# TMCS1170 285kHz Hall-Effect Current Sensor With Overcurrent Protection in a Small QFN Package

## 1 Features

- Small 3mm × 3mm low profile QFN package
- High continuous current capability: $60A_{RMS}$
  - Low loss 0.6mΩ conductor
- ±100V Functional isolation
- Current sense accuracy
  - Sensitivity error: ±1%, typical
  - Sensitivity error: ±2.85% , $T_A$ = 25°C to 125°C
  - Offset error: ±15mV, $T_A$ = 25°C to 125°C
  - Offset lifetime drift: ±20mV
- High immunity to external magnetic fields
- Built- In Overcurrent Detection
  - Signal bandwidth: 285kHz
  - Output propagation delay: 300ns
  - Overcurrent detection response: 1.3µs
- Operating supply range: 3V to 5.5V
- Bidirectional and unidirectional current sensing
- Multiple sensitivity options:
  - Ranging from 26.4mV/A to 200mV/A

## 2 Applications

- Robotics
- Motor control
- Solar Energy
- Power supplies
- Overcurrent protection

## 3 Description

The TMCS1170 is a galvanically isolated Hall-effect current sensor with 100V functional isolation in a small QFN package. An output voltage proportional to the input current is provided with excellent linearity and low drift at all sensitivity options. Signal conditioning circuitry with built-in drift compensation is capable of less than 2.85% maximum sensitivity error over temperature with less than 3% lifetime shift with no system level calibration.

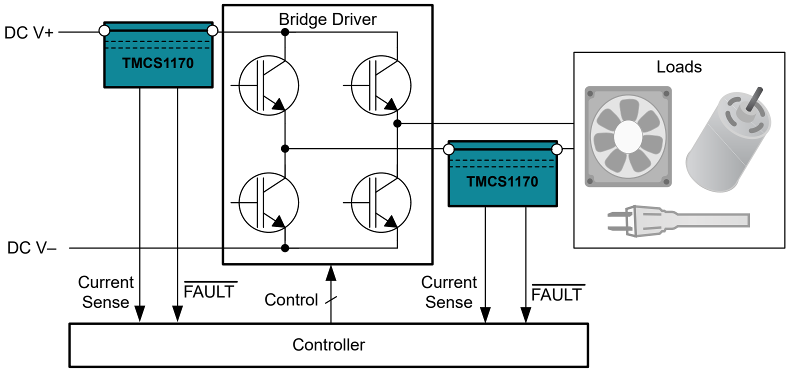
AC or DC input current flows through an internal conductor generating a magnetic field measured by integrated on-chip Hall-effect sensors. Core-less construction eliminates the need for magnetic concentrators. Differential Hall sensors reject interference from stray external magnetic fields. Low conductor resistance increases measurable current ranges up to ±60A while minimizing power loss and easing thermal dissipation requirements. Integrated shielding enables excellent common-mode rejection and transient immunity.

Fixed sensitivity allows the device to operate from a single 3V to 5.5V power supply, eliminating ratiometry errors and improving supply noise rejection. The small solution size, current capability, and ambient field rejection make the device an ideal solution for monitoring currents in tight spaces.

**Package Information** (1)

| PART NUMBER | PACKAGE | PACKAGE SIZE(2) |
|---|---|---|
| TMCS1170 | VAP (VQFN, 12) | 3mm × 3mm |

(1) For all available packages, see Section 12.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



**Typical Application**

## Table of Contents

# 4 Device Comparison

| Device | Reference Voltage | Sensitivity | Linear Range(1) (2) | Fault Trip Level |
|---|---|---|---|---|
| TMCS1170B7F | 1.65V | 132mV/A | ±10A | ±10A |
| TMCS1170B9F | 1.65V | 90mV/A | ±14.7A | ±14.7A |
| TMCS1170B3F | 1.65V | 44mV/A | ±30A | ±30A |
| TMCS1170B1F | 1.65V | 26.4mV/A | ±50A | ±50A |
| TMCS1170A8F | 2.5V | 200mV/A | ±10A | ±10A |
| TMCS1170A6F | 2.5V | 100mV/A | ±20A | ±20A |
| TMCS1170A4F | 2.5V | 66mV/A | ±30A | ±30A |
| TMCS1170A2F | 2.5V | 40mV/A | ±50A | ±50A |
| TMCS1170C5F | 0.5V | 80mV/A | 50A | 50A |

(1) Linear range is specified for maximum device compatibility with wide power supply tolerance. Maximum linear range is limited by the actual supply tolerance and output linear swing range, not by thermal limitations. See Section 8.3.5 for calculating the maximum linear range.

(2) Current levels must remain below both allowable continuous DC/RMS and transient peak current safe operating areas to not exceed device thermal limits. See the *Safe Operating Area* section.

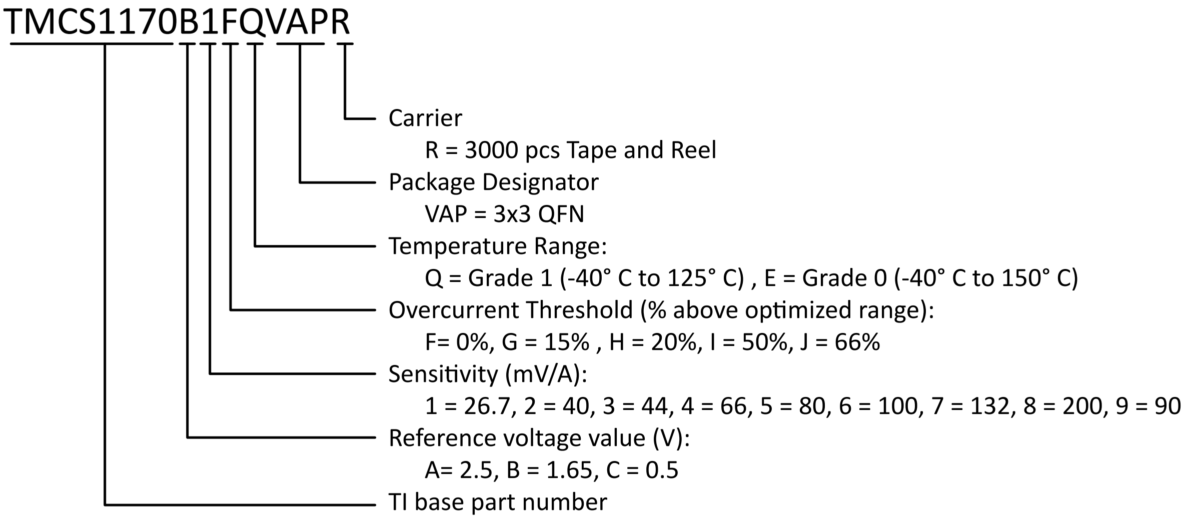


**Figure 4-1. Part Number Naming Designators**

# 5 Pin Configuration and Functions

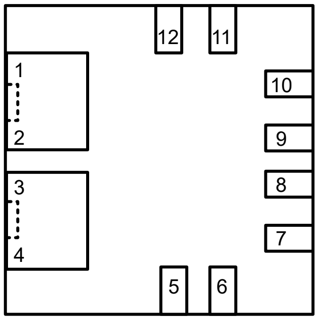


Figure 5-1. VAP Package 12-Pin VQFN Top View

Table 5-1. Pin Functions

| PIN | | TYPE | DESCRIPTION |
|---|---|---|---|
| NO. | NAME | | |
| 1,2 | IN+ | Analog Input | Input current positive pin. Positive current flow is measured going into these pins. |
| 3,4 | IN– | Analog Input | Input current negative pin. Positive current flow is measured going out of these pins. |
| 5 | GND | Analog | Ground. Connect to an analog ground plane. |
| 6 | $\overline{\text{FAULT}}$ | Digital Output | Open drain, active low overcurrent output. This pin goes low when the overcurrent threshold is exceeded. The overcurrent state is transparent and goes high when the overcurrent condition is removed. |
| 7-10 | N.C. | No Connect | No internal connection. Can be left floating or connected to ground as needed by the application. |
| 11 | VOUT | Analog Output | Output voltage representative of the sensed current. The zero current output voltage is dependent on the selected device. |
| 12 | VS | Analog | Power supply connection, a 3.0V to 5.5V supply can be used in accordance with the device selected to power the device. |

# 6 Specifications

## 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_S$ | Supply voltage | | GND – 0.3 | 6 | V |
| | Analog output | VOUT, VREF | GND – 0.3 | $(V_S)$ + 0.3 | V |
| | Digital output | $\overline{\text{FAULT}}$ | | | |
| $T_J$ | Junction temperature | | –65 | 165 | °C |
| $T_{stg}$ | Storage temperature | | –65 | 165 | °C |

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

## 6.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±5000 | V |
| | | Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002(2) | ±1000 | |

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

## 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{IN+}$,$V_{IN–}$ | Input voltage | –100 | | 100 | $V_{PK}$ |
| $V_S$ | Operating supply voltage | 3 | 5 | 5.5 | V |
| $T_A$ (1) | Operating free-air temperature | –40 | | 125 | °C |

(1) Input current safe operating area is constrained by junction temperature. Recommended condition based on use with the TMCS1170EVM. Input current rating is derated for elevated ambient temperatures.

## 6.4 Thermal Information

| THERMAL METRIC(1) | | TMCS1170(2) | UNIT |
|---|---|---|---|
| | | VAP | |
| | | 10 PINS | |
| $R_{θJA}$ | Junction-to-ambient thermal resistance | 34 | °C/W |
| $R_{θJC(top)}$ | Junction-to-case (top) thermal resistance | 58.7 | |
| $R_{θJB}$ | Junction-to-board thermal resistance | 1.7 | |
| $Ψ_{JT}$ | Junction-to-top characterization parameter | 17.3 | |
| $Ψ_{JB}$ | Junction-to-board characterization parameter | 28 | |

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application note.
(2) Applies when device is mounted on TMCS1170EVM. For more details, see the *Safe Operating Area* section.

