

# TPL0401x-10-Q1 128タップ・シングル・チャンネル・デジタル・ポテンシオメータ、I<sup>2</sup>Cインターフェイス付き

## 1 特長

- シングル・チャンネル、128ポジションの分解能
- エンド・ツー・エンド抵抗値10kΩのオプション
- 低温度ドリフト係数: 22ppm/°C
- I<sup>2</sup>Cシリアル・インターフェイス
- 2.7V~5.5Vの単電源で動作
- 抵抗誤差: ±20%
- AバージョンとBバージョンで異なるI<sup>2</sup>Cアドレス
- L端子を内部に備え、GNDに接続
- 動作温度範囲: -40°C~+125°C
- 業界標準のSC70パッケージで供給
- JESD 22に従ってESD性能をテスト済み
  - 人体モデルで2000V (A114-B、クラスII)

## 2 アプリケーション

- 機械式ポテンシオメータの置換
- 可変電源
- 可変ゲイン・アンプとオフセット・トリミング
- 目標スレッシュホールドの高精度な較正
- センサのトリミングと較正

## 3 概要

TPL0401x-10-Q1デバイスは、128のワイパー位置を有するシングル・チャンネル、リニア・テーパ・デジタル・ポテンシオメータです。TPL0401x-10-Q1は、“L”端子が内部にありGNDに接続されています。ワイパーの位置は、I<sup>2</sup>Cインターフェイスを使用して調整できます。TPL0401x-10-Q1は、6ピンのSC70パッケージで供給され、仕様温度範囲は-40°C~+125°Cです。デバイスのエンド・ツー・エンド抵抗値は10kΩであり、2.7V~5.5Vの電源電圧範囲で動作できます。この種の製品は、低消費電力DDR3メモリ用基準電圧の調整に広く使用されています。

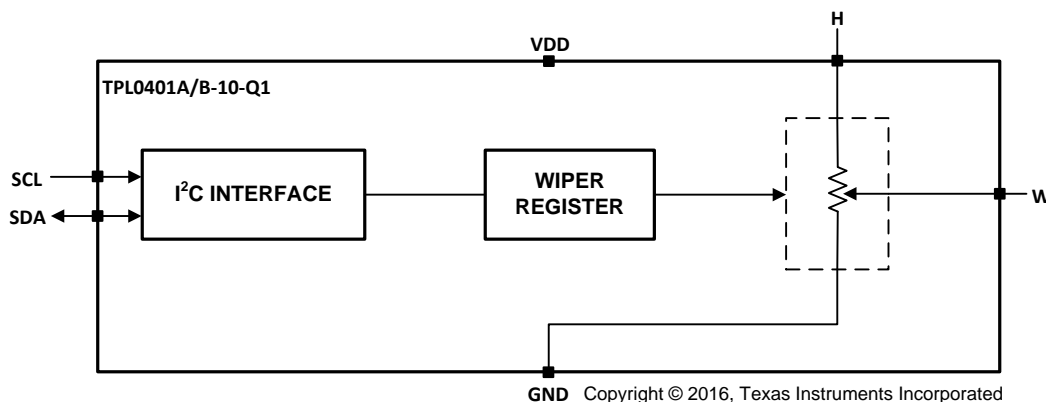
TPL0401x-10-Q1は、“L”端子が内部にありGNDに接続されています。

### 製品情報<sup>(1)</sup>

型番	パッケージ	本体サイズ(公称)
TPL0401A-10-Q1	SC70 (6)	2.00mm×1.25mm
TPL0401B-10-Q1		

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。

### 概略回路図



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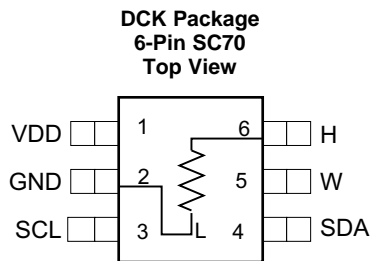
## 4 改訂履歴

日付	改訂内容	注
2016年11月	*	初版

## 5 Device Comparison Table

PART NUMBER	END-TO-END RESISTANCE	I <sup>2</sup> C ADDRESS
TPL0401A-10-Q1	10 kΩ	010 1110 (0x2E)
TPL0401B-10-Q1	10 kΩ	011 1110 (0x3E)

## 6 Pin Configuration and Functions



### Pin Functions

PIN		TYPE	DESCRIPTION
NO.	NAME		
1	VDD	Power	Positive supply voltage
2	GND	—	Ground
3	SCL	I	I <sup>2</sup> C Clock
4	SDA	I/O	I <sup>2</sup> C Data
5	W	I/O	Wiper terminal
6	H	I/O	High terminal
—	L	I/O	Low terminal (Internally connected to GND)

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT	
V <sub>DD</sub>	Supply voltage	V <sub>DD</sub> to GND	-0.3	7	V
I <sub>H</sub> , I <sub>L</sub> , I <sub>W</sub>	Continuous current		±5		mA
V <sub>I</sub>	Digital input pins (SDA, SCL)		-0.3	V <sub>DD</sub> + 0.3	V
	Potentiometer pins (H, W)		-0.3	V <sub>DD</sub> + 0.3	
T <sub>J(MAX)</sub>	Maximum junction temperature		130		°C
T <sub>stg</sub>	Storage temperature		-65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 7.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup>	±2500
		Charged-device model (CDM), per AEC Q100-011	±1000

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V <sub>DD</sub>	Supply voltage	2.7	5.5	V
V <sub>W</sub> , V <sub>H</sub> , SDA, SCL	Terminal voltage	0	V <sub>DD</sub>	V
V <sub>IH</sub>	Voltage input high ( SCL, SDA )	0.7 × V <sub>DD</sub>	V <sub>DD</sub>	V
V <sub>IL</sub>	Voltage input low ( SCL, SDA )	0	0.3 × V <sub>DD</sub>	V
I <sub>W</sub>	Wiper current	-2	2	mA
T <sub>A</sub>	Ambient operating temperature	-40	125	°C

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>	TPL0401x-10-Q1	UNIT	
	DCK (SC70)		
	6 PINS		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	234	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	110.5	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	79	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	7.2	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	77	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

### 7.5 Electrical Characteristics

Typical values are specified at 25°C and V<sub>DD</sub> = 3.3 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
R <sub>TOTAL</sub>	End-to-end resistance	8	10	12	kΩ
R <sub>H</sub>	Terminal resistance		100	200	Ω
R <sub>W</sub>	Wiper resistance		35	100	Ω

## Electrical Characteristics (continued)

Typical values are specified at 25°C and  $V_{DD} = 3.3\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$C_H$	Terminal capacitance			10		pF
$C_W$	Wiper capacitance			11		pF
$TC_R$	Resistance temperature coefficient			22		ppm/°C
$I_{DD(STBY)}$	$V_{DD}$ standby current	-40°C to +105°C			0.5	μA
		-40°C to +125°C			1.5	
$I_{IN-DIG}$	Digital pins leakage current (SCL, SDA Inputs)		-2.5		2.5	μA
<b>SERIAL INTERFACE SPECS (SDA, SCL)</b>						
$V_{IH}$	Input high voltage		$0.7 \times V_{DD}$		$V_{DD}$	V
$V_{IL}$	Input low voltage		0		$0.3 \times V_{DD}$	V
$V_{OL}$	Output low voltage	SDA Pin, $I_{OL} = 4\text{ mA}$			0.4	V
$C_{IN}$	Pin capacitance	SCL, SDA Inputs		7		pF
<b>VOLTAGE DIVIDER MODE (<math>V_H = V_{DD}</math>, <math>V_W = \text{Not Loaded}</math>)</b>						
$INL^{(1)(2)}$	Integral non-linearity		-0.5		0.5	LSB
$DNL^{(3)(2)}$	Differential non-linearity		-0.25		0.25	LSB
$ZS_{ERROR}^{(4)(5)}$	Zero-scale error		0	0.75	1.5	LSB
$FS_{ERROR}^{(6)(5)}$	Full-scale error		-1.5	-0.75	0	LSB
$TC_V$	Ratiometric temperature coefficient	Wiper set at mid-scale		4		ppm/°C
BW	Bandwidth	Wiper set at mid-scale, $C_{LOAD} = 10\text{ pF}$		2862		kHz
$T_{SW}$	Wiper settling time	See <a href="#">Figure 10</a>		0.152		μs
THD+N	Total harmonic distortion	$V_H = 1\text{ V}_{RMS}$ at 1 kHz, measurement at W		0.03		%
<b>RHEOSTAT MODE (<math>V_H = V_{DD}</math>, <math>V_W = \text{Not Loaded}</math>)</b>						
$RINL^{(7)(8)}$	Rheostat mode integral non-linearity		-1		1	LSB
$RDNL^{(9)(8)}$	Rheostat mode differential non-linearity		0.5		0.5	LSB
$R_{OFFSET}^{(10)(11)}$	Rheostat-mode zero-scale error		0	0.75	2	LSB

