | .666 | .680 | 16.9 | 17.2 | Q | .050 | .070 | 1.27 | 1.79 |
| | | | | | S | .040 | .060 | 1.02 | 1.52 |



# VRE410
# Precision
# Dual Reference

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## FEATURES

- **±10.000 V OUTPUT ± 1.000 mV (.01%)**
- **TEMPERATURE DRIFT: 0.6 ppm/°C**
- **LOW NOISE: 6μ$V_{pp}$ (0.1-10Hz)**
- **TRACKING ERROR: 0.5 mV max.**
- **EXCELLENT LINE REGULATION: 6ppm/V Typ.**
- **SURFACE MOUNT AND DIP PACKAGES**

## PIN CONFIGURATION

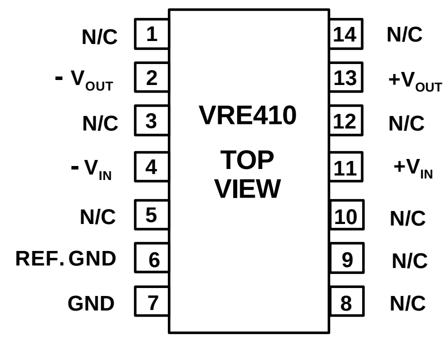



**FIGURE 1**

## DESCRIPTION

The VRE410 is a low cost, high precision, ±10.0V reference. Packaged in 14 pin DIP or SMT packages, the device is ideal for new designs that need a high performance reference.

The device provides ultrastable ±10.000V output with ±1.000 mV (.01%) initial accuracy and a temperature coefficient of 0.6 ppm/°C. This improvement in accuracy is made possible by a unique, patented multipoint laser compensation technique developed by Thaler Corporation.

Another key feature of this reference is the 0.5 mV maximum tracking error between the positive and negative output voltages over the full operating temperature range. This is extremely important in high performance systems for reducing overall system errors.

For designs which use the DIP package in a socket, there is a reference ground pin to eliminate reference ground errors.

The VRE410 is recommended for use as a reference for high precision D/A and A/D converters which require an external precision reference. The device is also ideal for calibrating scale factor on high resolution A/D converters. The VRE410 offers superior performance over monolithic references.

### SELECTION GUIDE

| Model | Initial Error mV | Temp. Coeff. ppm/°C | Temp. Range °C |
|---|---|---|---|
| VRE410A | 1.0 | 0.6 | 0°C to +70°C |
| VRE410B | 1.6 | 1.0 | 0°C to +70°C |
| VRE410C | 2.0 | 2.0 | 0°C to +70°C |
| VRE410J | 1.0 | 0.6 | -40°C to +85°C |
| VRE410K | 1.6 | 1.0 | -40°C to +85°C |
| VRE410L | 2.0 | 2.0 | -40°C to +85°C |

For package option add D for DIP or S for Surface Mount to end of model number.

## ELECTRICAL SPECIFICATIONS

**VRE410**

Vps =±15V, T = 25°C, RL = 10KΩ unless otherwise noted.