## 6.5 Insulation Specifications

| PARAMETER | | TEST CONDITIONS | VALUE | UNIT |
|---|---|---|---|---|
| **GENERAL** | | | | |
| $V_{IOWM}$ | Maximum basic isolation working voltage | Voltage applied between pins 1-2 and pins 3-10 | 100 | $V_{DC}$ |

## 6.6 Electrical Characteristics

at $T_A$ = 25°C, $V_S$ = 5V on TMCS1170AxFand TMCS1170CxF, $V_S$ = 3.3V on TMCS1170BxF (unless otherwise noted)

| PARAMETERS | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **INPUT** | | | | | | |
| $R_{IN}$ | Input Conductor Resistance | IN+ to IN– | | 0.6 | | mΩ |
| $R_{IN}$ | Input conductor resistance temperature drift | $T_A$= –40ºC to +125ºC | | 1.9 | | µΩ/°C |
| $I_{IN,MAX}$ | Maximum Continuous Input Current[1] | $T_A$= 25ºC | | 60 | | $A_{RMS}$ |
| | | $T_A$= 125ºC | | 35 | | |
| **OUTPUT** | | | | | | |
| S | Sensitivity | TMCS1170x1x | | 26.4 | | mV/A |
| | | TMCS1170x2x | | 40 | | |
| | | TMCS1170x3x | | 44 | | |
| | | TMCS1170x4x | | 66 | | |
| | | TMCS1170x5x | | 80 | | |
| | | TMCS1170x9x | | 90 | | |
| | | TMCS1170x6x | | 100 | | |
| | | TMCS1170x7x | | 132 | | |
| | | TMCS1170x8x | | 200 | | |
| $e_S$ | Sensitivity Error | $0.05V \le V_{OUT} \le V_S - 0.2V$ | | ±1 | | % |
| $S_{drift}$ | Sensitivity Error Over Temperature | $0.05V \le V_{OUT} \le V_S - 0.2V$, $T_A$ = 25°C to 125°C | | ±1 | ±2.85 | % |
| | | $0.05V \le V_{OUT} \le V_S - 0.2V$, $T_A$ = −40°C to 25°C | | ±2.2 | | % |
| $S_{drift, life}$ | Sensitivity Lifetime Drift | $0.05V \le V_{OUT} \le V_S - 0.2V$ | | ±0.6 | ±3 | % |
| $e_{NL}$ | Nonlinearity Error | $V_{OUT}$ = 0.1V to $V_S$ – 0.1V | | ±0.1 | | % |
| $V_{OUT,0A}$ | Zero Current Output Voltage | TMCS1170AxF, $I_{IN}$ = 0A, Bidirectional, $V_S$ = 5.0V | | 2.5 | | V |
| | | TMCS1170BxF, $I_{IN}$ = 0A, Bidirectional, $V_S$ = 3.3V | | 1.65 | | |
| | | TMCS1170CxF, $I_{IN}$ = 0A, Unidirectional | | 0.5 | | |
| $V_{OE}$ | Output Voltage Offset Error | TMCS1170xxF, $V_{OUT,0A}$, $I_{IN}$ = 0A | | ±4 | ±12 | mV |
| | | TMCS1170xxF, $V_{OUT,0A}$, $I_{IN}$ = 0A, $T_A$ = 25°C to 125°C | | ±6 | ±15 | mV |
| | | TMCS1170xxF, $V_{OUT,0A}$, $I_{IN}$ = 0A, $T_A$ = -40°C to 25°C | | ±4 | ±40 | mV |
| $I_{OS, life}$ | Offset Lifetime Drift | Output Referred, $I_{IN}$ = 0A | | ±6 | ±20 | mV |
| PSRR | Power Supply Rejection Ratio | Output Referred, $V_S$ = 3V to 5.5V, DC | 40 | 53 | | dB |
| CMRR | Common Mode Rejection Ratio | Input referred, DC to 60Hz | | 8 | | µA/V |
| CMFR | Common Mode Field Rejection | Uniform External Magnetic Field, Input Referred, DC to 1kHz | | 5 | 20 | mA/mT |
| | Input Noise Density | Input Referred, Full Bandwidth | | 235 | | µA/√Hz |
| $C_{L,MAX}$ | Maximum capacitive load | VOUT to GND | | 4.7 | | nF |
| | Short circuit output current | VOUT short to GND, short to $V_S$ | | 30 | | mA |
| $Swing_{VS}$ | Swing to $V_S$ power supply rail | $R_L$ = 10kΩ to GND, $T_A$= –40ºC to 125ºC | | $V_S$ – 0.02 | $V_S$ – 0.05 | V |
| $Swing_{GND}$ | Swing to GND | | | 5 | 10 | mV |

at $T_A$ = 25°C, $V_S$ = 5V on TMCS1170AxFand TMCS1170CxF, $V_S$ = 3.3V on TMCS1170BxF (unless otherwise noted)

| PARAMETERS | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **BANDWIDTH & RESPONSE** | | | | | | |
| BW | Analog Bandwidth | - 3dB Gain | | 285 | | kHz |
| SR | Slew Rate(2) | Output rate of change between reaching 10% and 90% of final value, 1V output step, 100ns input step(2) | | 1 | | V/µs |
| $t_r$ | Response Time(2) | Time between input and output reaching 90% of final values, 100ns input step, 1V output transition(2) | | 1.2 | | µs |
| $t_{pd}$ | Propagation Delay(2) | Time between input and output reaching 10% of final values, 100ns input step, 1V output transition(2) | | 300 | | ns |
| | Current Overload Recovery Time | | | 600 | | ns |
| **OVER CURRENT DETECTION** | | | | | | |
| | Over Current Threshold Error | $T_A$ = –40°C to 125°C | | ±8 | | % |
| | Over Current Hysteresis | Percentage of overcurrent trip threshold | | 15 | | % |
| | Over Current Detection Response Time | $I_{IN}$ step = 120% of measured $I_{OC}$, $R_{PULLUP}$ = 1kΩ | | 0.8 | 1.3 | µs |
| $\overline{OC}_{,OL}$ | $\overline{\text{FAULT}}$ Pin Pull-down Voltage | $I_{OL}$ = 3mA, $T_A$ = –40°C to 125°C | GND | 0.07 | 0.2 | V |
| **POWER SUPPLY** | | | | | | |
| $V_S$ | Supply voltage | $T_A$ = –40ºC to +125ºC | 3.0 | | 5.5 | V |
| $I_Q$ | Quiescent current | $T_A$ = –40ºC to +125ºC | | 5.5 | 7 | mA |
| | Power on time | Time from $V_S$ > 3V to valid output | | 500 | | µs |

(1) Thermally limited by junction temperature. Applies when device mounted on the device EVM. For more details, see the *Safe Operating Area* section.
(2) Refer to the *Transient Response* section for details on transient response of the device.

## 6.7 Typical Characteristics

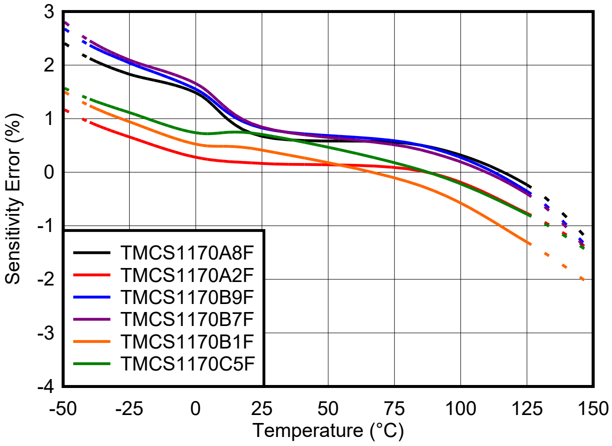


**Figure 6-1. Sensitivity Error vs Temperature**

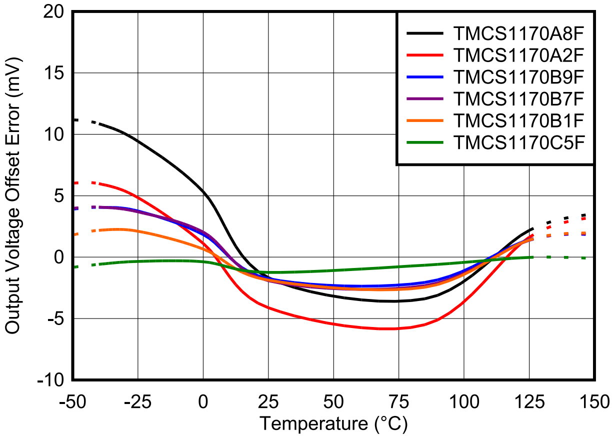


**Figure 6-2. Offset Error vs Temperature**

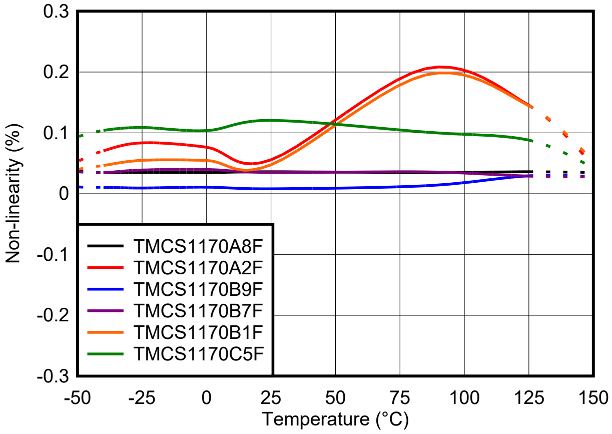
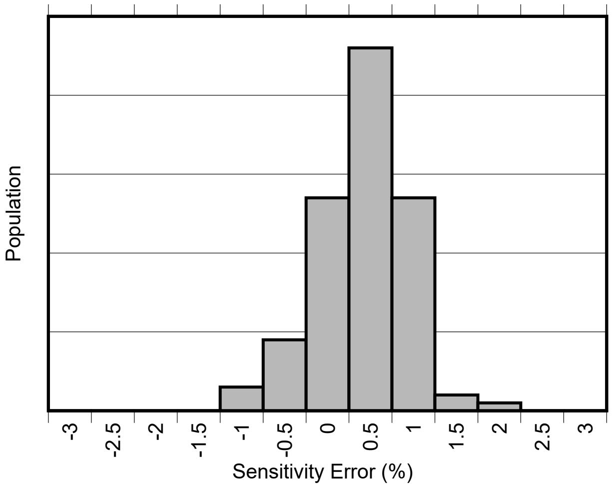


