

# ISL23415

Single, Low Voltage Digitally Controlled Potentiometer (XDCP™)

FN7780  
Rev.3.00  
Mar 17, 2022

The **ISL23415** is a volatile, low voltage, low noise, low power, SPI™ bus, 256 taps, single digitally controlled potentiometer (DCP), which integrates DCP core, wiper switches and control logic on a monolithic CMOS integrated circuit.

The digitally controlled potentiometer is implemented with a combination of resistor elements and CMOS switches. The position of the wipers are controlled by the user through the SPI bus interface. The potentiometer has an associated volatile Wiper Register (WR) that can be directly written to and read by the user. The contents of the WR controls the position of the wiper. When powered on, the ISL23415's wiper will always commence at mid-scale (128 tap position).

The low voltage, low power consumption, and small package of the ISL23415 make it an ideal choice for use in battery operated equipment. In addition, the ISL23415 has a  $V_{\text{LOGIC}}$  pin allowing down to 1.2V bus operation, independent from the  $V_{\text{CC}}$  value. This allows for low logic levels to be connected directly to the ISL23415 without passing through a voltage level shifter.

The DCP can be used as a three-terminal potentiometer or as a two-terminal variable resistor in a wide variety of applications including control, parameter adjustments, and signal processing.

## Features

- 256 resistor taps
- SPI serial interface
  - No additional level translator for low bus supply
  - Daisy Chaining of multiple DCP
- Power supply
  - $V_{\text{CC}} = 1.7\text{V}$  to 5.5V analog power supply
  - $V_{\text{LOGIC}} = 1.2\text{V}$  to 5.5V SPI bus/logic power supply
- Wiper resistance:  $70\Omega$  typical @  $V_{\text{CC}} = 3.3\text{V}$
- Shutdown Mode - forces the DCP into an end-to-end open circuit and RW is shorted to RL internally
- Power-on preset to mid-scale (128 tap position)
- Shutdown and standby current  $<2.8\mu\text{A}$  max
- DCP terminal voltage from 0V to  $V_{\text{CC}}$
- $10\text{k}\Omega$  or  $100\text{k}\Omega$  total resistance
- Extended industrial temperature range:  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$
- 10 Ld MSOP or 10 Ld  $\mu\text{TQFN}$  packages
- Pb-free (RoHS compliant)

## Applications

- Power supply margining
- RF power amplifier bias compensation
- LCD bias compensation
- Gain adjustment in battery powered instruments
- Portable medical equipment calibration