| MODEL | A/J | | | B/K | | | C/L | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PARAMETER** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **MIN** | **TYP** | **MAX** | **UNITS** |
| **ABSOLUTE RATINGS** | | | | | | | | | | |
| Power Supply | ±13.5 | ±15 | ±22 | * | * | * | * | * | * | V |
| Operating Temp. (A,B,C) | 0 | | +70 | * | | * | * | | * | °C |
| Operating Temp. (J,K,L) | -40 | | +85 | * | | * | * | | * | °C |
| Storage Temperature | -65 | | +150 | * | | * | * | | * | °C |
| Short Circuit Protection | Continuous | | | | * | | | * | | |
| **OUTPUT VOLTAGE** | | | | | | | | | | |
| VRE410 | | ±10.00 | | | * | | | * | | V |
| **OUTPUT VOLTAGE ERRORS** | | | | | | | | | | |
| Initial Error (1) | | | 1.00 | | | 1.60 | | | 2.00 | mV |
| Warmup Drift | | 1 | | | 2 | | | 3 | | ppm |
| $T_{min}$ - $T_{max}$ (2) | | | 0.6 | | | 1.0 | | | 2.0 | ppm/ °C |
| Tracking Error (3) | | | 0.5 | | | 0.7 | | | 1.0 | mV |
| Long-Term Stability | | 6 | | | * | | | * | | ppm/1000hrs |
| Noise (.1-10Hz) | | 6 | | | * | | | * | | µVpp |
| **OUTPUT CURRENT** | | | | | | | | | | |
| Range | ±10 | | | * | | | * | | | mA |
| **REGULATION** | | | | | | | | | | |
| Line | | 3 | 10 | | * | * | | * | * | ppm/V |
| Load | | 3 | | | * | | | * | | ppm/mA |
| **POWER SUPPLY CURRENTS** (4) | | | | | | | | | | |
| +PS | | 7 | 9 | | * | * | | * | * | mA |
| -PS | | 4 | 6 | | * | * | | * | * | mA |

NOTES: *Same as A/J Models.

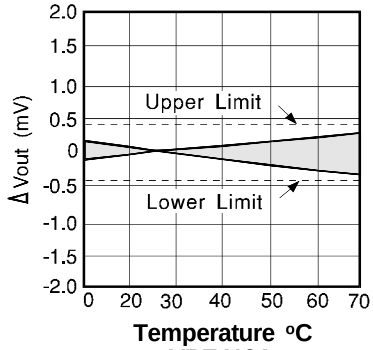
1. The specified values are without external trim.
2. The temperature coefficient (tc) is determined by the box method using the following formula:

$$tc = \frac{V_{max} - V_{min}}{V_{nominal} \times (T_{max} - T_{min})} \times 10^{6}$$

3. The tracking error is the deviation between the positive and negative output over the operating temp. range.
4. The specified values are unloaded.