**Figure 6-3. Non-Linearity vs Temperature**



All sensitivities

**Figure 6-4. Sensitivity Error Production Distribution**

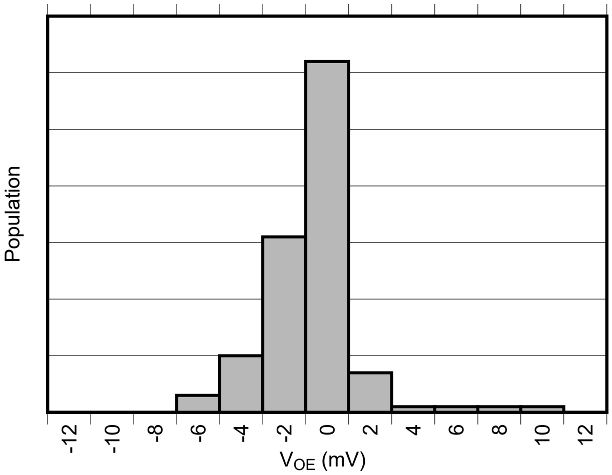


**Figure 6-5. Offset Error Production Distribution**

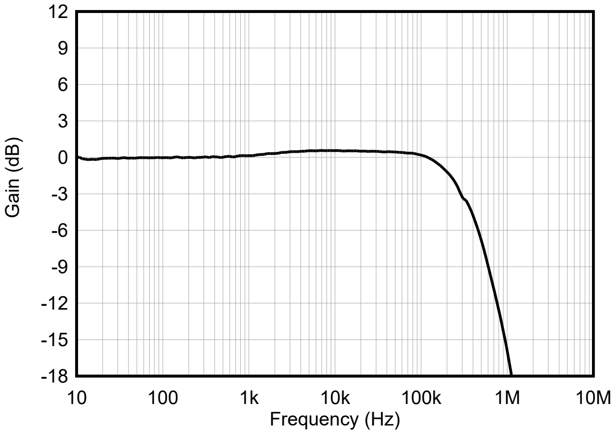


**Figure 6-6. Sensitivity vs Frequency, All Sensitivities Normalized to 1Hz**

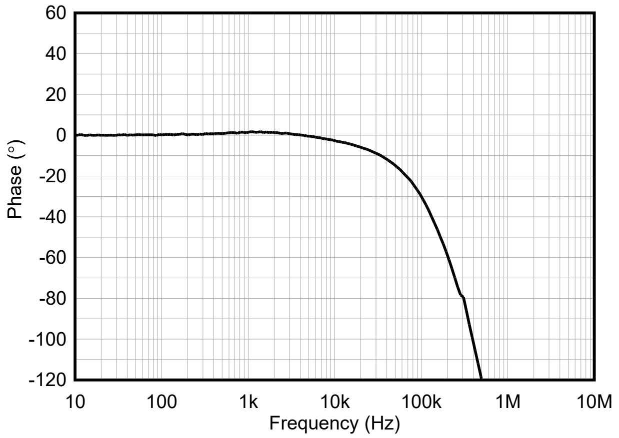


**Figure 6-7. Phase vs Frequency, All Sensitivities**

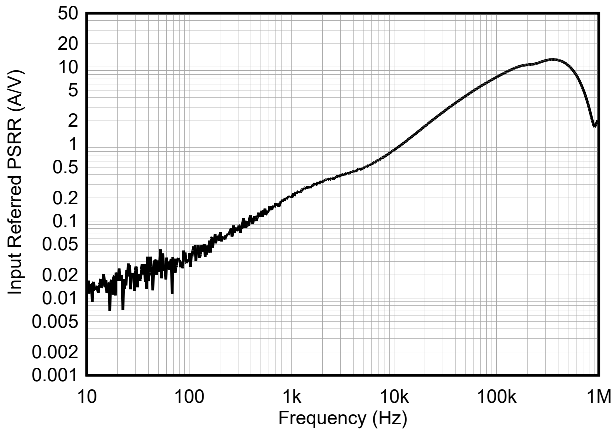


**Figure 6-8. PSRR vs Frequency**

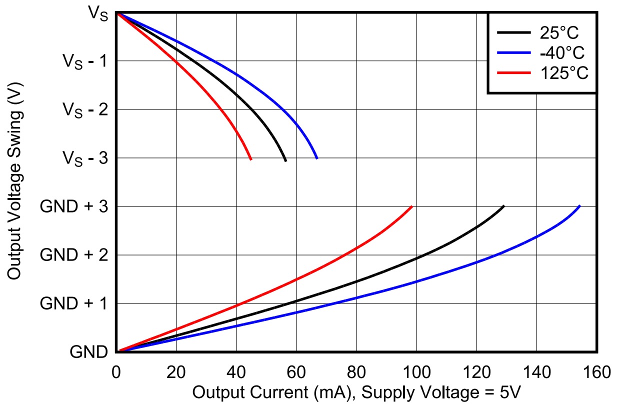


**Figure 6-9. Output Swing vs Output Current**

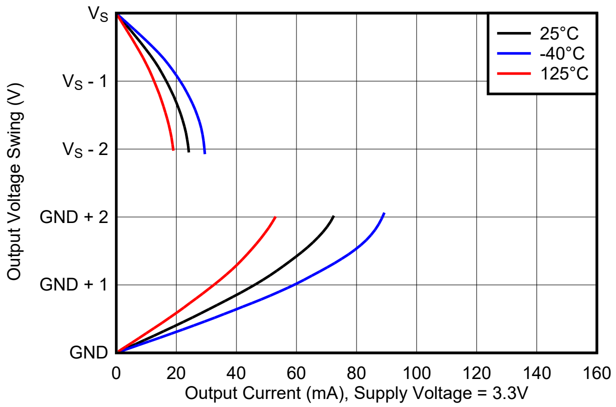


**Figure 6-10. Output Swing vs Output Current**

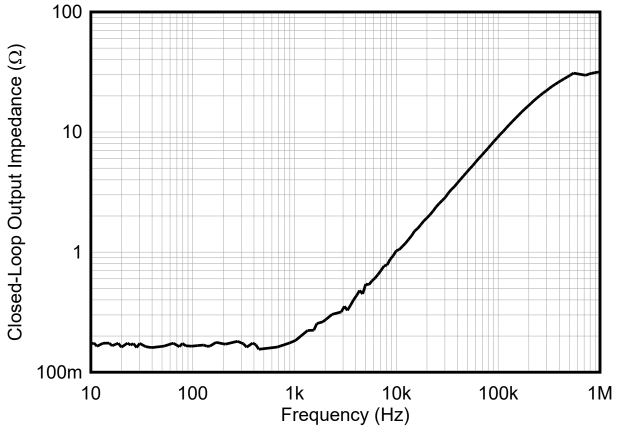


**Figure 6-11. Output Impedance vs Frequency**

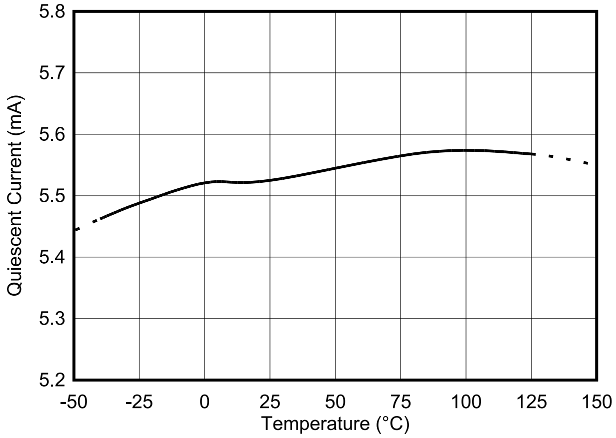
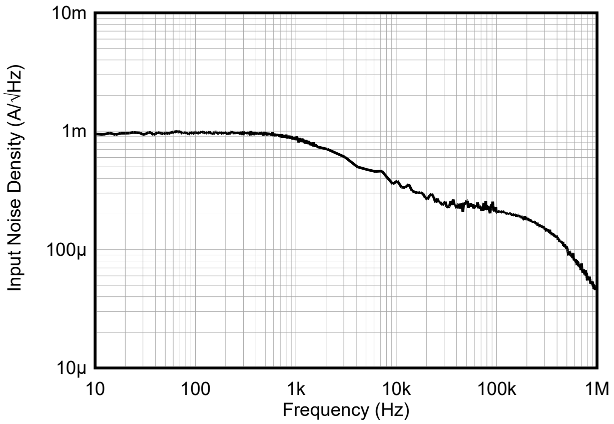


**Figure 6-12. Quiescent Current vs Temperature**



All sensitivities

Figure 6-13. Input-Referred Noise vs Frequency

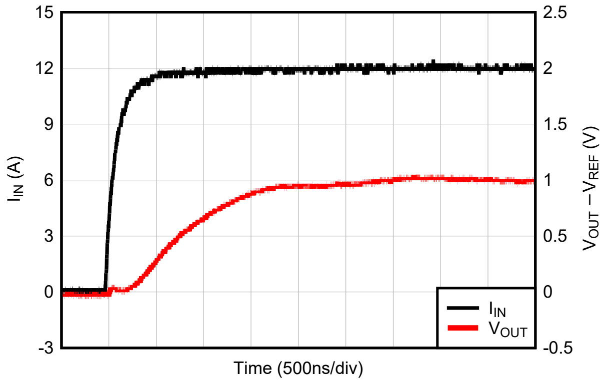


Figure 6-14. Voltage Output Step Response, Rising

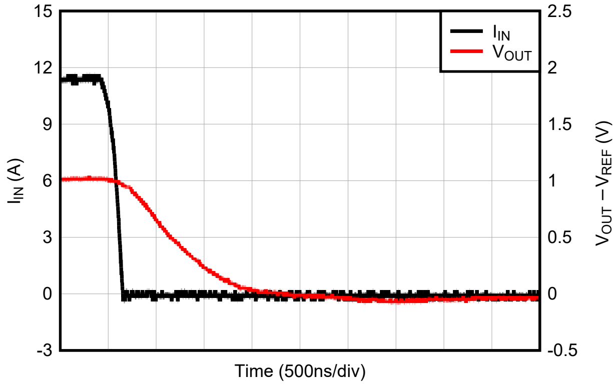


Figure 6-15. Voltage Output Step Response, Falling

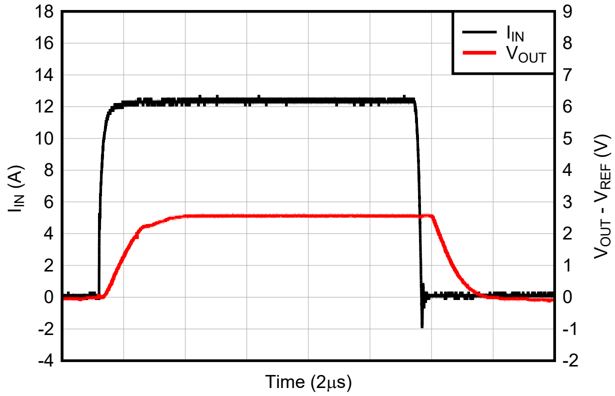


Figure 6-16. Current Overload Response

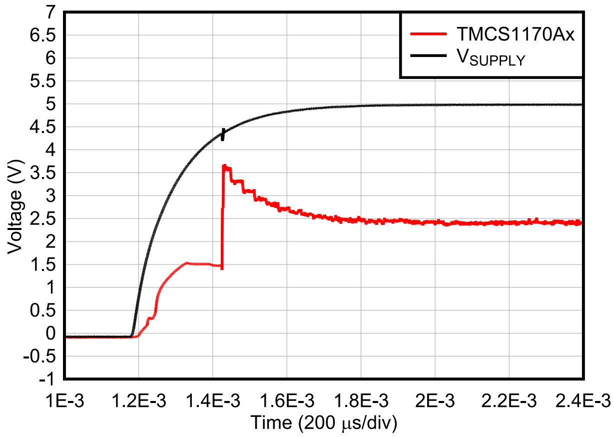


Figure 6-17. Startup Transient Response

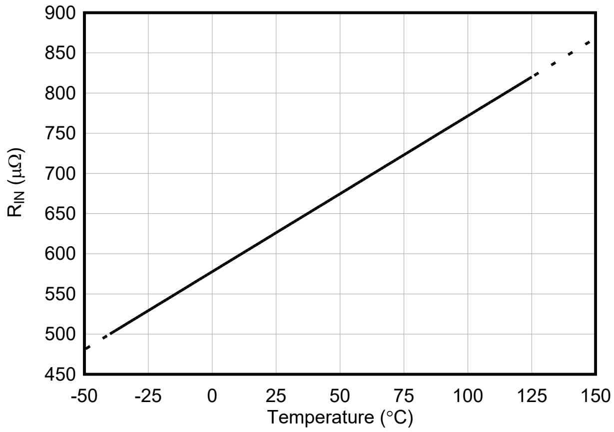


Figure 6-18. Input Conductor Resistance vs Temperature

# 7 Parameter Measurement Information

## 7.1 Accuracy Parameters

The ideal first-order transfer function of the TMCS1170 is given by Equation 1, where the output voltage is a linear function of input current. The accuracy of the device is quantified both by the error terms in the transfer function parameters, as well as by nonidealities that introduce additional error terms not in the simplified linear model. See *Total Error Calculation Examples* for example calculations of total error, including all device error terms.

$$V_{OUT} = S \times I_{IN} + V_{OUT,0A} \quad (1)$$

where

- $V_{OUT}$ is the analog output voltage.
- $I_{IN}$ is the isolated input current.
- S is the sensitivity of the device.
- $V_{OUT,0A}$ is the zero current output voltage for the device variant.

### *7.1.1 Sensitivity Error*

Sensitivity is the proportional change in the sensor output voltage due to a change in the input conductor current. This sensitivity is the slope of the first-order transfer function of the sensor (see Figure 7-1). The sensitivity of the TMCS1170 is tested and calibrated at the factory for high accuracy.