(1)  $INL = ((V_{MEAS[code\ x]} - V_{MEAS[code\ 0]}) / LSB) - [code\ x]$

(2)  $LSB = (V_{MEAS[code\ 127]} - V_{MEAS[code\ 0]}) / 127$

(3)  $DNL = ((V_{MEAS[code\ x]} - V_{MEAS[code\ x-1]}) / LSB) - 1$

(4)  $ZS_{ERROR} = V_{MEAS[code\ 0]} / IDEAL\_LSB$

(5)  $IDEAL\_LSB = V_H / 128$

(6)  $FS_{ERROR} = ((V_{MEAS[code\ 127]} - V_H) / IDEAL\_LSB) + 1$

(7)  $RINL = ((R_{MEAS[code\ x]} - R_{MEAS[code\ 0]}) / RLSB) - [code\ x]$

(8)  $RLSB = (R_{MEAS[code\ 127]} - R_{MEAS[code\ 0]}) / 127$

(9)  $RDNL = ((R_{MEAS[code\ x]} - R_{MEAS[code\ x-1]}) / RLSB) - 1$

(10)  $R_{OFFSET} = R_{MEAS[code\ 0]} / IDEAL\_RLSB$

(11)  $IDEAL\_RLSB = R_{TOT} / 128$

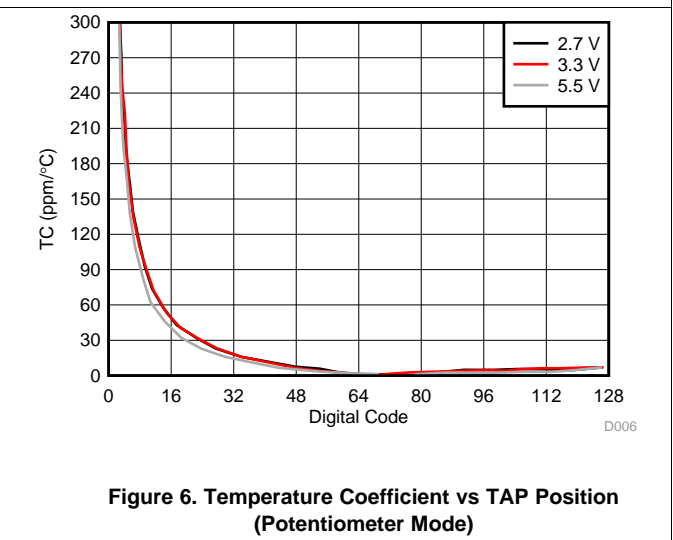
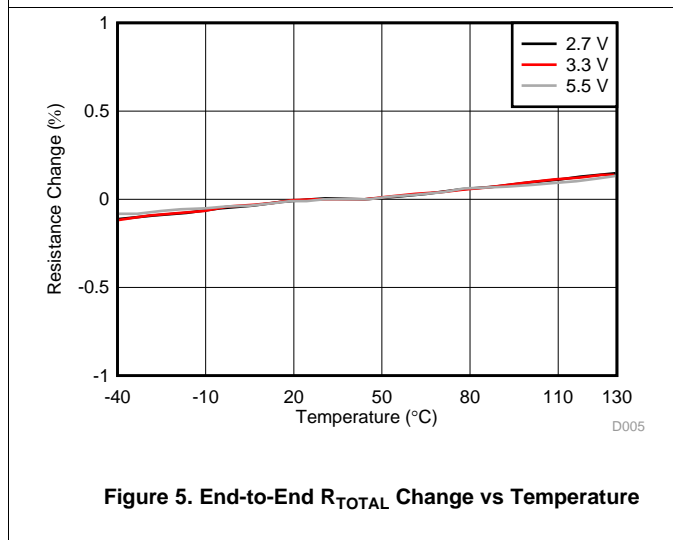
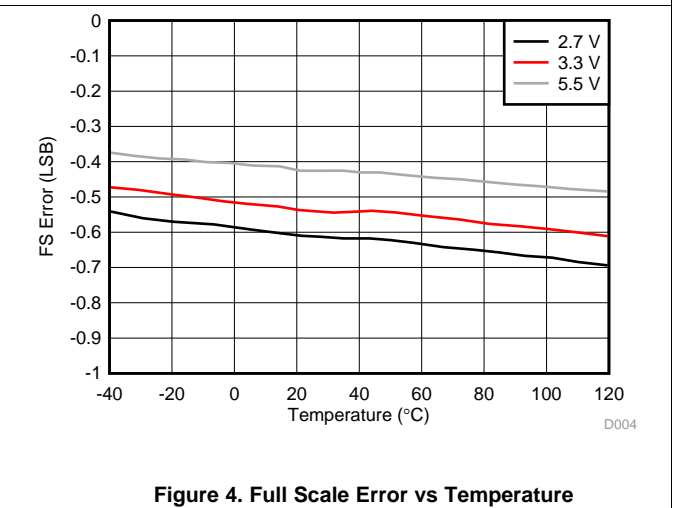
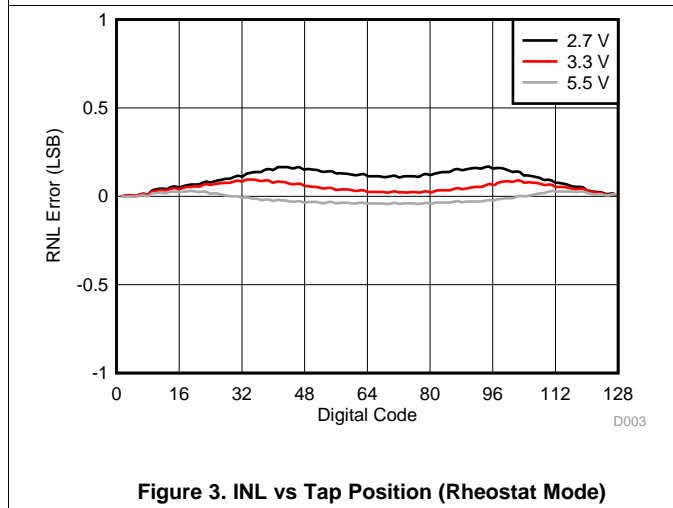
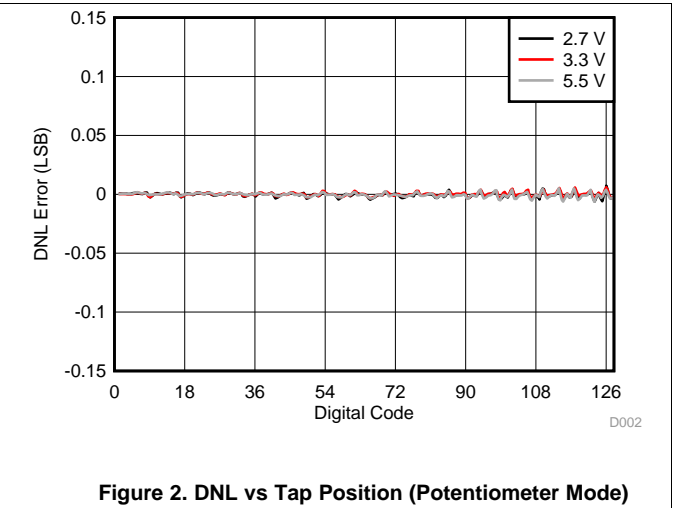
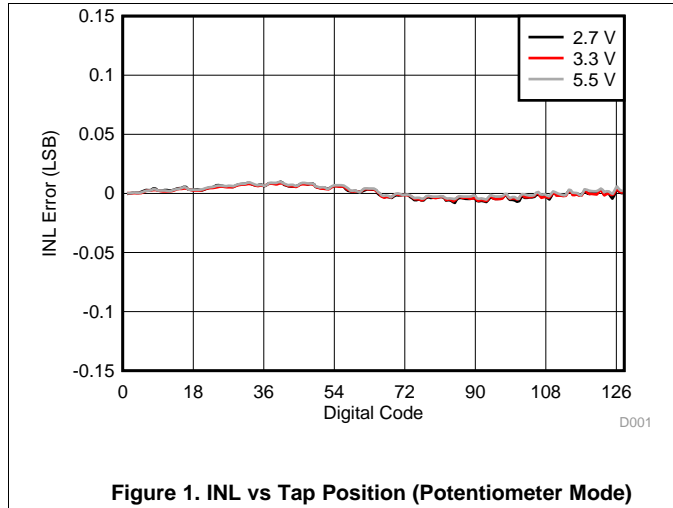
## 7.6 Timing Requirements

		MIN	MAX	UNIT
<b>STANDARD MODE</b>				
$f_{SCL}$	I <sup>2</sup> C Clock frequency	0	100	kHz
$t_{SCH}$	I <sup>2</sup> C Clock high time	4		μs
$t_{SCL}$	I <sup>2</sup> C Clock low time	4.7		μs
$t_{sp}$	I <sup>2</sup> C Spike time	0	50	ns
$t_{SDS}$	I <sup>2</sup> C Serial data setup time	250		ns

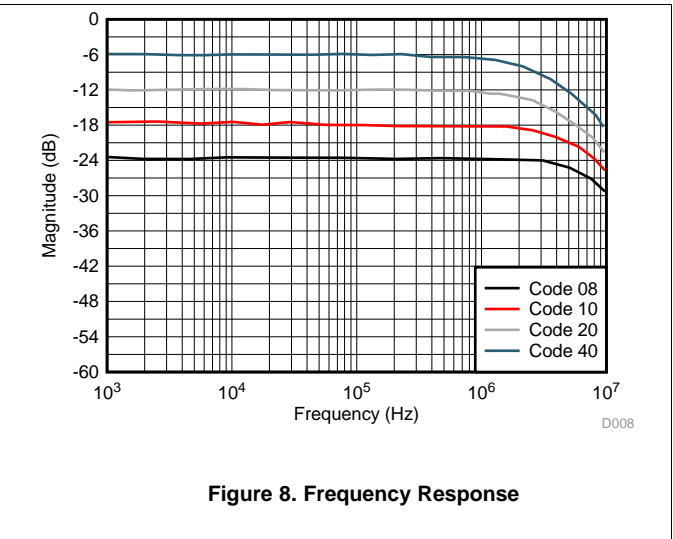
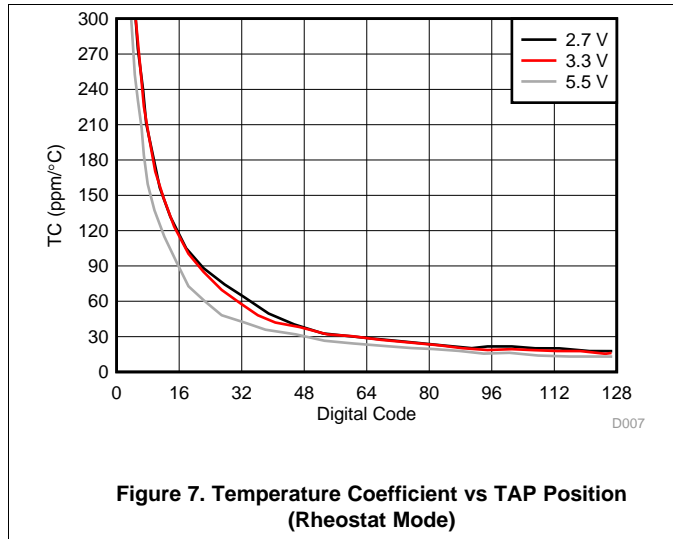
### Timing Requirements (continued)