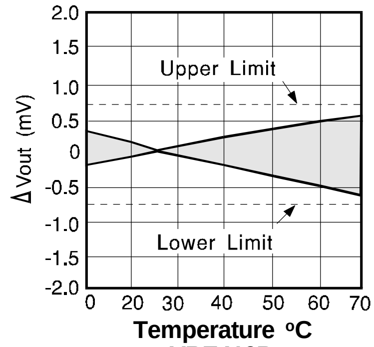
# TYPICAL PERFORMANCE CURVES

$V_{OUT}$ vs. TEMPERATURE



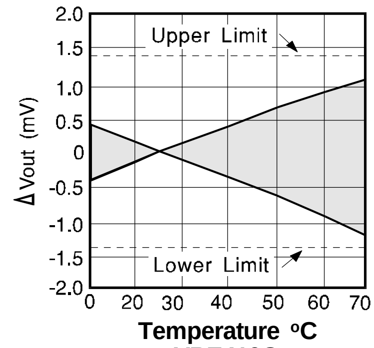

VRE410A

$V_{OUT}$ vs. TEMPERATURE



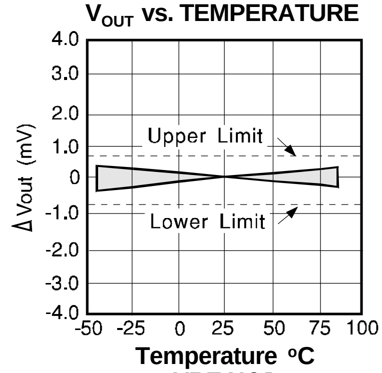

VRE410B

$V_{OUT}$ vs. TEMPERATURE



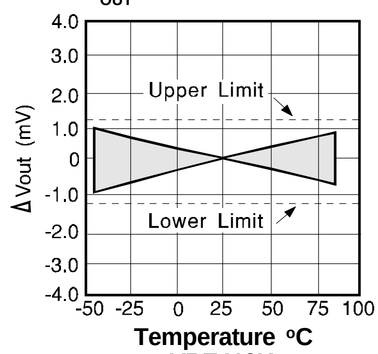

VRE410C

$V_{OUT}$ vs. TEMPERATURE



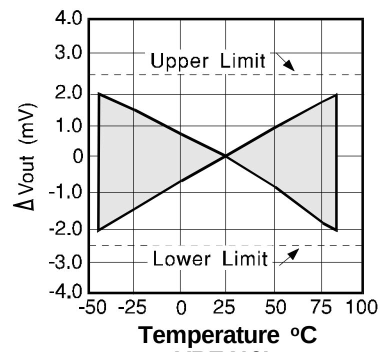

VRE410J

$V_{OUT}$ vs. TEMPERATURE




VRE410K

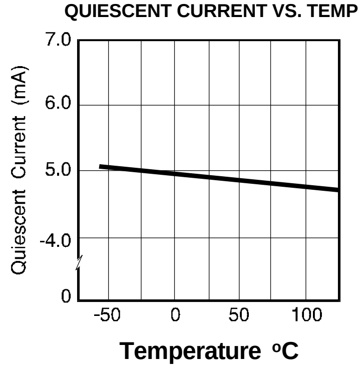
$V_{OUT}$ vs. TEMPERATURE



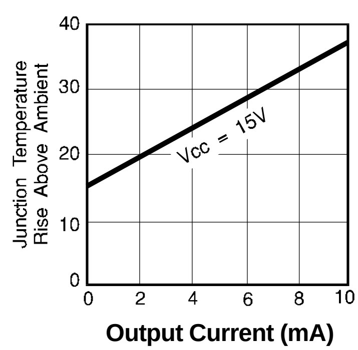

VRE410L

*POSITIVE OUTPUT (TYP)*

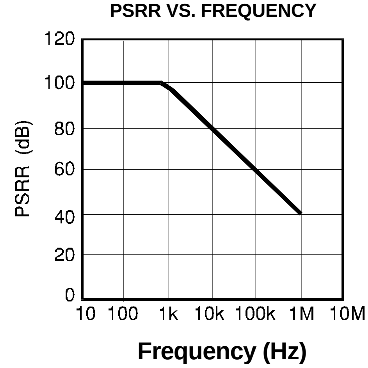
**QUIESCENT CURRENT VS. TEMP**




**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**

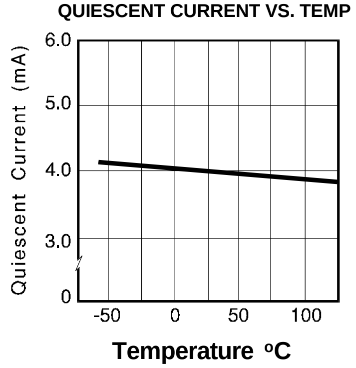



**PSRR VS. FREQUENCY**

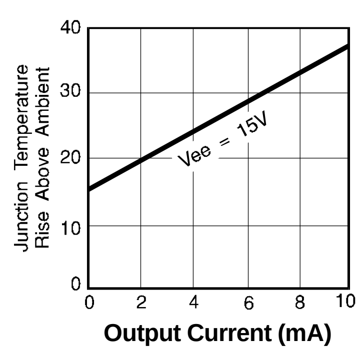



*NEGATIVE OUTPUT (TYP)*

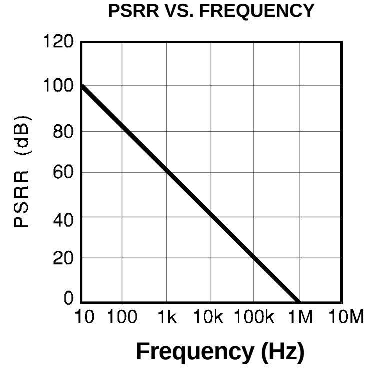
**QUIESCENT CURRENT VS. TEMP**




**JUNCTION TEMP. RISE VS. OUTPUT CURRENT**




**PSRR VS. FREQUENCY**



# DISCUSSION OF PERFORMANCE

**THEORY OF OPERATION**

The following discussion refers to the schematic below. In operation, approximately 6.3 volts is applied to the noninverting input of the op amp. The voltage is amplified by the op amp to produce a 10.000V output. The gain is determined by the networks R1 and R2: G=1 + R2/R1. The 6.3V zener diode is used because it is the most stable diode over time and temperature.