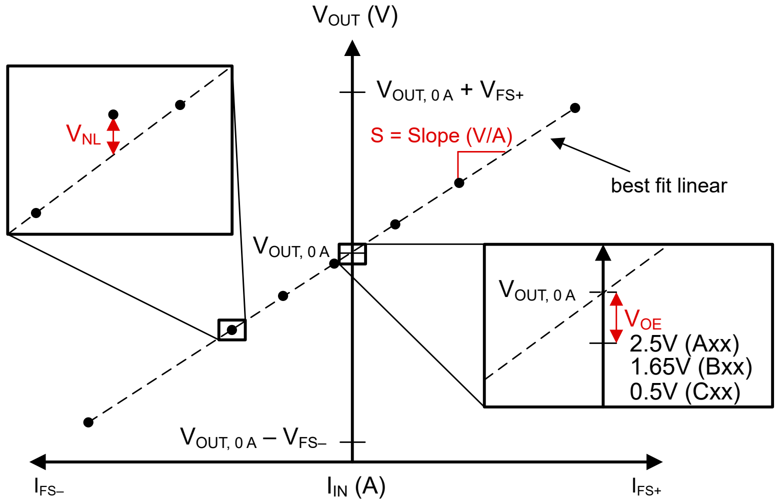


**Figure 7-1. Sensitivity, Offset, and Nonlinearity Error**

Sensitivity error $e_S$ is the deviation from ideal sensitivity and is defined in Equation 2 as the variation of the best-fit measured sensitivity from the ideal sensitivity.

$$e_S = \frac{(S_{fit} - S_{ideal})}{S_{ideal}} \quad (2)$$

where

- $e_S$ is the sensitivity error.
- $S_{fit}$ is the best fit sensitivity.
- $S_{Ideal}$ is the ideal sensitivity.

Sensitivity lifetime drift $S_{drift,life}$ is the change in sensitivity due to operational and environmental stresses over the entire lifetime of the device, and is reported as a worst-case percentage change in sensitivity over lifetime.

### 7.1.2 Offset Error

Offset error is the deviation from the ideal output with zero input current and most often limits measurement accuracy at low input current levels. Offset error can be referred to the output as offset voltage error or referred to the input as offset current error. When divided by device sensitivity, S, output voltage offset error $V_{OE}$ is input referred as input current offset error $I_{OS}$ (see Equation 3). Offset error referred to the input (RTI) allows for more direct comparisons of offset error with input current. Regardless of whether offset error is referred to the input as current offset error $I_{OS}$, or to the output as voltage offset error $V_{OE}$, offset error is a single error source and must only be included once in either input-referred or output-referred error calculations.

$$I_{OS} = \frac{V_{OE}}{S} \tag{3}$$

As shown in Figure 7-1, the output voltage offset error $V_{OE}$ of the TMCS1170 is the difference between the zero current output voltage $V_{OUT,0A}$ and fixed internal reference $V_{REF}$ (see Equation 4).

$$V_{OE} = V_{OUT,\,0A} - V_{REF} \tag{4}$$

The output offset error $V_{OE}$ includes magnetic offset error in the Hall sensor, offset voltage error in the signal chain, and offset error in the internal zero current output reference voltage $V_{REF}$. The value of the internal reference is 2.5V, 1.65V, or 0.5V depending on chosen device number, TMCS1170Axx, TMCS1170Bxx, or TMCS1170Cxx respectively.

### 7.1.3 Nonlinearity Error

Nonlinearity is the deviation of the output voltage from a linear relationship to the input current. Nonlinearity voltage, as shown in Figure 7-1, is the maximum voltage deviation from the best-fit line based on measured parameters (see Equation 5).

$$V_{NL} = V_{OUT,\,meas} - \left[\left(I_{meas} \times S_{fit}\right) + V_{OUT,\,0A}\right] \tag{5}$$

where

- $V_{OUT,meas}$ is the voltage output at maximum deviation from best fit.
- $I_{meas}$ is the input current at maximum deviation from best fit.
- $S_{fit}$ is the best-fit sensitivity of the device.
- $V_{OUT,0A}$ is the device zero current output voltage.

Nonlinearity error for the TMCS1170 is specified as a percentage of the full-scale output range, $V_{FS}$ (see Equation 6).

$$e_{NL} = 100\% * \frac{V_{NL}}{V_{FS}} \tag{6}$$

### 7.1.4 Power Supply Rejection Ratio

Power supply rejection ratio (PSRR) for the TMCS1170 is output referred and reflects the change in the device output due to variations in supply voltage. Use Equation 7 to calculate output referred error caused by supply variations on TMCS1170Axx and TMCS1170Cxx variants. Use Equation 8 to calculate input referred offset errors caused by supply variations on TMCS1170Bxx variants.

$$e_{PSRR\ A,\,C} = 10^{-\frac{PSRR}{20}} \times \left(V_S - 5V\right) \tag{7}$$

$$e_{PSRR\ B} = 10^{-\frac{PSRR}{20}} \times \left(V_S - 3.3V\right) \tag{8}$$

where

- PSRR is the output referred power supply rejection ratio in dB.
- $V_S$ is the operational supply voltage.

### 7.1.5 Common-Mode Rejection Ratio

Common-mode rejection ratio (CMRR) quantifies the effective input current error due to a varying voltage on the isolated input of the device. Due to magnetic coupling and galvanic isolation of the current signal, the TMCS1170 has very high rejection of input common-mode voltage. Use Equation 9 to calculate the error contribution from the input common-mode voltage $V_{CM}$.

$$e_{\mathrm{CMRR}} = \mathrm{CMRR} \times V_{\mathrm{CM}} \tag{9}$$

where

- CMRR is the input-referred common-mode rejection in µA/V.
- $V_{CM}$ is the operational AC or DC voltage on the input of the device.

### 7.1.6 External Magnetic Field Errors

The TMCS1170 suppresses interference from external magnetic fields generated by adjacent high-current carrying conductors, nearby motors, magnets, or any other sources of stray magnetic fields. Common-mode field rejection (CMFR) quantifies the effective input-referred error caused by stray magnetic fields. Use Equation 10 to calculate error contributions from stray external magnetic fields $B_{EXT}$.

$$e_{\mathrm{Bext}} = B_{\mathrm{EXT}} \times \mathrm{CMFR} \tag{10}$$

where

- $B_{EXT}$ is the intensity of the external magnetic field in mT.
- CMRF is the common-mode field rejection in mA/mT.

## 7.2 Transient Response Parameters

Critical TMCS1170 transient step response parameters are shown in Figure 7-2. Propagation delay, $t_{pd}$, is the time period between the input current waveform reaching 10% of the final value and the output voltage, $V_{OUT}$, reaching 10% of the final value. Response time, $t_r$, is the time period between the input current reaching 90% of the final value and the output voltage reaching 90% of the final value, for an input current step sufficient to cause a 1V change in the output voltage. Slew rate, SR, is a large signal response of the output voltage and is defined as the rate of change between the output voltage reaching 10% and 90% of the final value during the sufficiently fast input current step.

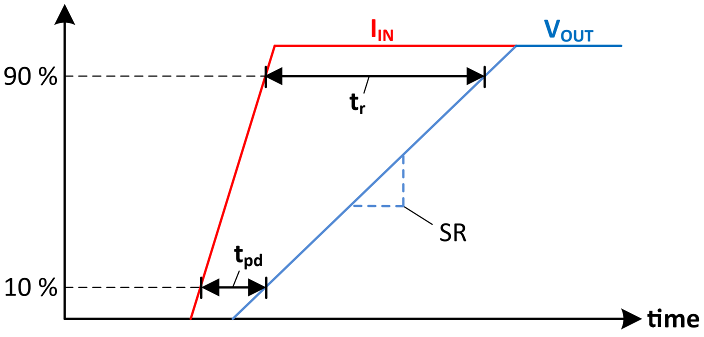


**Figure 7-2. Transient Step Response**

### 7.2.1 CMTI, Common-Mode Transient Immunity

CMTI is the capability of the device to tolerate a rising or falling voltage step on the input without coupling significant disturbance on the output signal. The device is specified for the maximum common-mode transition rate under which the output signal does not experience a disturbance greater than 200mV lasting longer than 1µs, as shown in Figure 7-3 with a 40V/ns common-mode input step. Higher edge rates than the specified CMTI can be supported with sufficient filtering or blanking time after common-mode transitions.

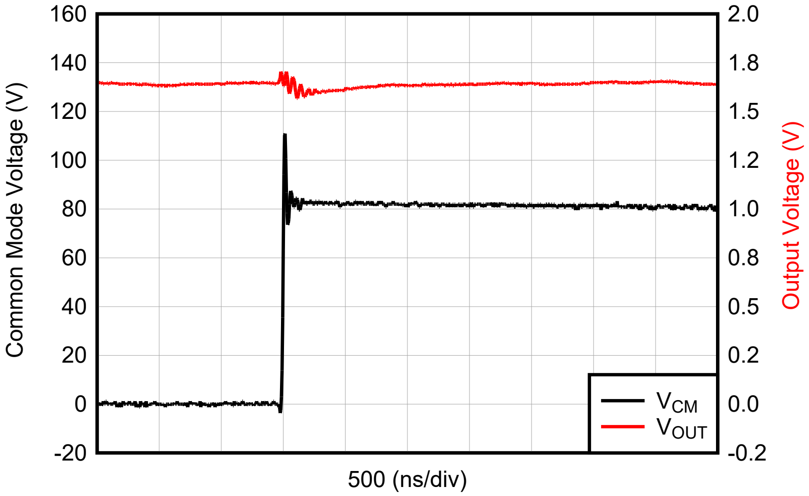


**Figure 7-3. Common-Mode Transient Response**

## 7.3 Safe Operating Area

The isolated input current safe operating area (SOA) of the TMCS1170 is constrained by self-heating due to power dissipation in the input conductor. Depending upon the use case, the SOA is constrained by multiple conditions, including exceeding maximum junction temperature, Joule heating in the leadframe, or leadframe fusing under extremely high currents. These mechanisms depend greatly on input current amplitude and duration, along with ambient thermal conditions.

Current SOA strongly depends on the thermal environment and design of the system-level printed circuit board(PCB). Multiple thermal variables control the transfer of heat from the device to the surrounding environment, including air flow, ambient temperature, and PCB construction and design. All ratings are for a single TMCS1170 device mounted on the TMCS1170EVM , or equivalent PCB design with no air flow under specified ambient temperature conditions. Device use profiles must satisfy continuous current conduction SOA capabilities for the thermal environment planned for system operation.

### *7.3.1 Continuous DC or Sinusoidal AC Current*

The longest thermal time constants of device packaging and PCBs are in the order of seconds; therefore, any continuous DC or sinusoidal AC periodic waveform with a frequency higher than 1Hz can be evaluated based on the RMS continuous-current levels. The continuous-current capability has a strong dependence upon the operating ambient temperature range expected in operation. Figure 7-4 shows the maximum continuous current-handling capability of the device when mounted on the TMCS1170EVM . Current capability falls off at higher ambient temperatures because of the reduced thermal transfer from junction-to-ambient and increased power dissipation in the leadframe. By improving the thermal design of an application, the SOA can be extended to higher currents at elevated temperatures. Using larger and heavier copper power planes, providing air flow over the board, or adding heat sinking structures to the area of the device can all improve thermal performance.