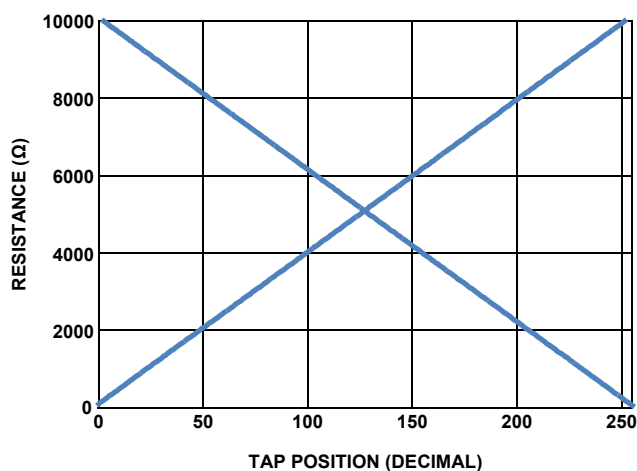


FIGURE 1. FORWARD AND BACKWARD RESISTANCE vs TAP POSITION, 10k

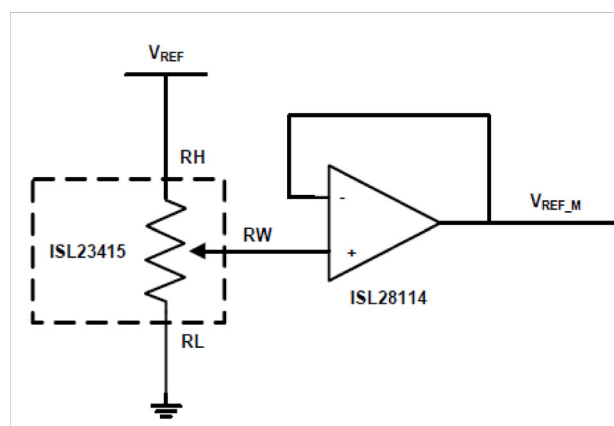
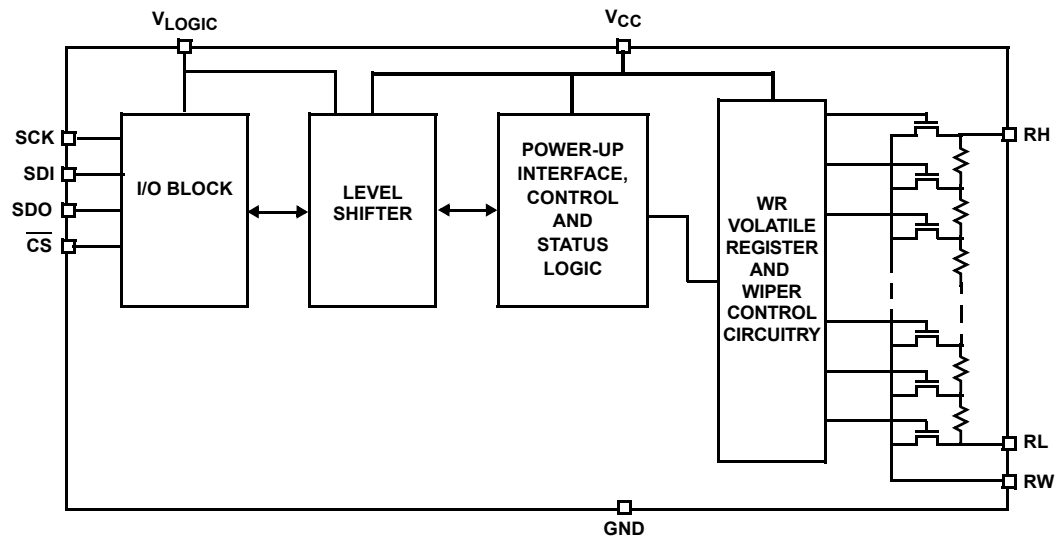
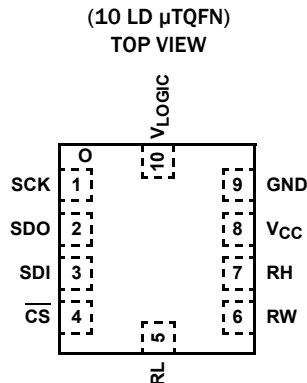
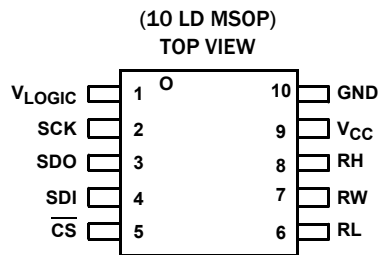


FIGURE 2.  $V_{\text{REF}}$  ADJUSTMENT

# Block Diagram



# Pin Configurations



# Pin Descriptions

| MSOP | $\mu$ TQFN | SYMBOL      | DESCRIPTION                                          |
|------|------------|-------------|------------------------------------------------------|
| 1    | 10         | $V_{LOGIC}$ | SPI bus/logic supply.<br>Range 1.2V to 5.5V          |
| 2    | 1          | SCK         | Logic Pin - Serial bus clock input                   |
| 3    | 2          | SDO         | Logic Pin - Serial bus data output<br>(configurable) |
| 4    | 3          | SDI         | Logic Pin - Serial bus data input                    |
| 5    | 4          | CS          | Logic Pin - Active low Chip Select                   |
| 6    | 5          | RL          | DCP “low” terminal                                   |
| 7    | 6          | RW          | DCP wiper terminal                                   |
| 8    | 7          | RH          | DCP “high” terminal                                  |
| 9    | 8          | $V_{CC}$    | Analog power supply.<br>Range 1.7V to 5.5V           |
| 10   | 9          | GND         | Ground pin                                           |