The zener operating current is derived from the regulated output voltage through R3. This feedback arrangement provides a closely regulated zener current. This current determines the slope of the references' voltage vs. temperature function. By trimming the zener current a lower drift over temperature can be achieved. But since the voltage vs. temperature function is nonlinear this compensation technique is not well suited for wide temperature ranges.

Thaler Corporation has developed a nonlinear compensation network of thermistors and resistors that is used in the VRE series voltage references. This proprietary network eliminates most of the nonlinearity in the voltage vs. temperature function. By then adjusting the slope, Thaler Corporation produces a very stable voltage over wide temperature ranges.

The VRE400 series voltage references have the ground terminal brought out on two pins (pin 6 and 7) which are connected together internally. This allows the user to achieve greater accuracy when using a socket. Voltage references have a voltage drop across their power supply ground pin due to quiescent current flowing through the contact resistance. If the contact resistance was constant with time and temperature, this voltage drop could be trimmed out. When the reference is plugged into a socket, this source of error can be as high as 20ppm. By connecting pin 7 to the power supply ground and pin 6 to a high impedance ground point in the measurement circuit, the error due to the contact resistance can be eliminated. If the unit is soldered into place the contact resistance is sufficiently small that it doesn't effect performance.

## VRE410

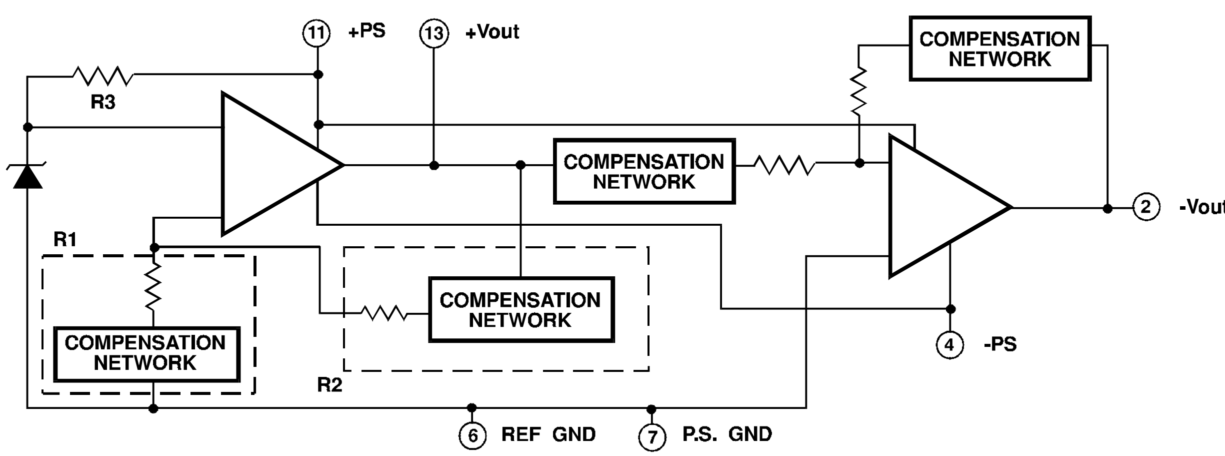
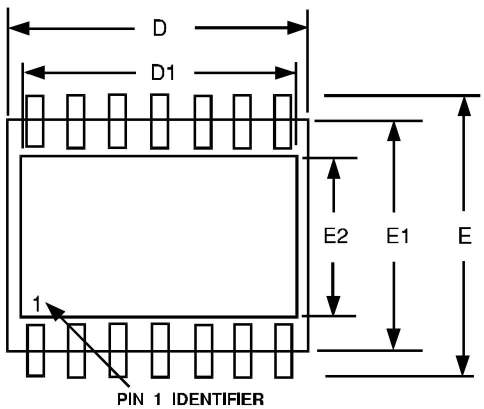