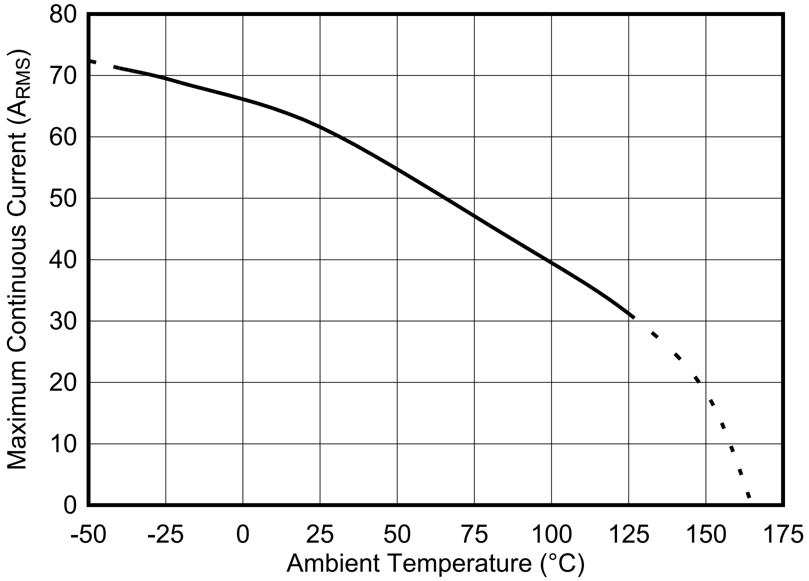


**Figure 7-4. Maximum Continuous RMS Current vs Ambient Temperature**

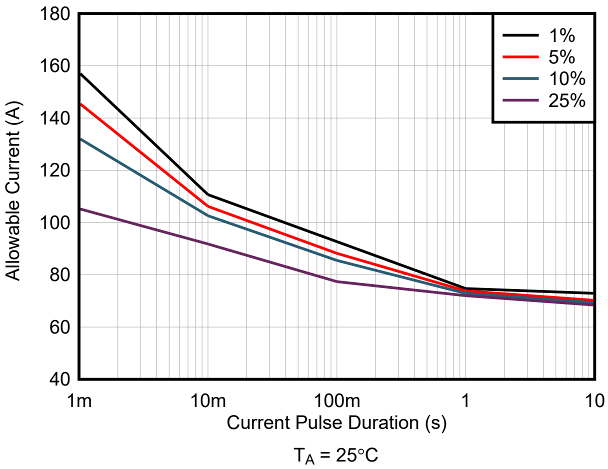
### *7.3.2 Repetitive Pulsed Current SOA*

For applications where current is pulsed between a high current and no current, the allowable capabilities are limited by short-duration heating in the leadframe. The TMCS1170 can tolerate higher current ranges under some conditions, however, for repetitive pulsed events, the current levels must satisfy both the pulsed current SOA and the RMS continuous current constraint. Pulse duration, duty cycle, and ambient temperate all impact the SOA for repetitive pulsed events. Figure 7-5, Figure 7-6, Figure 7-7, and Figure 7-8 illustrate repetitive stress levels based on test results from the TMCS1170EVM under which parametric performance and isolation integrity is not impacted post-stress for multiple ambient temperatures. At high duty cycles or long pulse durations, this limit approaches the continuous current SOA for a RMS value defined by Equation 11.

$$I_{IN,\,RMS} = I_{IN,\,P} \times \sqrt{D} \tag{11}$$

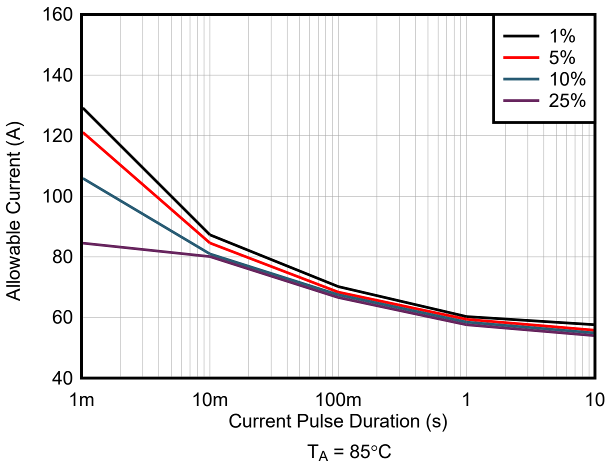
where

- $I_{IN,RMS}$ is the RMS input current level
- $I_{IN,P}$ is the pulse peak input current
- D is the pulse duty cycle



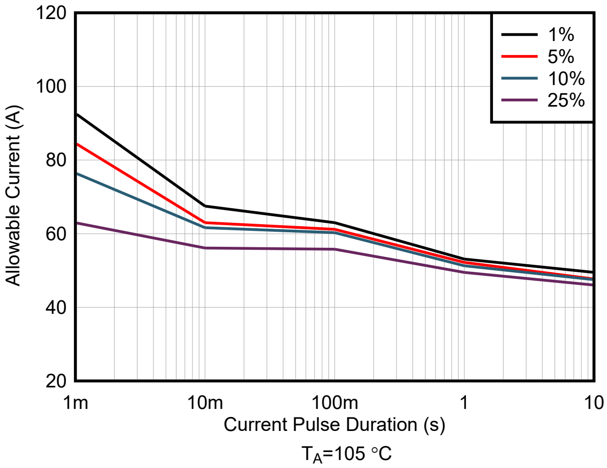
$T_A$ = 25°C

**Figure 7-5. Maximum Repetitive Pulsed Current vs. Pulse Duration**



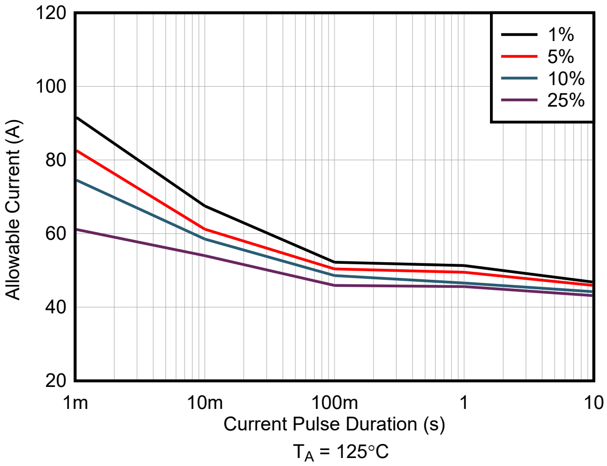
$T_A$ = 85°C

**Figure 7-6. Maximum Repetitive Pulsed Current vs. Pulse Duration**



$T_A$ = 105°C

**Figure 7-7. Maximum Repetitive Pulsed Current vs. Pulse Duration**



$T_A$ = 125°C

**Figure 7-8. Maximum Repetitive Pulsed Current vs. Pulse Duration**

### *7.3.3 Single Event Current Capability*

Single higher-current events that are shorter duration can be tolerated by the TMCS1170, because the junction temperature does not reach thermal equilibrium within the pulse duration. Figure 7-9 shows the short-circuit duration curve for the device for single current-pulse events, where the leadframe resistance changes after stress. This level is reached before a leadframe fusing event, but must be considered an upper limit for short duration SOA. For long-duration pulses, the current capability approaches the continuous RMS limit at the given ambient temperature.

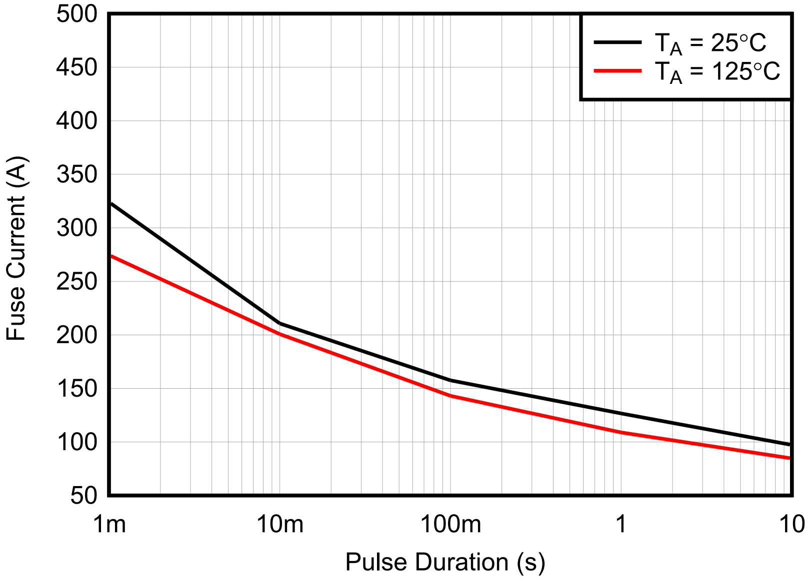


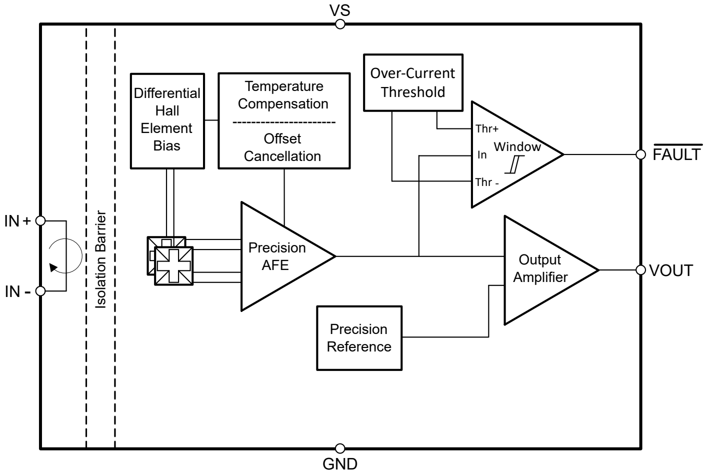
**Figure 7-9. Single-Pulse Leadframe Capability**

# 8 Detailed Description

## 8.1 Overview

The TMCS1170 is a Hall-effect current sensor, featuring 100V functional isolation, ambient field rejection and high current carrying capability in a small 3mm × 3mm QFN package. Numerous device options are provided for both unidirectional and bidirectional current measurements. Input current flows through a conductor between the isolated input current pins. The conductor has a 0.6mΩ resistance at room temperature and accommodates up to $30A_{RMS}$ continuous current at 125°C ambient temperature when used with printed circuit boards of comparable thermal design as the TMCS1170EVM. The low-ohmic leadframe path reduces power dissipation compared to alternative current measurement methodologies, and does not require any external passive components, isolated supplies, or control signals on the high-voltage side. The magnetic field generated by the input current is sensed by a Hall sensor and amplified by a precision signal chain. The device can be used for both AC and DC current measurements and has a bandwidth of 285kHz. There are multiple fixed-sensitivity device options to select from, providing a wide variety of bidirectional linear current sensing ranges from ±10A to ±50A, as well as unidirectional linear current sensing range up to 50A. The TMCS1170 can operate with a low voltage supply ranging from 3V to 5.5V, and is optimized for high accuracy and temperature stability, with both offset and sensitivity compensated across the entire operating temperature range.

## 8.2 Functional Block Diagram



## 8.3 Feature Description

### *8.3.1 Current Input*

Input current to the TMCS1170 passes through the isolated high-voltage side of the package leadframe in to and out of the IN+ and IN– pins. The current flowing through the package generates a magnetic field that is proportional to the input current, which is measured by an integrated on-chip precision Hall sensor. Only the magnetic field generated by the input current is measured, thus limiting input voltage switching pass-through to the circuitry. This configuration allows for direct measurement of currents with high-voltage transients without signal distortion on the current-sensor output. The leadframe conductor has a low resistance and a positive temperature coefficient.

### *8.3.2 Input Isolation*

The separation between the input conductor and the Hall sensor die due to the TMCS1170 construction provides functional isolation between package pins 1,2 and 3,4 on the high-voltage input side, and package pins 5 through 12 on the low-voltage output side.