		MIN	MAX	UNIT
$t_{SDH}$	I <sup>2</sup> C Serial data hold time	0		ns
$t_{ICR}$	I <sup>2</sup> C Input rise time		1000	ns
$t_{ICF}$	I <sup>2</sup> C Input fall time		300	ns
$t_{OCF}$	I <sup>2</sup> C Output fall time, 10 pF to 400 pF bus		300	ns
$t_{BUF}$	I <sup>2</sup> C Bus free time between stop and start	4.7		μs
$t_{STS}$	I <sup>2</sup> C Start or repeater start condition setup time	4.7		μs
$t_{STH}$	I <sup>2</sup> C Start or repeater start condition hold time	4		μs
$t_{SPS}$	I <sup>2</sup> C Stop condition setup time	4		μs
$t_{VD(DATA)}$	Valid data time, SCL low to SDA output valid		1	μs
$t_{VD(ACK)}$	Valid data time of ACK condition, ACK signal from SCL low to SDA (out) low		1	μs
<b>FAST MODE</b>				
$f_{SCL}$	I <sup>2</sup> C Clock frequency	0	400	kHz
$t_{SCH}$	I <sup>2</sup> C Clock high time	0.6		μs
$t_{SCL}$	I <sup>2</sup> C Clock low time	1.3		μs
$t_{sp}$	I <sup>2</sup> C Spike time	0	50	ns
$t_{SDS}$	I <sup>2</sup> C Serial data setup time	100		ns
$t_{SDH}$	I <sup>2</sup> C Serial data hold time	0		ns
$t_{ICR}$	I <sup>2</sup> C Input rise time	20	300	ns
$t_{ICF}$	I <sup>2</sup> C Input fall time	$20 \times (V_{DD} / 5.5)$	300	ns
$t_{OCF}$	I <sup>2</sup> C Output fall time, 10 pF to 400 pF bus	$(V_{DD} / 5.5) \times 20$	300	ns
$t_{BUF}$	I <sup>2</sup> C Bus free time between stop and start	1.3		μs
$t_{STS}$	I <sup>2</sup> C Start or repeater start condition setup time	1.3		μs
$t_{STH}$	I <sup>2</sup> C Start or repeater start condition hold time	0.6		μs
$t_{SPS}$	I <sup>2</sup> C Stop condition setup time	0.6		μs
$t_{VD(DATA)}$	Valid data time, SCL low to SDA output valid		1	μs
$t_{VD(ACK)}$	Valid data time of ACK condition, ACK signal from SCL low to SDA (out) low		1	μs

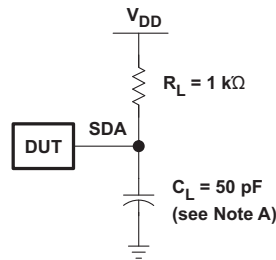
### 7.7 Typical Characteristics



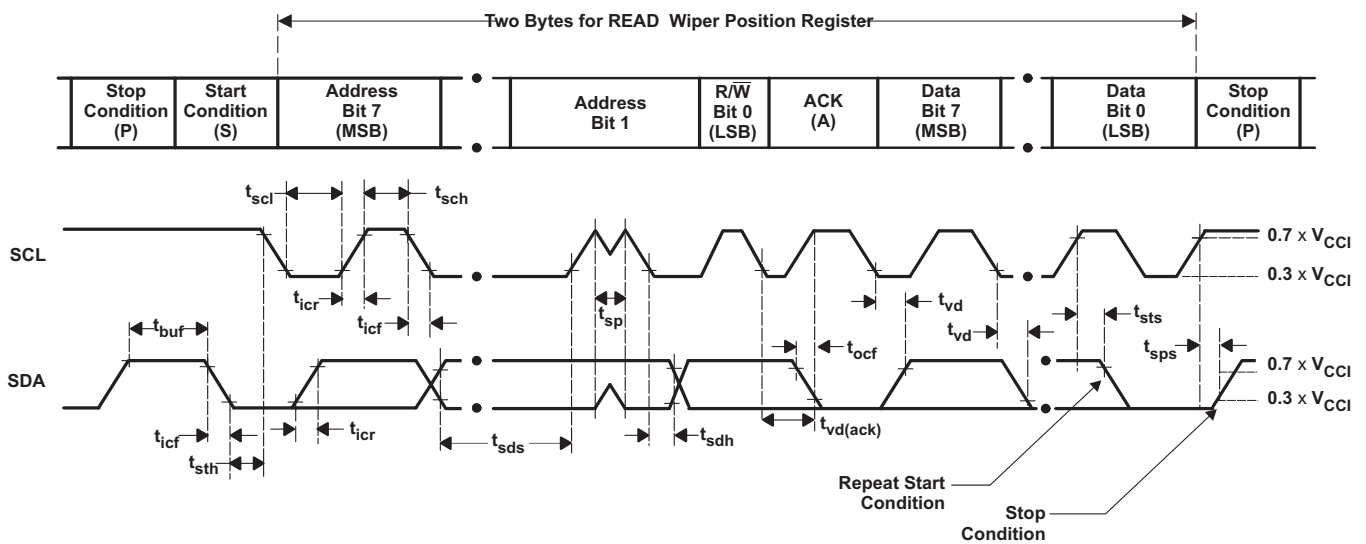
### Typical Characteristics (continued)



## 8 Parameter Measurement Information



SDA LOAD CONFIGURATION



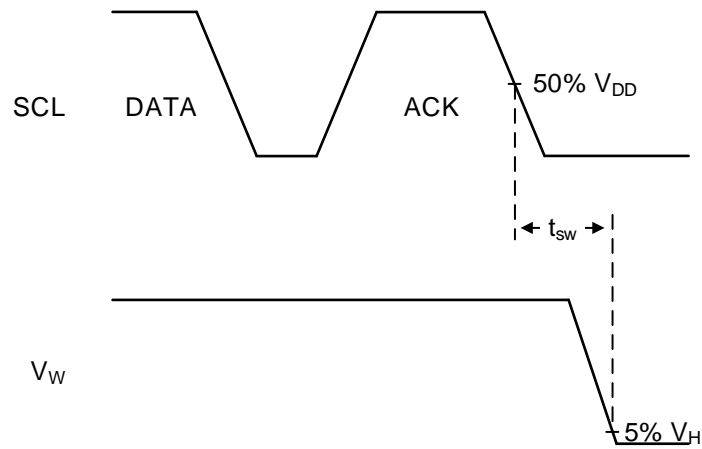
VOLTAGE WAVEFORMS

BYTE	DESCRIPTION
1	I <sup>2</sup> C address
2	Wiper Position Data

- A.  $C_L$  includes probe and jig capacitance.  $t_{ocf}$  is measured with  $C_L$  of 10 pF or 400 pF.
- B. All inputs are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.
- C. All parameters and waveforms are not applicable to all devices.

Figure 9. I<sup>2</sup>C Interface Load Circuit and Voltage Waveforms

### Parameter Measurement Information (continued)



- A. Code change is from 0x40 to 0x00
- B. All inputs are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.

**Figure 10. Switch Time Waveform ( $t_{sw}$ )**

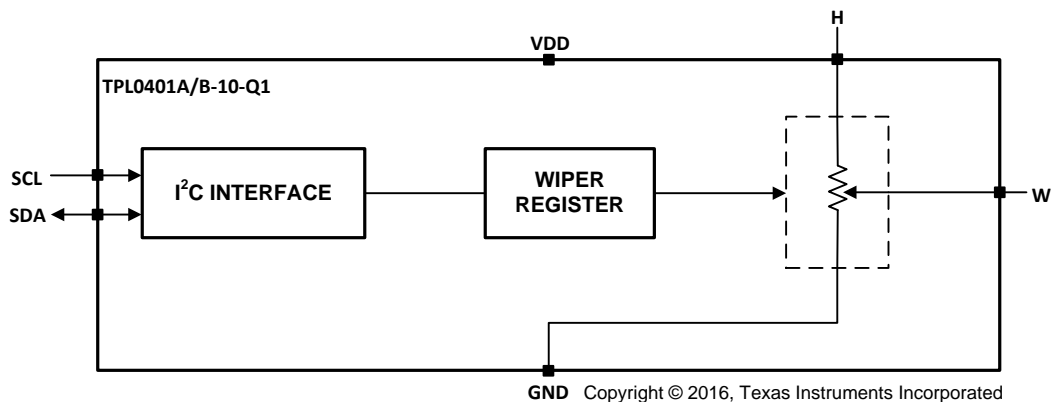
## 9 Detailed Description

### 9.1 Overview

The TPL0401x-10-Q1 has a single linear-taper digital potentiometer with 128 wiper positions and an end-to-end resistance of 10 k $\Omega$ . The potentiometer can be used as a three-terminal potentiometer. The main operation of TPL0401x-10-Q1 is in voltage divider mode.