## Ordering Information

| PART NUMBER<br>(Note 4)    | PART<br>MARKING | RESISTANCE<br>OPTION<br>(kΩ) | PACKAGE DESCRIPTION<br>(RoHS Compliant) | PKG.<br>DWG. # | CARRIER TYPE<br>(Note 1) | TEMP. RANGE   |
|----------------------------|-----------------|------------------------------|-----------------------------------------|----------------|--------------------------|---------------|
| ISL23415TFUZ (Note 2)      | 3415T           | 100                          | 10 Ld MSOP                              | M10.118        | Tube                     | -40 to +125°C |
| ISL23415TFUZ-TK (Note 2)   |                 |                              |                                         |                | Reel, 1k                 |               |
| ISL23415TFUZ-T7A (Note 2)  |                 |                              |                                         |                | Reel, 250                |               |
| ISL23415WTFUZ (Note 2)     | 3415W           | 10                           | 10 Ld MSOP                              | M10.118        | Tube                     |               |
| ISL23415WTFUZ-TK (Note 2)  |                 |                              |                                         |                | Reel, 1k                 |               |
| ISL23415WTFUZ-T7A (Note 2) |                 |                              |                                         |                | Reel, 250                |               |
| ISL23415TFRUZ-T7A (Note 3) | HE              | 100                          | 10 Ld μTQFN 2.1x1.6                     | L10.2.1x1.6A   | Reel, 250                |               |
| ISL23415TFRUZ-TK (Note 3)  |                 |                              |                                         |                | Reel, 1k                 |               |

### NOTES:

1. See [TB347](#) for details about reel specifications.
2. These Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
3. These Pb-free plastic packaged products employ special Pb-free material sets; molding compounds/die attach materials and NiPdAu plate - e4 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
4. For Moisture Sensitivity Level (MSL), see the [ISL23415](#) product information page. For more information about MSL please see [TB363](#).

## Absolute Maximum Ratings

|                                            |                |
|--------------------------------------------|----------------|
| Supply Voltage Range                       |                |
| $V_{CC}$                                   | -0.3V to 6.0V  |
| $V_{LOGIC}$                                | -0.3V to 6.0V  |
| Voltage on any DCP Terminal Pin            | -0.3V to 6.0V  |
| Voltage on any Digital Pins                | -0.3V to 6.0V  |
| Wiper Current $I_W$ (10s)                  | $\pm 6$ mA     |
| ESD Rating                                 |                |
| Human Body Model (Tested per JESD22-A114E) | 6.5kV          |
| CDM Model (Tested per JESD22-A114E)        | 1kV            |
| Machine Model (Tested per JESD22-A115-A)   | 200V           |
| Latch Up                                   |                |
| (Tested per JESD-78B; Class 2, Level A)    | 100mA @ +125°C |

## Thermal Information

| Thermal Resistance (Typical)                   | $\theta_{JA}$ (°C/W)      | $\theta_{JC}$ (°C/W) |
|------------------------------------------------|---------------------------|----------------------|
| 10 Ld MSOP Package (Note 5, 6)                 | 170                       | 70                   |
| 10 Ld $\mu$ TQFN Package (Note 5, 6)           | 145                       | 90                   |
| Maximum Junction Temperature (Plastic Package) | +150°C                    |                      |
| Storage Temperature Range                      | -65°C to +150°C           |                      |
| Pb-Free Reflow Profile                         | see <a href="#">TB493</a> |                      |

## Recommended Operating Conditions

|                            |                 |
|----------------------------|-----------------|
| Temperature                | -40°C to +125°C |
| $V_{CC}$ Supply Voltage    | 1.7V to 5.5V    |
| $V_{LOGIC}$ Supply Voltage | 1.2V to 5.5V    |
| DCP Terminal Voltage       | 0 to $V_{CC}$   |
| Max Wiper Current          | $\pm 3$ mA      |

**CAUTION:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

### NOTES:

- $\theta_{JA}$  is measured with the component mounted on a high effective thermal conductivity test board in free air. See [TB379](#) for details.
- For  $\theta_{JC}$ , the case temperature location is the center top of the package.