### *8.3.3 Ambient Field Rejection*

The TMCS1170 is designed to provide high levels of current measurement accuracy in harsh environments. Immunity to interference from stray magnetic fields allows for use in close proximity to high current carrying traces, motor windings, inductors, or any other erroneous source of stray magnetic fields. The TMCS1170 incorporates differential Hall sensors that are strategically located and configured to reject interference from stray external magnetic fields. Ambient Field Rejection (AFR) limited only by Hall element matching and package leadframe coupling reduces errors from stray magnetic fields.

### 8.3.4 Internal Reference Voltage

The TMCS1170 has an internal reference that determines the zero current output voltage, $V_{OUT,0A}$. Overall current sensing dynamic range can be optimized by choosing either of the three different zero current output voltage options listed in the *Device Comparison* table. These zero current reference options listed in Equation 12, Equation 13, and Equation 14 provide bidirectional or unidirectional current measurements using various supply voltages ranging between 3.0V to 5.5V.

- TMCS1170Axx ➔ $V_{OUT,0A} = V_{REF} = 2.5V$ (12)
- TMCS1170Bxx ➔ $V_{OUT,0A} = V_{REF} = 1.65V$ (13)
- TMCS1170Cxx ➔ $V_{OUT,0A} = V_{REF} = 0.5V$ (14)

### 8.3.5 Current-Sensing Measurable Ranges

The zero current reference voltage, $V_{OUT,0A}$, along with device sensitivity, S, and supply voltage, $V_S$, determine the TMCS1170 linear input current measurement ranges listed in the *Device Comparison* table. The maximum linear output voltage, $V_{OUT,max}$, is limited to 100mV less than the supply voltage as shown in Equation 15. The minimum linear output voltage, $V_{OUT,min}$, is limited to 100mV above ground as shown in Equation 16.

$$V_{OUT,\,max} = V_{S,min} - 100mV \tag{15}$$

$$V_{OUT,\,min} = 100mV \tag{16}$$

Overall maximum dynamic range can be optimized with proper device selection by referring minimum and maximum linear output voltage swing to minimum and maximum linear input current range by dividing output voltage by sensitivity, S (see Equation 17 and Equation 18).

$$I_{IN,\ max+} = \frac{\left(V_{OUT,\,max} - V_{OUT,\,0A}\right)}{S} \tag{17}$$

$$I_{IN,\ max-} = \frac{\left(V_{OUT,\,0A} - V_{OUT,\,min}\right)}{S} \tag{18}$$

where

- $I_{IN,max+}$ is the maximum linear measurable positive input current.
- $I_{IN,max–}$ is the maximum linear measurable negative input current.
- S is the sensitivity of the device variant.
- $V_{OUT,0A}$ is the appropriate zero current output voltage.

### 8.3.6 Overcurrent Detection

In addition to a fast precision analog signal response, the TMCS1170 also offers a fast digital overcurrent response. The Overcurrent Detection (OCD) circuit provides a comparator output that can be used to trigger a warning or system shutdown to prevent damage from excessive current flow caused by short circuits, motor stalls, or other system conditions. The fast digital overcurrent detection response is internally fixed as indicated by the orderable part number. Device options can be offered for both bidirectional and unidirectional devices to trip anywhere between approximately half and up-to twice the full-scale measurement range.

Figure 8-1 shows the overcurrent digital output $\overline{\text{FAULT}}$ response as active-low. When the input current exceeds $\pm I_{OC}$ on a bidirectional device, the fast $\overline{\text{FAULT}}$ pin is pulled low. The input current must return to within $\pm I_{OC}$ by more than a hysteresis current $I_{Hys}$ before the $\overline{\text{FAULT}}$ pin resets back to the normal high-state.

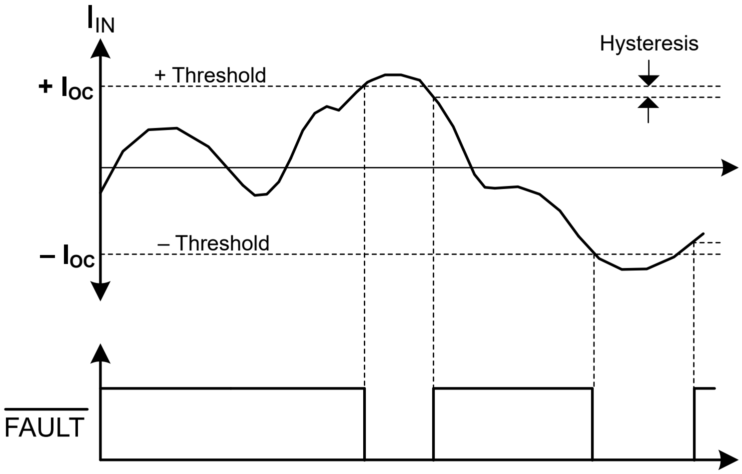


**Figure 8-1. Overcurrent Detection Diagram**

## 8.4 Device Functional Modes

### *8.4.1 Power-Down Behavior*

As a result of the inherent galvanic isolation of the device, very little consideration must be paid to powering down the device, as long as the limits in the *Absolute Maximum Ratings* table are not exceeded on any pins. The isolated current input and the low-voltage signal chain can be decoupled in operational behavior, as either can be energized with the other shut down, as long as the isolation barrier capabilities are not exceeded. The low-voltage power supply can be powered down while the isolated input is still connected to an active high-voltage signal or system.

# 9 Application and Implementation

---

**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

---

## 9.1 Application Information

The key feature sets of the TMCS1170 provide significant advantages in any application where an isolated current measurement is required.

- Functional isolation provides excellent immunity to input voltage transients.
- Hall-based measurement simplifies system level solutions without the need for a power supply on the high-voltage (HV) side.
- An input current path through the low impedance conductor minimizes power dissipation.
- Good accuracy and low temperature drift eliminate the need for multipoint calibrations without sacrificing system performance.
- A wide operating supply range enables a single device to function across a wide range of voltage levels.

These advantages increase system-level performance while minimizing complexity for any application where precision current measurements must be made on isolated currents. Specific examples and design requirements are detailed in the following section.

## 9.2 Typical Application

Inline sensing of inductive load currents, such as motor phases, provides significant benefits to the performance of a control systems, allowing advanced control algorithms and diagnostics with minimal postprocessing. A primary challenge to inline sensing is that the current sensor is subjected to full HV supply-level PWM transients driving the load. The inherent isolation of an in-package Hall-effect current sensor topology helps overcome this challenge, providing high common-mode immunity, as well as isolation between the high-voltage motor drive levels and the low-voltage control circuitry. Figure 9-1 shows the use of the TMCS1170 in such an application, driving the inductive load presented by a three phase motor.

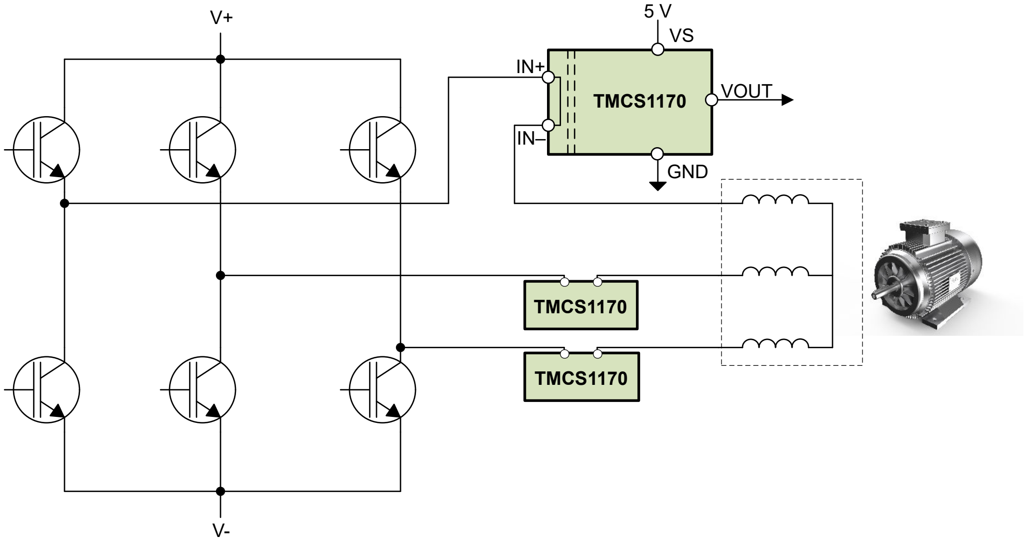


Figure 9-1. Inline Motor Phase Current Sensing

### 9.2.1 Design Requirements

For a 3-phase current sensing application, make sure to provide linear sensing across the expected current range, and make sure that the device remains within working thermal constraints. A single TMCS1170 can be used to measure current in each phase if necessary. For this example, consider a nominal supply of 5V but a minimum of 4.9V to include for some supply variation. Maximum output swings are defined according to TMCS1170 specifications, and a full-scale current measurement of ±20A is required.

**Table 9-1. Example Application Design Requirements**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| $V_{S,nom}$ | 5V |
| $V_{S,min}$ | 4.9V |
| $I_{IN,FS}$ | ±20A |

### 9.2.2 Detailed Design Procedure

The primary design parameter for using the TMCS1170 is the optimum sensitivity variant based on the required measured current levels and the selected supply voltage. Positive and negative currents are measured in this in-line phase current application example, therefore select a bidirectional variant. The TMCS1170 has a precision internal reference voltage that determines the zero current output voltage, $V_{OUT,0A}$. The internal reference voltage on TMCS1170Axx variants, with zero current output voltage $V_{OUT,0A}$ = 2.5V is intended for bidirectional current measurements when used with 5V power supplies. The internal reference voltage on TMCS1170Bxx variants, with zero current output voltage $V_{OUT,0A}$ = 1.65V is intended for bidirectional current measurements when used with 3.3V power supplies. Further consideration of noise and integration with an ADC can be explored, but is beyond the scope of this application design example. The TMCS1170 output voltage $V_{OUT}$ is proportional to the input current $I_{IN}$ as defined by Equation 19 with output offset set by $V_{OUT,0A}$.

$$V_{OUT} = (I_{IN} \times S) + V_{OUT,\,0A} \tag{19}$$

This sensing design focuses on maximizing the sensitivity of the device while maintaining linear measurement over the expected current input range. The TMCS1170 has a linear measurable current range that is constrained by either the positive swing to supply or negative swing to ground. To account for the operating margin, consider the previously defined minimum possible supply voltage $V_{S,min}$ = 4.9V. With the previous parameters, the maximum linear output voltage $V_{OUT,max}$ is defined by Equation 20 and the minimum linear output voltage $V_{OUT,min}$ is defined by Equation 21.

$$V_{OUT,\,max} = V_{S,\,min} - 100\text{mV} \tag{20}$$

$$V_{OUT,\,min} = 100\text{mV} \tag{21}$$

Design parameters for this example application are shown in Table 9-2 along with the calculated output range.

**Table 9-2. Example Application Design Parameters**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| $V_{OUT,max}$ | 4.8V |
| $V_{OUT,0A}$ | 2.5V |
| $V_{OUT,max} - V_{OUT,0A}$ | 2.3V |

These design parameters result in a maximum positive linear output voltage swing of ±2.3V about $V_{OUT,0A}$ = 2.5V. To determine which sensitivity variant of the TMCS1170 most fully uses this linear range, use Equation 22 to calculate the maximum current range for a bidirectional current $\pm I_{IN,max}$.

$$I_{IN,\;max} = \frac{\left(V_{OUT,\,max} - V_{OUT,\,0A}\right)}{S} \tag{22}$$

where

- S is the sensitivity of the relevant AxA variant.