The low (L) terminal of the TPL0401x-10-Q1 is tied directly to GND. The high (H) and low (GND) terminals of TPL0401-10-Q1 are equivalent to the fixed terminals of a mechanical potentiometer. The H terminal must have a higher voltage than the low terminal (GND). The position of the wiper (W) terminal is controlled by the value in the Wiper Resistance (WR) 8-bit register. When the WR register contains all zeroes (zero-scale), the wiper terminal is closest to its L terminal. As the value of the WR register increases from all zeroes to all ones (full-scale), the wiper moves from the position closest to the GND terminal to the position closest to the H terminal. At the same time, the resistance between W and GND increases, whereas the resistance between W and H decreases.

### 9.2 Functional Block Diagram



### 9.3 Feature Description

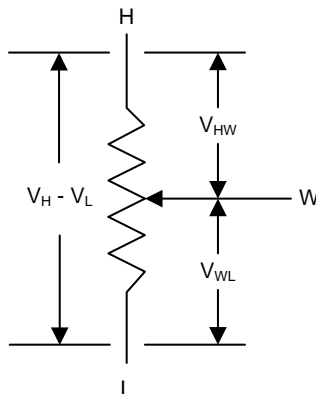
The TPL0401x-10-Q1 device is a single-channel, linear taper digital potentiometer with 128 wiper positions. Default power up state for the TPL0401x-10-Q1 is mid code (0x40). The TPL0401x-10-Q1 has the low terminal connected to GND internally. The position of the wiper can be adjusted using an I<sup>2</sup>C interface. The TPL0401x-10-Q1 is available in a 6-pin SOT package with a specified temperature range of –40°C to +125°C. The part has a 10-k $\Omega$  end-to-end resistance and can operate with a supply voltage range of 2.7 V to 5.5 V. This kind of product is widely used in setting the voltage reference for low power DDR3 memory. The TPL0401x-10-Q1 has the low terminal internal and connected to GND.

### 9.4 Device Functional Modes

#### 9.4.1 Voltage Divider Mode

The digital potentiometer generates a voltage divider when all three terminals are used. The voltage divider at wiper-to-H and wiper-to-GND is proportional to the input voltage at H to L (see [Figure 11](#)).

## Device Functional Modes (continued)



**Figure 11. Equivalent Circuit for Voltage Divider Mode**

For example, connecting terminal H to 5 V, the output voltage at terminal W can range from 0 V to 5 V. [Equation 1](#) is the general equation defining the output voltage at terminal W for any valid input voltage applied to terminal H and terminal L (GND).

$$V_W = V_{WL} = (V_H - V_L) \times \frac{D}{128} \quad (1)$$

The voltage difference between terminal H and terminal W can also be calculated in [Equation 2](#).

$$V_{HW} = (V_H - V_L) \times \left( 1 - \left( \frac{D}{128} \right) \right)$$

where

- D is the decimal value of the wiper code (2)

[Table 1](#) shows the ideal values for DPOT with end-to end resistance of 10 kΩ. The absolute values of resistance can vary significantly but the Ratio ( $R_{WL}/R_{TOT}$ ) is extremely accurate.

The linearity values are *relative* linearity values (that is, linearity after zero-scale and full-scale offset errors are removed). Consider this when expecting a certain absolute accuracy because some error is introduced when the device gets close in magnitude to the offset errors.

Note that the MSB is always discarded during a write to the wiper position register. For example, if 0x80 is written to the wiper position register, a read returns 0x00. Another similar example is if 0xFF is written, then 0x7F is read.

**Table 1. Resistance Values Table**

STEP	HEX	R <sub>WL</sub> (KΩ)	R <sub>HW</sub> (KΩ)	R <sub>WL</sub> /R <sub>TOT</sub>
0	0x00	0.00	10.00	0.0%
1	0x01	0.08	9.92	0.8%
2	0x02	0.16	9.84	1.6%
3	0x03	0.23	9.77	2.3%
4	0x04	0.31	9.69	3.1%
5	0x05	0.39	9.61	3.9%
6	0x06	0.47	9.53	4.7%
7	0x07	0.55	9.45	5.5%
8	0x08	0.63	9.38	6.3%
9	0x09	0.70	9.30	7.0%
10	0x0A	0.78	9.22	7.8%

**Table 1. Resistance Values Table (continued)**

STEP	HEX	R <sub>WL</sub> (KΩ)	R <sub>HW</sub> (KΩ)	R <sub>WL</sub> /R <sub>TOT</sub>
11	0x0B	0.86	9.14	8.6%
12	0x0C	0.94	9.06	9.4%
13	0x0D	1.02	8.98	10.2%
14	0x0E	1.09	8.91	10.9%
15	0x0F	1.17	8.83	11.7%
16	0x10	1.25	8.75	12.5%
17	0x11	1.33	8.67	13.3%
18	0x12	1.41	8.59	14.1%
19	0x13	1.48	8.52	14.8%
20	0x14	1.56	8.44	15.6%
21	0x15	1.64	8.36	16.4%
22	0x16	1.72	8.28	17.2%
23	0x17	1.80	8.20	18.0%
24	0x18	1.88	8.13	18.8%
25	0x19	1.95	8.05	19.5%
26	0x1A	2.03	7.97	20.3%
27	0x1B	2.11	7.89	21.1%
28	0x1C	2.19	7.81	21.9%
29	0x1D	2.27	7.73	22.7%
30	0x1E	2.34	7.66	23.4%
31	0x1F	2.42	7.58	24.2%
32	0x20	2.50	7.50	25.0%
33	0x21	2.58	7.42	25.8%
34	0x22	2.66	7.34	26.6%
35	0x23	2.73	7.27	27.3%
36	0x24	2.81	7.19	28.1%
37	0x25	2.89	7.11	28.9%
38	0x26	2.97	7.03	29.7%
39	0x27	3.05	6.95	30.5%
40	0x28	3.13	6.88	31.3%
41	0x29	3.20	6.80	32.0%
42	0x2A	3.28	6.72	32.8%
43	0x2B	3.36	6.64	33.6%
44	0x2C	3.44	6.56	34.4%
45	0x2D	3.52	6.48	35.2%
46	0x2E	3.59	6.41	35.9%
47	0x2F	3.67	6.33	36.7%
48	0x30	3.75	6.25	37.5%
49	0x31	3.83	6.17	38.3%
50	0x32	3.91	6.09	39.1%
51	0x33	3.98	6.02	39.8%
52	0x34	4.06	5.94	40.6%
53	0x35	4.14	5.86	41.4%
54	0x36	4.22	5.78	42.2%
55	0x37	4.30	5.70	43.0%
56	0x38	4.38	5.63	43.8%
57	0x39	4.45	5.55	44.5%

**Table 1. Resistance Values Table (continued)**

STEP	HEX	R <sub>WL</sub> (KΩ)	R <sub>HW</sub> (KΩ)	R <sub>WL</sub> /R <sub>TOT</sub>
58	0x3A	4.53	5.47	45.3%
59	0x3B	4.61	5.39	46.1%
60	0x3C	4.69	5.31	46.9%
61	0x3D	4.77	5.23	47.7%
62	0x3E	4.84	5.16	48.4%
63	0x3F	4.92	5.08	49.2%
64 (POR Default)	0x40	5.00	5.00	50.0%
65	0x41	5.08	4.92	50.8%
66	0x42	5.16	4.84	51.6%
67	0x43	5.23	4.77	52.3%
68	0x44	5.31	4.69	53.1%
69	0x45	5.39	4.61	53.9%
70	0x46	5.47	4.53	54.7%
71	0x47	5.55	4.45	55.5%
72	0x48	5.63	4.38	56.3%
73	0x49	5.70	4.30	57.0%
74	0x4A	5.78	4.22	57.8%
75	0x4B	5.86	4.14	58.6%
76	0x4C	5.94	4.06	59.4%
77	0x4D	6.02	3.98	60.2%
78	0x4E	6.09	3.91	60.9%
79	0x4F	6.17	3.83	61.7%
80	0x50	6.25	3.75	62.5%
81	0x51	6.33	3.67	63.3%
82	0x52	6.41	3.59	64.1%
83	0x53	6.48	3.52	64.8%
84	0x54	6.56	3.44	65.6%
85	0x55	6.64	3.36	66.4%
86	0x56	6.72	3.28	67.2%
87	0x57	6.80	3.20	68.0%
88	0x58	6.88	3.13	68.8%
89	0x59	6.95	3.05	69.5%
90	0x5A	7.03	2.97	70.3%
91	0x5B	7.11	2.89	71.1%
92	0x5C	7.19	2.81	71.9%
93	0x5D	7.27	2.73	72.7%
94	0x5E	7.34	2.66	73.4%
95	0x5F	7.42	2.58	74.2%
96	0x60	7.50	2.50	75.0%
97	0x61	7.58	2.42	75.8%
98	0x62	7.66	2.34	76.6%
99	0x63	7.73	2.27	77.3%
100	0x64	7.81	2.19	78.1%
101	0x65	7.89	2.11	78.9%
102	0x66	7.97	2.03	79.7%
103	0x67	8.05	1.95	80.5%
104	0x68	8.13	1.88	81.3%

Table 1. Resistance Values Table (continued)

STEP	HEX	R <sub>WL</sub> (KΩ)	R <sub>HW</sub> (KΩ)	R <sub>WL</sub> /R <sub>TOT</sub>
105	0x69	8.20	1.80	82.0%
106	0x6A	8.28	1.72	82.8%
107	0x6B	8.36	1.64	83.6%
108	0x6C	8.44	1.56	84.4%
109	0x6D	8.52	1.48	85.2%
110	0x6E	8.59	1.41	85.9%
111	0x6F	8.67	1.33	86.7%
112	0x70	8.75	1.25	87.5%
113	0x71	8.83	1.17	88.3%
114	0x72	8.91	1.09	89.1%
115	0x73	8.98	1.02	89.8%
116	0x74	9.06	0.94	90.6%
117	0x75	9.14	0.86	91.4%
118	0x76	9.22	0.78	92.2%
119	0x77	9.30	0.70	93.0%
120	0x78	9.38	0.63	93.8%
121	0x79	9.45	0.55	94.5%
122	0x7A	9.53	0.47	95.3%
123	0x7B	9.61	0.39	96.1%
124	0x7C	9.69	0.31	96.9%
125	0x7D	9.77	0.23	97.7%
126	0x7E	9.84	0.16	98.4%
127	0x7F	9.92	0.08	99.2%

## 9.5 Programming

### 9.5.1 I<sup>2</sup>C General Operation and Overview

#### 9.5.1.1 START and STOP Conditions

I<sup>2</sup>C communication with this device is initiated by the master sending a START condition and terminated by the master sending a STOP condition. A high-to-low transition on the SDA line while the SCL is high defines a START condition. A low-to-high transition on the SDA line while the SCL is high defines a STOP condition. See Figure 12.