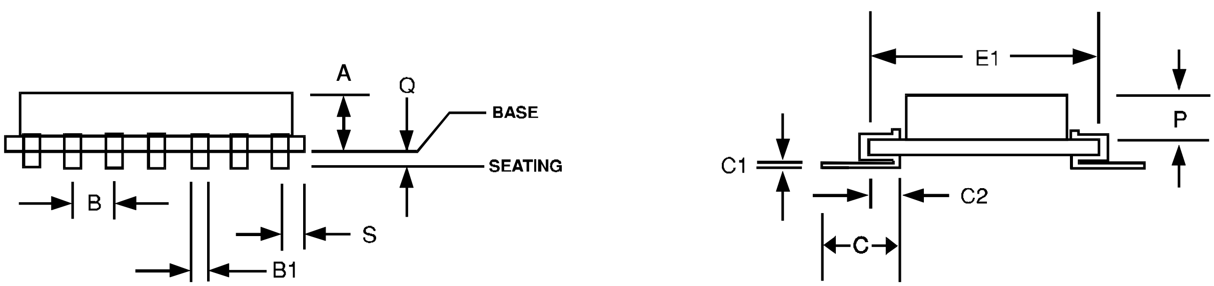

**FIGURE 2**

# MECHANICAL

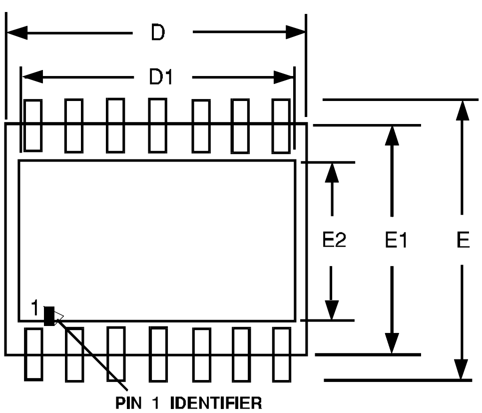
## FIGURE 3




| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .495 | .526 | 12.5 | 13.3 |
| B | .098 | .103 | 2.48 | 2.62 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| C | .103 | .118 | 2.62 | 3.00 | P | .090 | .110 | 2.29 | 2.79 |
| C1 | .009 | .020 | 0.22 | 0.51 | Q | .024 | .035 | 0.61 | .890 |
| C2 | .054 | .062 | 1.37 | 1.57 | S | .040 | .060 | 1.02 | 1.52 |
| D | .690 | .715 | 17.5 | 18.1 | | | | | |
| D1 | .666 | .680 | 16.9 | 17.2 | | | | | |




## FIGURE 4




| | INCHES | | MILLIMETER | | | INCHES | | MILLIMETER | |
|---|---|---|---|---|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX | DIM | MIN | MAX | MIN | MAX |
| A | .114 | .136 | 2.90 | 3.45 | E | .410 | .435 | 10.4 | 11.0 |
| B | .018 | .027 | .460 | .690 | E1 | .390 | .415 | 9.91 | 10.5 |
| B1 | .047 | .056 | 1.19 | 1.42 | E2 | .265 | .270 | 6.73 | 6.86 |
| B2 | .097 | .103 | 2.46 | 2.62 | G1 | .285 | .315 | 7.24 | 8.00 |
| C | .009 | .020 | 0.22 | 0.51 | L | .195 | .225 | 4.95 | 5.72 |
| D | .690 | .715 | 17.5 | 18.1 | P | .090 | .110 | 2.29 | 2.79 |
| D 1 | .666 | .680 | 16.9 | 17.2 | Q | .050 | .070 | 1.27 | 1.79 |
| | | | | | S | .040 | .060 | 1.02 | 1.52 |