Table 9-3 shows the calculation for each gain variant of the TMCS1170 with the appropriate sensitivities.

**Table 9-3. Maximum Full-Scale Current Range With 2.3V Positive Output Swing**

| VARIANT | SENSITIVITY | $I_{IN,max}$ |
|---|---|---|
| TMCS1170A2x | 40mV/A | 57.5A |
| TMCS1170A4x | 66mV/A | 34.8A |
| TMCS1170A6x | 100mV/A | 23A |
| TMCS1170A8x | 200mV/A | 11.5A |

In general, the highest sensitivity variant is selected to provide the lowest maximum input current range that is larger than the desired full-scale current range. For the design parameters in this example, the TMCS1170A6x with sensitivity of 100mV/A is the proper selection because the maximum 23A linear measurable range is larger than the desired 20A full-scale current range.

### 9.2.3 Application Curve

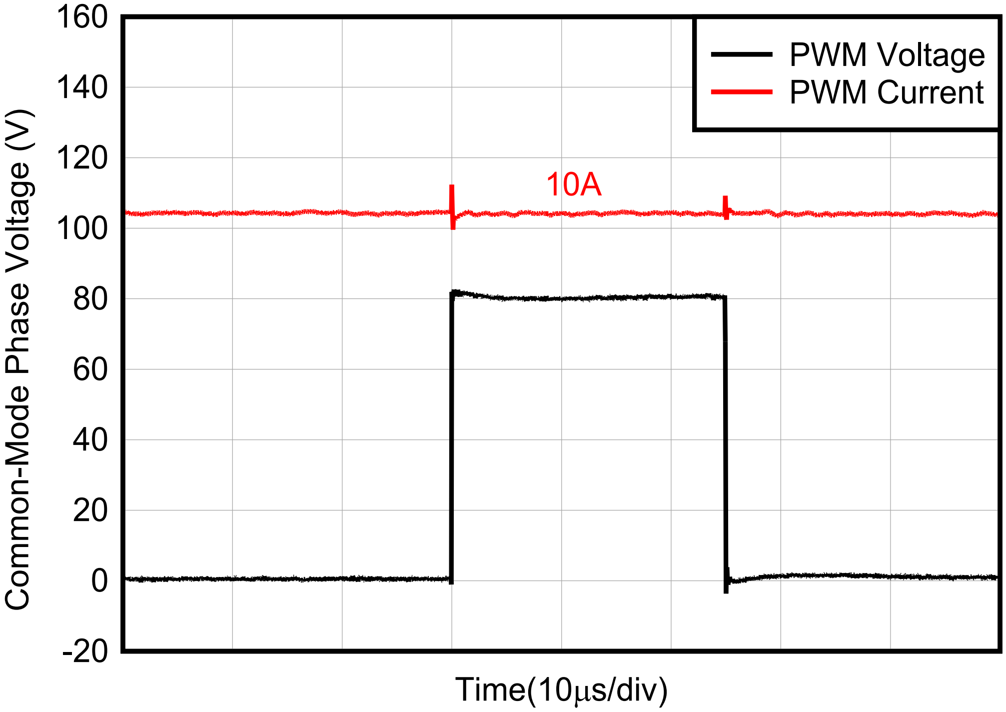


**Figure 9-2. Inline Motor Current-Sense Input and Output Signals**

## 9.3 Power Supply Recommendations

The TMCS1170 only requires a power supply ($V_S$) on the low-voltage isolated side, which powers the analog circuitry independent of the isolated current input. $V_S$ determines the full-scale output range of the analog output $V_{OUT}$, and can be supplied with any voltage between 3V and 5.5V. The TMCS1170 zero-current output voltage is derived internally; therefore, take care to optimize the power supply path for both noise and stability across temperature to provide the highest precision measurement. To filter noise in the power-supply path, place a low-ESR decoupling capacitor of 0.1µF between $V_S$ and GND pins as close as possible to the supply and ground pins of the device. To compensate for noisy or high-impedance power supplies, add more decoupling capacitance.

The TMCS1170 power supply $V_S$ can be sequenced independently of current flowing through the input. However, there is a power-on delay between $V_S$ reaching the recommended operating voltage and the analog output validation. During this power-on time, the output voltage $V_{OUT}$ can transition between GND and $V_S$ as the output transfers from a high impedance reset state to the active drive state. If this behavior must be avoided, then provide a stable supply voltage $V_S$ for longer than the power-on time prior to applying input current.

## 9.4 Layout

### 9.4.1 Layout Guidelines

The TMCS1170 is specified for a continuous current handling capability on the TMCS1170EVM which uses 3oz copper planes. This current capability is fundamentally limited by the maximum device junction temperature and the thermal environment, primarily the PCB layout and design. To maximize current-handling capability and thermal stability of the device, take care with PCB layout and construction to optimize the thermal capability. Efforts to improve the thermal performance beyond the design and construction of the TMCS1170EVM can result in increased continuous-current capability due to higher heat transfer to the ambient environment. Keys to improving thermal performance of the PCB include:

- Use large copper planes for both input current path and isolated power planes and signals.

- Use heavier copper PCB construction.
- Place thermal via *farms* around the isolated current input.
- Provide airflow across the surface of the PCB.

### *9.4.2 Layout Example*

An example layout, shown in Figure 9-3, is from the *TMCS1170EVM User's Guide* . Device performance is targeted for thermal and magnetic characteristics of this layout, which provides optimal current flow from the terminal connectors to the device input pins while large copper planes enhance thermal performance.

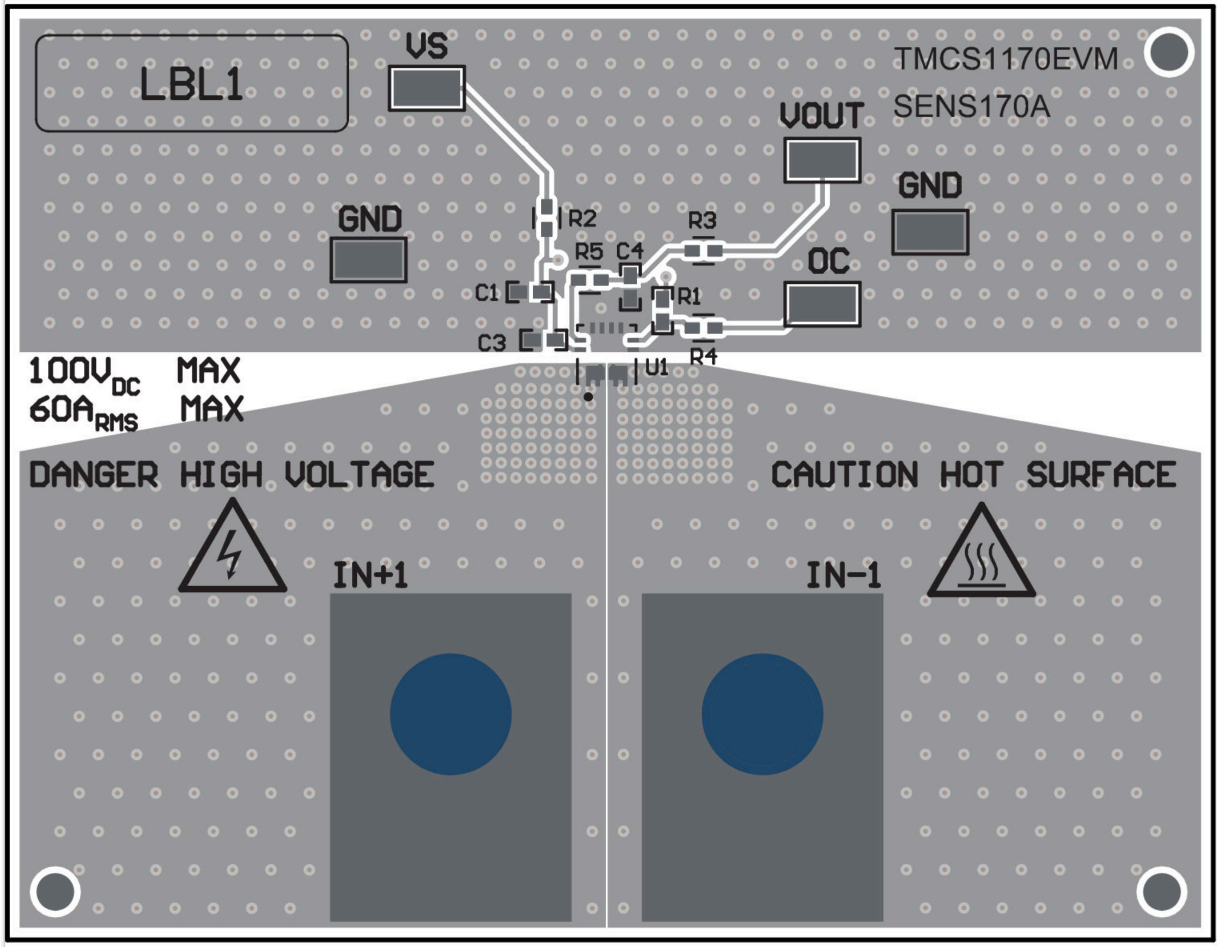


**Figure 9-3. Recommended Board Layout**

# 10 Device and Documentation Support

## 10.1 Device Support

### *10.1.1 Development Support*

For development tool support see the following:

- TMCS1170xEVM

## 10.2 Documentation Support

### *10.2.1 Related Documentation*

For related documentation see the following:

- Texas Instruments, *TMCS1170xEVM User's Guide*
- Texas Instruments, *Isolation Glossary*

## 10.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 10.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

## 10.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

## 10.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 10.7 Glossary

| | |
|---|---|
| TI Glossary | This glossary lists and explains terms, acronyms, and definitions. |

# 11 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| DATE | REVISION | NOTES |
|---|---|---|
| June 2026 | * | Initial Release |

# 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this datasheet, refer to the left-hand navigation.

# PACKAGE OPTION ADDENDUM

## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/Ball material (4) | MSL rating/Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| TMCS1170A2FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170A2 |
| TMCS1170A4FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170A4 |
| TMCS1170A6FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170A6 |
| TMCS1170A8FQVAPR | Active | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170A8 |
| TMCS1170B1FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170B1 |
| TMCS1170B3FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170B3 |
| TMCS1170B7FQVAPR | Active | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170B7 |
| TMCS1170B9FQVAPR | Active | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170B9 |
| TMCS1170C5FQVAPR | Preview | Production | VQFN-HR(VAP) \| 12 | 3000 \| Large T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | 1170C5 |

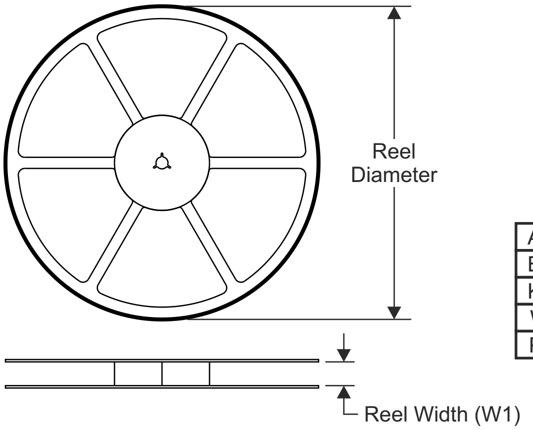
(1) **Status:** For more details on status, see our product life cycle.
(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.
(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.
(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**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.