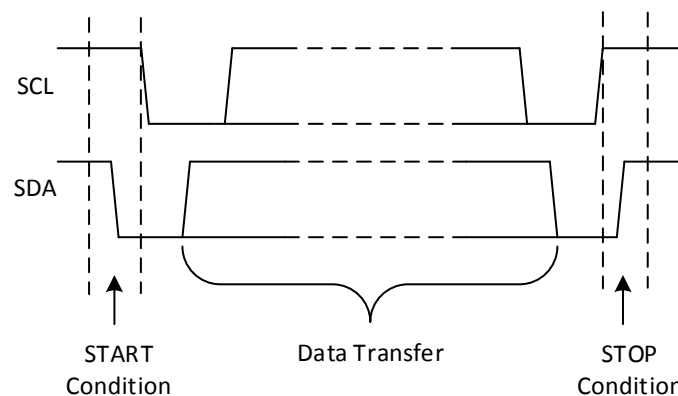


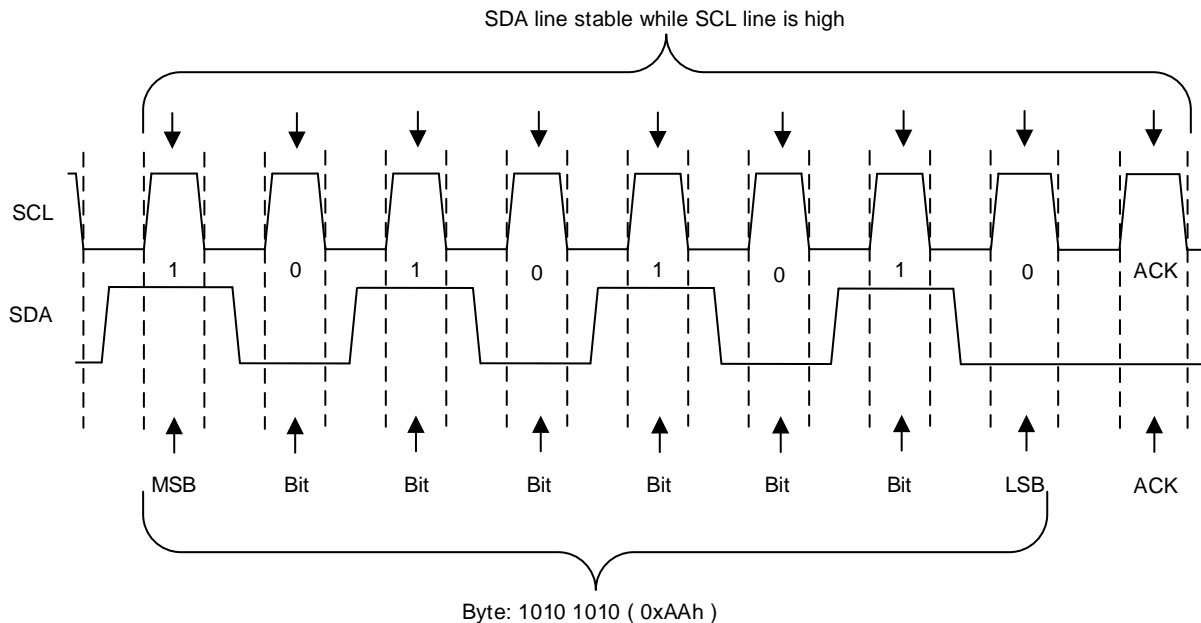
Figure 12. Definition of START and STOP Conditions

## Programming (continued)

### 9.5.1.2 Data Validity and Byte Formation

One data bit is transferred during each clock pulse of the SCL. One byte is comprised of eight bits on the SDA line. See [Figure 13](#). A byte may either be a device address, register address, or data written to or read from a slave.

Data is transferred Most Significant Bit (MSB) first. Any number of data bytes can be transferred from the master to slave between the START and STOP conditions. Data on the SDA line must remain stable during the high phase of the clock period, as changes in the data line when the SCL is high are interpreted as control commands (START or STOP).



**Figure 13. Definition of Byte Formation**

### 9.5.1.3 Acknowledge (ACK) and Not Acknowledge (NACK)

Each byte is followed by one ACK bit from the receiver. The ACK bit allows the receiver to communicate to the transmitter that the byte was successfully received and another byte may be sent.

The transmitter must release the SDA line before the receiver can send the ACK bit. To send an ACK bit, the receiver shall pull down the SDA line during the low phase of the ACK/NACK-related clock period (period 9), so that the SDA line is stable low during the high phase of the ACK/NACK-related clock period. Consider setup and hold times. [Figure 14](#) shows an example use of ACK.

Programming (continued)

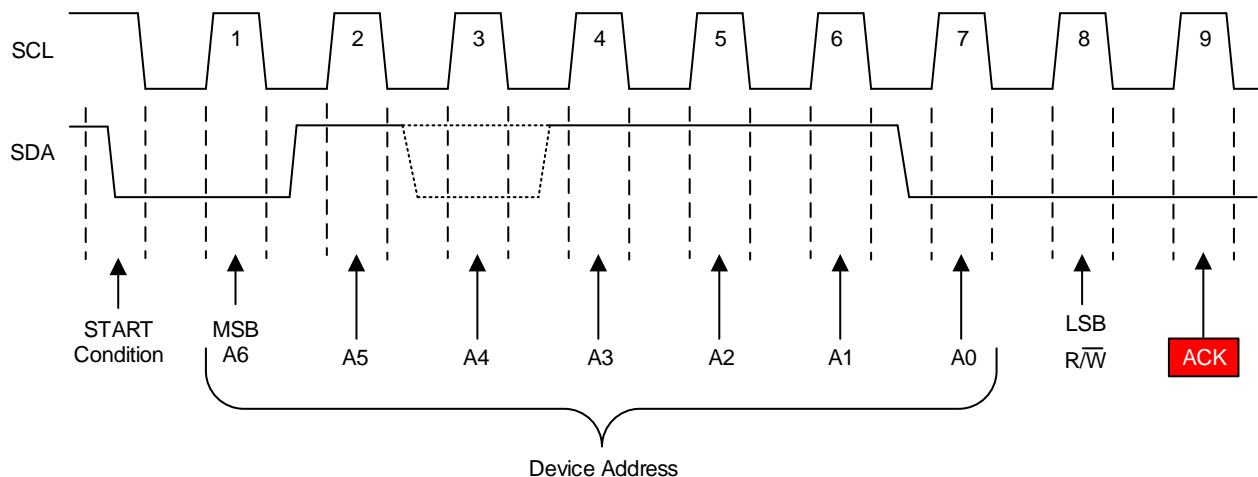


Figure 14. Example Use of ACK

When the SDA line remains high during the ACK/NACK-related clock period, this is a NACK signal. There are several conditions that lead to the generation of a NACK:

- The receiver is unable to receive or transmit because it is performing some real-time function and is not ready to start communication with the master.
- During the transfer, the receiver gets data or commands that it does not understand.
- During the transfer, the receiver cannot receive any more data bytes.
- A master-receiver is done reading data and indicates this to the slave through a NACK.

Figure 15 shows an example use of NACK.

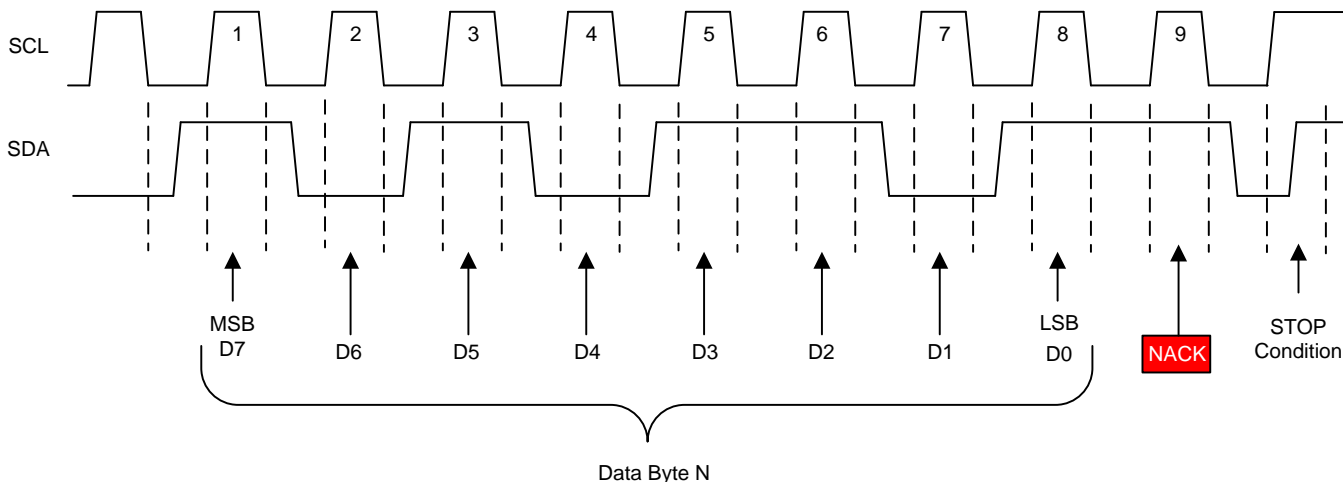


Figure 15. Example Use of NACK

9.5.1.4 Repeated Start

A repeated START condition may be used in place of a complete STOP condition followed by another START condition when performing a read function. The advantage of this is that the I<sup>2</sup>C bus does not become available after the stop and therefore prevents other devices from grabbing the bus between transfers.

## Programming (continued)

### 9.5.2 Programming With I<sup>2</sup>C

#### 9.5.2.1 Write Operation

To write on the I<sup>2</sup>C bus, the master sends a START condition on the bus with the address of the slave, as well as the last bit (the R/W bit) set to 0, which signifies a write. After the slave responds with an acknowledge, the master then sends the register address of the register to which it wishes to write. The slave acknowledges again, letting the master know that it is ready. After this, the master starts sending the register data to the slave until the master has sent all the data necessary (which is sometimes only a single byte), and the master terminates the transmission with a STOP condition. See [Figure 16](#).

Master controls SDA line

Slave controls SDA line

#### Write to one register in a device

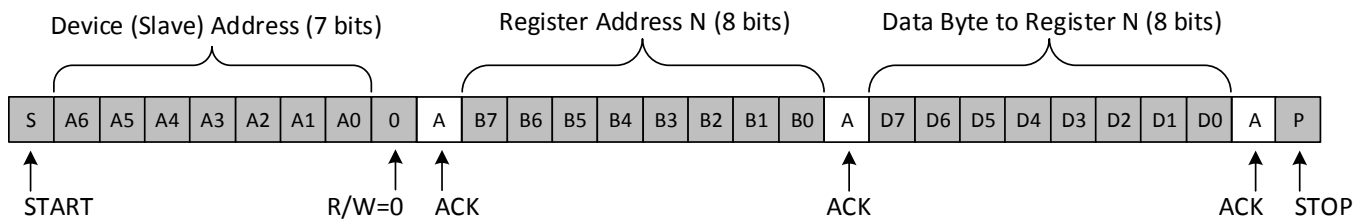


Figure 16. Write Operation

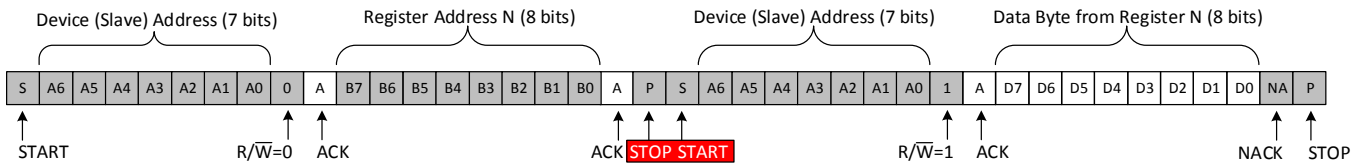
#### 9.5.2.2 Read Operation

Reading from a slave is very similar to writing, but requires some additional steps. In order to read from a slave, the master must first instruct the slave which register it wishes to read from. This is done by the master starting off the transmission in a similar fashion as the write, by sending the address with the R/W bit equal to 0 (signifying a write), followed by the register address it wishes to read from. When the slave acknowledges this register address, the master sends a START condition again, followed by the slave address with the R/W bit set to 1 (signifying a read). This time, the slave acknowledges the read request, and the master releases the SDA bus but continues supplying the clock to the slave. During this part of the transaction, the master becomes the master-receiver, and the slave becomes the slave-transmission.

The master continues to send out the clock pulses, for each byte of data that it wishes to receive. At the end of every byte of data, the master sends an ACK to the slave, letting the slave know that it is ready for more data. When the master has received the number of bytes it was expecting (or needs to stop communication), it sends a NACK, signaling to the slave to halt communications and release the bus. The master follows this up with a STOP condition. [Figure 17](#) shows the read operation from one register.

## Programming (continued)

### Read from one register in a device



### Read from one register in a device (Repeated Start)

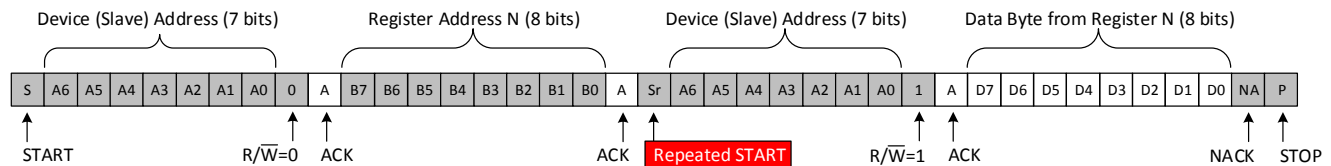


Figure 17. Read Operation from One Register

### Read from one register in a device with single register

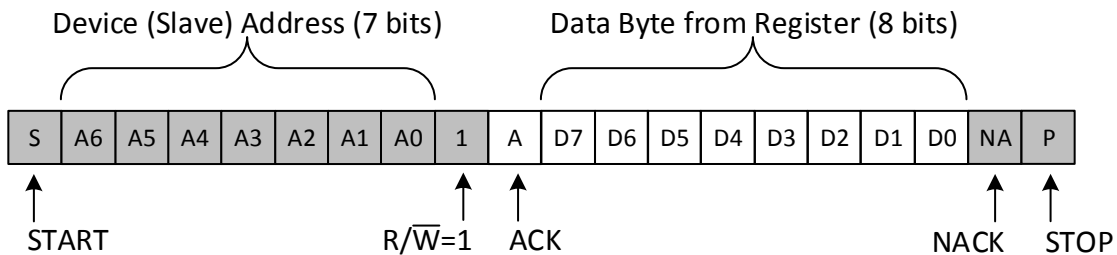


Figure 18. Short Read Operation

The TPL0401x-10-Q1 has 1 register, and it is not a requirement that the register address be sent before a read. A shorter read allows the user to simply send a read request to the device address as shown in [Figure 18](#).

## 9.6 Register Maps

### 9.6.1 Slave Address

[Table 2](#) and [Table 3](#) show the TPL0401A-10-Q1 and TPL0401B-10-Q1 bit address respectively.

Table 2. TPL0401A-10-Q1 Bit Address

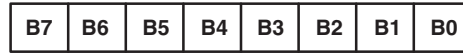
BIT 7 (MSB)	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0 (LSB)
0	1	0	1	1	1	0	R/W

Table 3. TPL0401B-10-Q1 Bit Address

BIT 7 (MSB)	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0 (LSB)
0	1	1	1	1	1	0	R/W

### 9.6.2 Register Address

Following the successful acknowledgment of the address byte, the bus master sends a command byte as shown in [Figure 19](#), which is stored in the Control Register in the TPL0401x-10-Q1. The TPL0401x-10-Q1 has only 1 register, but requires the command byte be sent during communication.



**Figure 19. Register Address Byte**

[Table 4](#) shows the TPL0401x-10-Q1 register address byte.

**Table 4. Register Address Byte**

REGISTER ADDRESS BITS								REGISTER ADDRESS (HEX)	REGISTER	PROTOCOL	POWER-UP DEFAULT
B7	B6	B5	B4	B3	B2	B1	B0				
0	0	0	0	0	0	0	0	0x00	Wiper Position	Read/Write byte	0100 0000 (0x40)

See [Table 1](#) for more information on the wiper position register values. Note that the MSB is always discarded during a write to the wiper position register. For example, if 0x80 is written to the wiper position register, a read returns 0x00. Another similar example is if 0xFF is written, then 0x7F is read.

## 10 Application and Implementation

### 10.1 Application Information

There are many applications in which voltage division is needed through the use of a digital potentiometer such as the TPL0401x-10-Q1; this is one example of the many. In conjunction with many amplifiers, the TPL0401x-10-Q1 can effectively be used in voltage divider mode to create a buffer to adjust the reference voltage for DDR3 DIMM1 Memory.

### 10.2 Typical Application

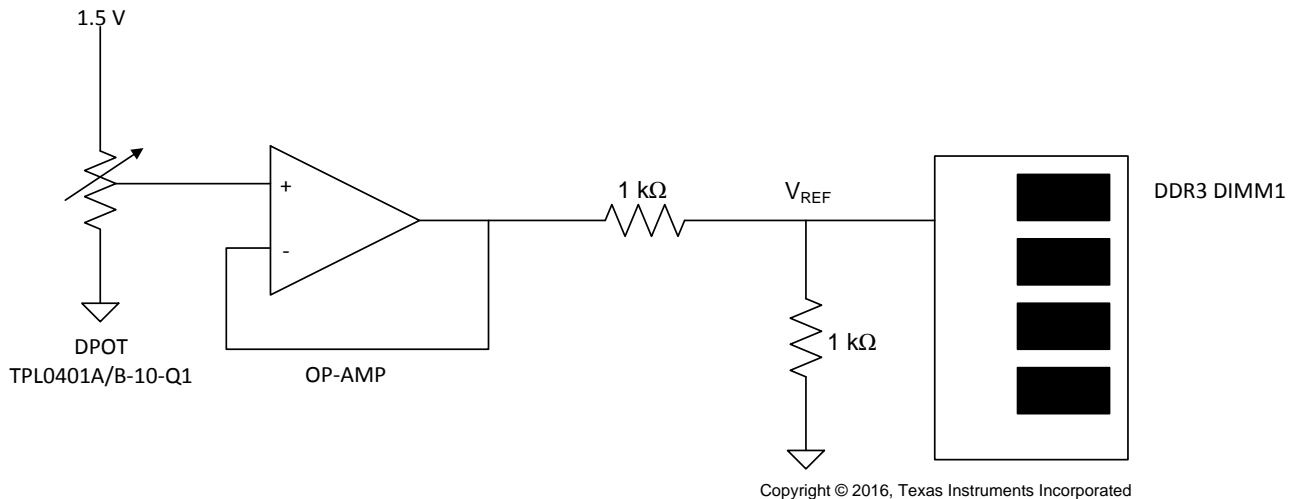


Figure 20. DDR3 Voltage Reference Adjustment

#### 10.2.1 Design Requirements

Table 5 lists the design parameters for this example.