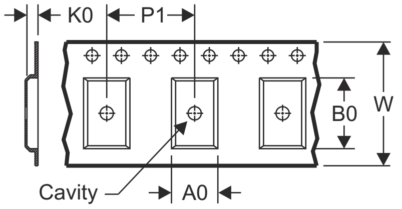
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## 12.1 Tape and Reel Information

**REEL DIMENSIONS**

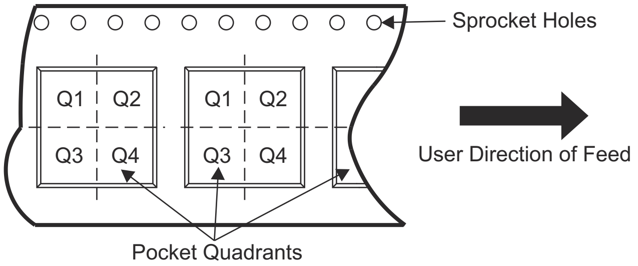


**TAPE DIMENSIONS**



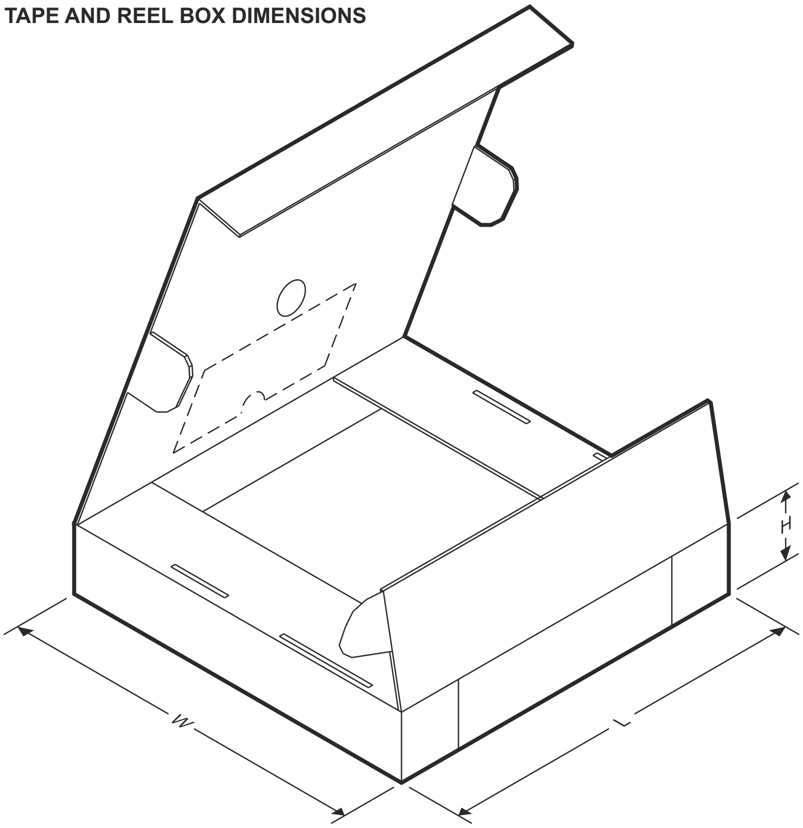
| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**



| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMCS1170A2FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170A4FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170A6FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170A8FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170B1FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170B3FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170B7FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170B9FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |
| TMCS1170C5FQVAPR | VQFN-HR | VAP | 12 | 3000 | 330 | 12.4 | 3.3 | 3.3 | 1.1 | 8 | 12 | Q2 |

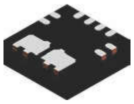
**TAPE AND REEL BOX DIMENSIONS**



| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) (1) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TMCS1170A2FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170A4FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170A6FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170A8FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170B1FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170B3FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170B7FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170B9FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |
| TMCS1170C5FQVAPR | VQFN-HR | VAP | 12 | 3000 | 367 | 367 | 35 |
| | | | | | 346 | 346 | 33 |

(1) The orderable parts come in two different box sizes.

## 12.2 Mechanical Data

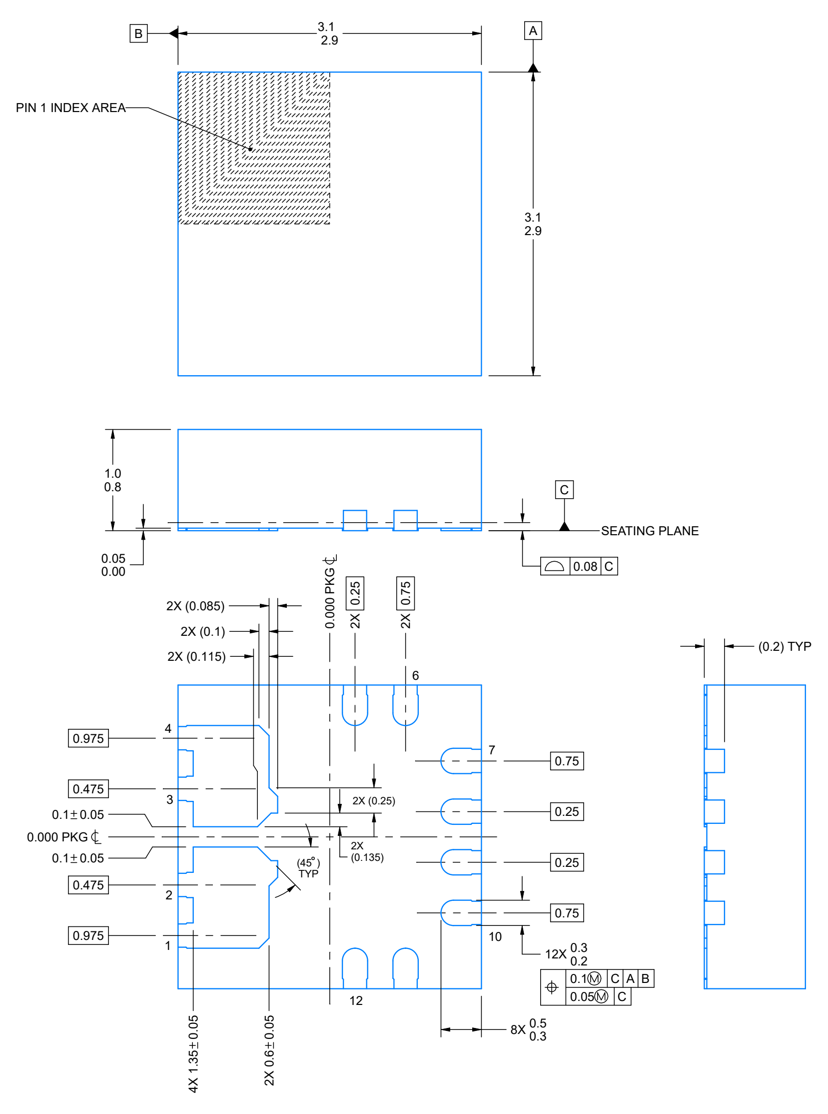


**PACKAGE OUTLINE**

**VAP0012A**

**VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



4230521/D 09/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

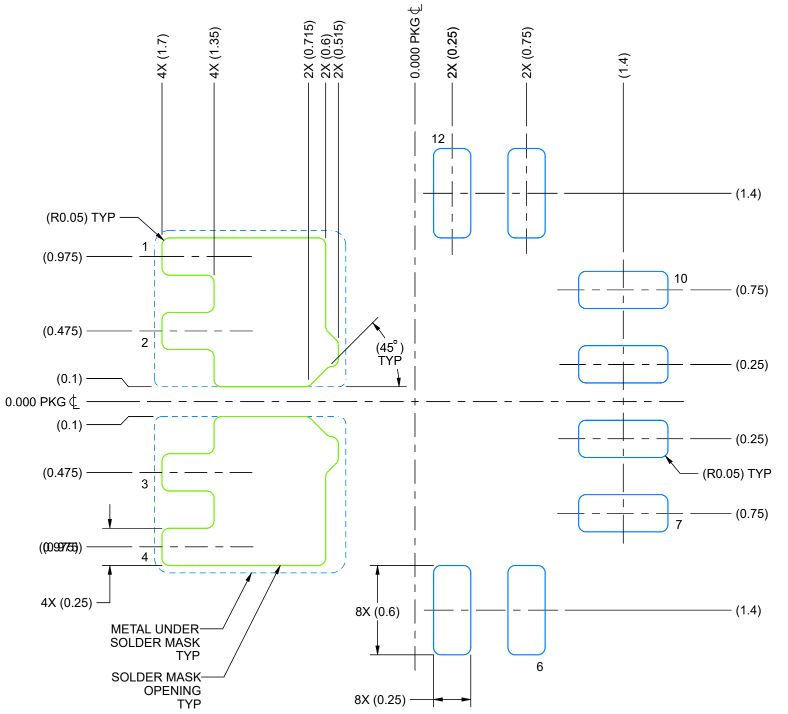
www.ti.com

# EXAMPLE BOARD LAYOUT

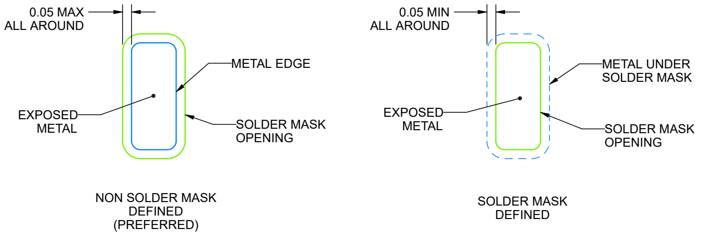
## VAP0012A

## VQFN-HR - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 25X



NON SOLDER MASK DEFINED (PREFERRED)

SOLDER MASK DEFINED

SOLDER MASK DETAILS

NOTES: (continued)

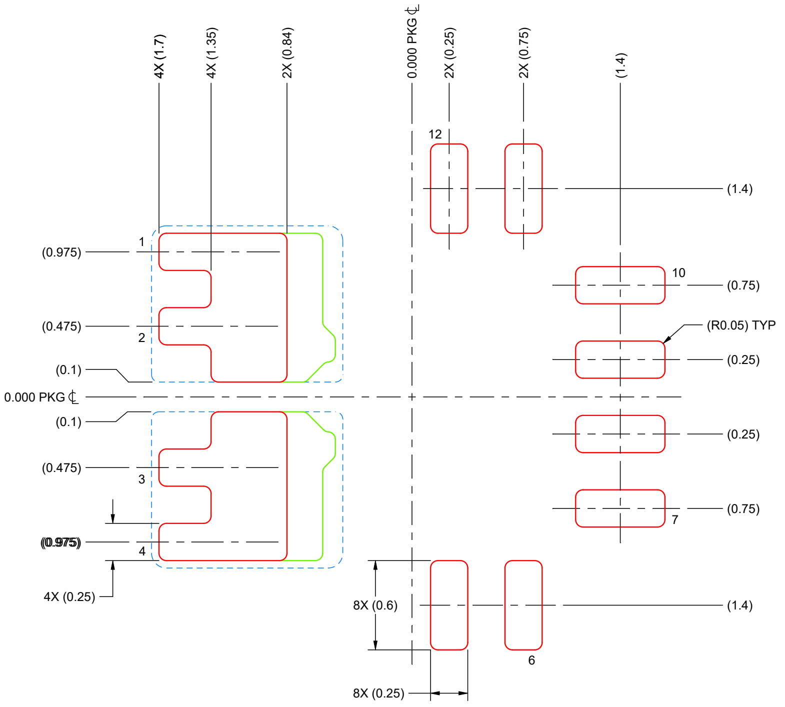
3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

www.ti.com

## EXAMPLE STENCIL DESIGN

**VAP0012A** **VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE: 25X

PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
PADS 1 & 2: 73%

4230521/D 09/2024

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

www.ti.com

# IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025