Table 5. Design Parameters

PARAMETER	EXAMPLE VALUE
Input voltage	1.5 V
$V_{REF}$	0 V to 0.75 V

#### 10.2.2 Detailed Design Procedure

The TPL0401x-10-Q1 can be used in voltage divider mode with a unity-gain op amp buffer to provide a clean voltage reference for DDR3 DIMM1 Memory. The analog output voltage,  $V_{REF1}$  is determined by the wiper setting programmed through the I<sup>2</sup>C bus.

The op amp is required to buffer the high-impedance output of the TPL0401x-10-Q1 or else loading placed on the output of the voltage divider affects the output voltage.

### 10.2.3 Application Curve

The voltage, 1.5 V, applied to terminal H of TPL0401x-10-Q1 determines the voltage that is buffered by the unity-gain op amp and divided as the DDR3 DIMM1 voltage reference. By using the TPL0401x-10-Q1, and dividing the 1.5 V, a maximum of 0.75 V is applied to the buffer and passed to the voltage divider. The output voltage then ranges from 0 V to 0.75 V.

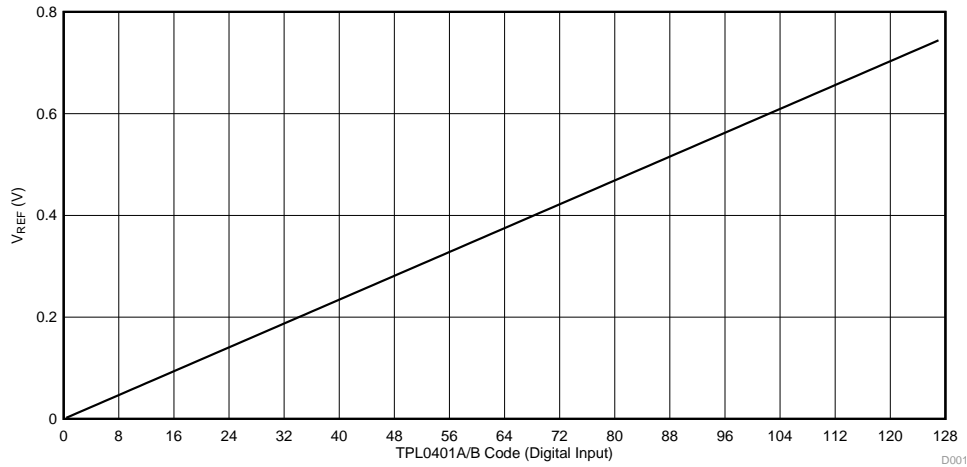


Figure 21. TPL0401-10-Q1 Digital Input vs Reference Voltage for DDR3 DIMM Memory

## 11 Power Supply Recommendations

### 11.1 Power Sequence

Protection diodes limit the voltage compliance at SDA, SCL, terminal H, and terminal W, making it important to power up  $V_{DD}$  first before applying any voltage to SDA, SCL, terminal H, and terminal W. The diodes are forward-biasing, meaning  $V_{DD}$  can be powered unintentionally if  $V_{DD}$  is not powered first. The ideal power-up sequence is  $V_{DD}$ , digital inputs, and  $V_W$  and  $V_H$ . The order of powering digital inputs,  $V_H$  and  $V_W$  does not matter as long as they are powered after  $V_{DD}$ .

### 11.2 Power-On Reset Requirements

In the event of a glitch or data corruption, the TPL0401-10-Q1 can be reset to its default conditions by using the power-on reset feature. Power-on reset requires that the device go through a power cycle to be completely reset. This reset also happens when the device is powered on for the first time in an application.

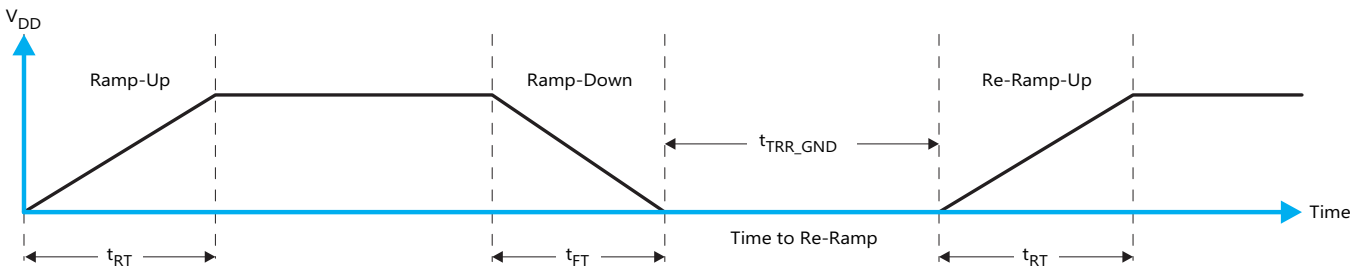


Figure 22.  $V_{DD}$  is Lowered to 0 V and then Ramped Up to  $V_{DD}$

Table 6 specifies the performance of the power-on reset feature for TCA6408A for both types of power-on reset.

Table 6. Recommended Supply Sequencing and Ramp Rates at  $T_A = 25^\circ\text{C}$  <sup>(1)</sup>

PARAMETER			MIN	MAX	UNIT
$t_{FT}$	Fall rate	See Figure 22	0.0001	1000	ms
$t_{RT}$	Rise rate	See Figure 22	0.0001	1000	ms
$t_{RR\_GND}$	Time to re-ramp (when $V_{DD}$ drops to GND)	See Figure 22	1		$\mu\text{s}$

(1) Not tested. Specified by design.

### 11.3 I<sup>2</sup>C Communication After Power Up

In order to ensure a complete device reset after a power up condition, the user must wait 120  $\mu\text{s}$  after power up before initiating communication with the TPL0401x-10-Q1. See Figure 23 for an example waveform.

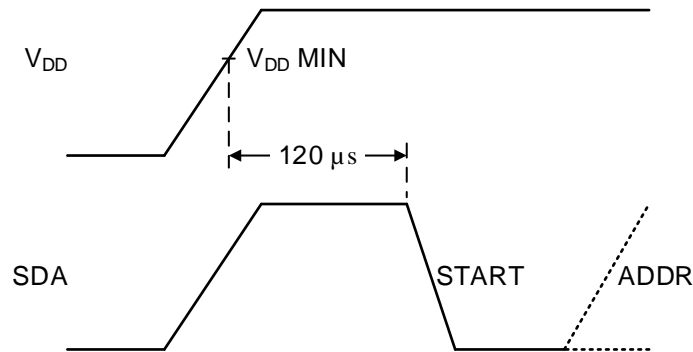


Figure 23. Recommended Start Up Sequence

#### **11.4 Wiper Position While Unpowered and After Power Up**

When DPOT is powered off, the impedance of the device is undefined and not known.

Upon power-up, the device returns to 0x40h code because this device does not contain non-volatile memory.

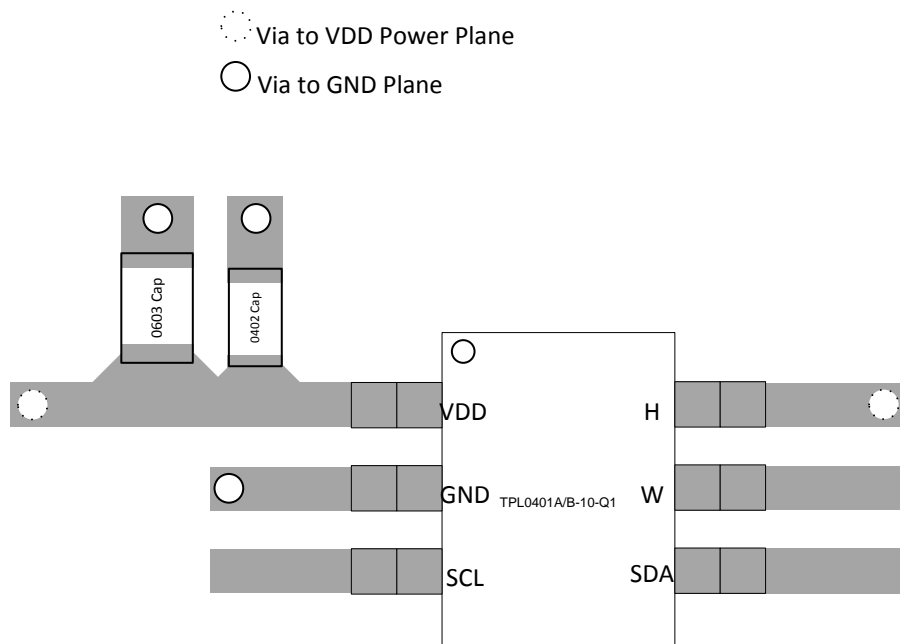
## 12 Layout

### 12.1 Layout Guidelines

To ensure reliability of the device, follow common printed-circuit board (PCB) layout guidelines:

- Leads to the input must be as direct as possible with a minimum conductor length.
- The ground path must have low resistance and low inductance.
- Use short trace-lengths to avoid excessive loading.
- It is common to have a dedicated ground plane on an inner layer of the board.
- Terminals that are connected to ground must have a low-impedance path to the ground plane in the form of wide polygon pours and multiple vias.
- Use bypass capacitors on power supplies and placed them as close as possible to the  $V_{DD}$  pin.
- Apply low equivalent series resistance (0.1- $\mu$ F to 10- $\mu$ F tantalum or electrolytic capacitors) at the supplies to minimize transient disturbances and to filter low-frequency ripple.
- To reduce the total I<sup>2</sup>C bus capacitance added by PCB parasitics, data lines (SCL and SDA) must be as short as possible and the widths of the traces must also be minimized (for example, 5 to 10 mils depending on copper weight).

### 12.2 Layout Example



**Figure 24. Layout Recommendation**

## 13 デバイスおよびドキュメントのサポート

### 13.1 ドキュメントのサポート

#### 13.1.1 関連資料

関連資料については、以下を参照してください。

- 『[PCバスのプルアップ抵抗値の計算](#)』
- 『[PCバスについて理解する](#)』
- 『[TPL0401評価モジュール・ユーザーズ・ガイド](#)』

### 13.2 関連リンク

次の表に、クイック・アクセス・リンクを示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびサンプル注文またはご購入へのクイック・アクセスが含まれます。

表 7. 関連リンク

製品	プロダクト・フォルダ	サンプルとご購入	技術資料	ツールとソフトウェア	サポートとコミュニティ
TPL0401A-Q1	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
TPL0401B-Q1	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>

### 13.3 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[ti.com](#)のデバイス製品フォルダを開いてください。右上の隅にある「通知を受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

### 13.4 コミュニティ・リソース

The following links connect to TI community resources. Linked contents are 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](#).

**TI E2E™オンライン・コミュニティ** *TIのE2E ( Engineer-to-Engineer )* コミュニティ。エンジニア間の共同作業を促進するために開設されたものです。e2e.ti.comでは、他のエンジニアに質問し、知識を共有し、アイデアを検討して、問題解決に役立てることができます。

**設計サポート** *TIの設計サポート* 役に立つE2Eフォーラムや、設計サポート・ツールをすばやく見つけることができます。技術サポート用の連絡先情報も参照できます。

### 13.5 商標

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

### 13.6 静電気放電に関する注意事項



すべての集積回路は、適切なESD保護方法を用いて、取扱いと保存を行うようにして下さい。

静電気放電はわずかな性能の低下から完全なデバイスの故障に至るまで、様々な損傷を与えます。高精度の集積回路は、損傷に対して敏感であり、極めてわずかなパラメータの変化により、デバイスに規定された仕様に適合しなくなる場合があります。

### 13.7 用語集

SLYZ022 — TI用語集。

この用語集には、用語や略語の一覧および定義が記載されています。

## 14 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

**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)
<a href="#">TPL0401A-10QDCKRQ1</a>	Active	Production	SC70 (DCK)   6	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15N
TPL0401A-10QDCKRQ1.B	Active	Production	SC70 (DCK)   6	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15N
<a href="#">TPL0401B-10QDCKRQ1</a>	Active	Production	SC70 (DCK)   6	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15O
TPL0401B-10QDCKRQ1.B	Active	Production	SC70 (DCK)   6	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15O

(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.

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**OTHER QUALIFIED VERSIONS OF TPL0401A-10-Q1, TPL0401B-10-Q1 :**

- Catalog : [TPL0401A-10](#), [TPL0401B-10](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

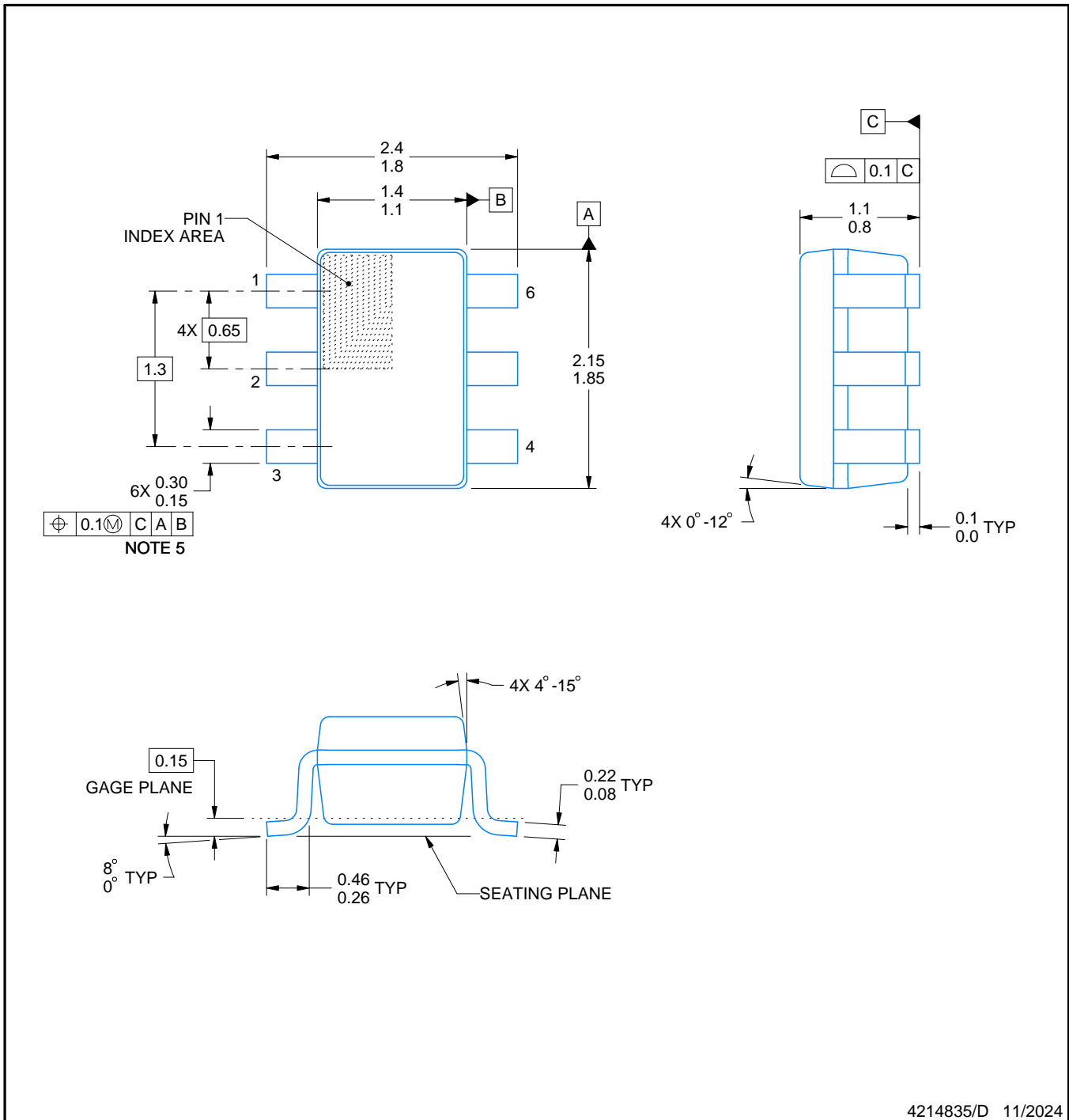
# DCK0006A



# PACKAGE OUTLINE

SOT - 1.1 max height

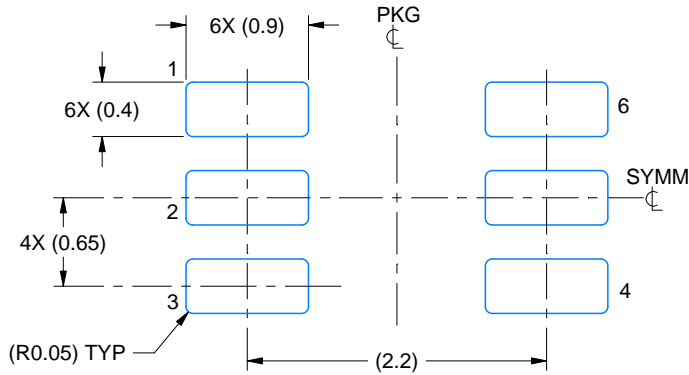
SMALL OUTLINE TRANSISTOR



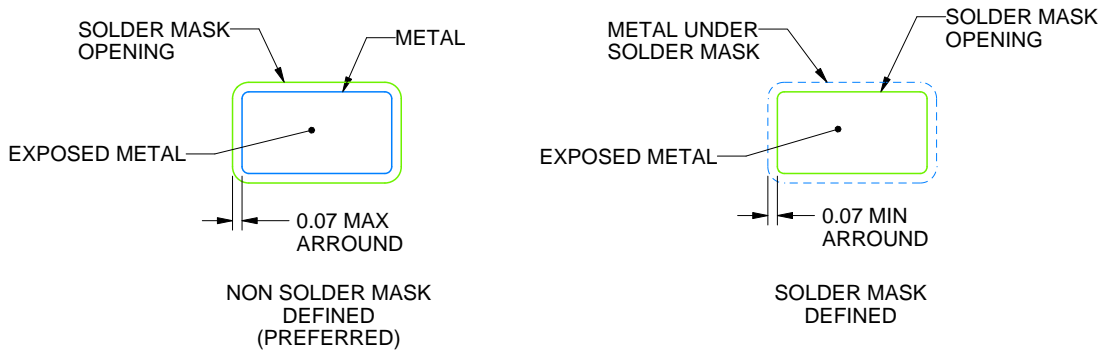
4214835/D 11/2024

## 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.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
4. Falls within JEDEC MO-203 variation AB.



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:18X



SOLDER MASK DETAILS

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NOTES: (continued)

- 5. Publication IPC-7351 may have alternate designs.
- 6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE  
BASED ON 0.125 THICK STENCIL  
SCALE:18X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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