## Analog Specifications $V_{CC} = 2.7V$ to 5.5V, $V_{LOGIC} = 1.2V$ to 5.5V over recommended operating conditions unless otherwise stated. Boldface limits apply over the operating temperature range, -40°C to +125°C.

| SYMBOL                                                                                                                               | PARAMETER                                    | TEST CONDITIONS                                                                                                                   | MIN<br>(Note 19) | TYP<br>(Note 7) | MAX<br>(Note 19)           | UNITS           |
|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------|----------------------------|-----------------|
| $R_{TOTAL}$                                                                                                                          | $R_H$ to $R_L$ Resistance                    | W option                                                                                                                          |                  | 10              |                            | k $\Omega$      |
|                                                                                                                                      |                                              | T option                                                                                                                          |                  | 100             |                            | k $\Omega$      |
|                                                                                                                                      | $R_H$ to $R_L$ Resistance Tolerance          |                                                                                                                                   | <b>-20</b>       | $\pm 2$         | <b>+20</b>                 | %               |
|                                                                                                                                      | End-to-End Temperature Coefficient           | W option                                                                                                                          |                  | 175             |                            | ppm/°C          |
|                                                                                                                                      |                                              | T option                                                                                                                          |                  | 70              |                            | ppm/°C          |
| $V_{RH}, V_{RL}$                                                                                                                     | DCP Terminal Voltage                         | $V_{RH}$ or $V_{RL}$ to GND                                                                                                       | <b>0</b>         |                 | <b><math>V_{CC}</math></b> | V               |
| $R_W$                                                                                                                                | Wiper Resistance                             | $R_H$ - floating, $V_{RL} = 0V$ , force $I_W$ current to the wiper, $I_W = (V_{CC} - V_{RL})/R_{TOTAL}$ , $V_{CC} = 2.7V$ to 5.5V |                  | 70              | <b>200</b>                 | $\Omega$        |
|                                                                                                                                      |                                              | $V_{CC} = 1.7V$                                                                                                                   |                  | 580             |                            | $\Omega$        |
| $C_H/C_L/C_W$                                                                                                                        | Terminal Capacitance                         | See "DCP Macro Model" on page 7.                                                                                                  |                  | 32              |                            | pF              |
| $I_{LkgDCP}$                                                                                                                         | Leakage on DCP Pins                          | Voltage at pin from GND to $V_{CC}$                                                                                               | <b>-0.4</b>      | <0.1            | <b>0.4</b>                 | $\mu A$         |
| Noise                                                                                                                                | Resistor Noise Density                       | Wiper at middle point, W option                                                                                                   |                  | 16              |                            | nV/ $\sqrt{Hz}$ |
|                                                                                                                                      |                                              | Wiper at middle point, T option                                                                                                   |                  | 61              |                            | nV/ $\sqrt{Hz}$ |
| Feed Thru                                                                                                                            | Digital Feedthrough from Bus to Wiper        | Wiper at middle point                                                                                                             |                  | -65             |                            | dB              |
| PSRR                                                                                                                                 | Power Supply Reject Ratio                    | Wiper output change if $V_{CC}$ change $\pm 10\%$ ; wiper at middle point                                                         |                  | -75             |                            | dB              |
| <b>VOLTAGE DIVIDER MODE (0V @ <math>R_L</math>; <math>V_{CC}</math> at <math>R_H</math>; measured at <math>R_W</math>, unloaded)</b> |                                              |                                                                                                                                   |                  |                 |                            |                 |
| INL<br>(Note 12)                                                                                                                     | Integral Non-linearity, Guaranteed Monotonic | W option                                                                                                                          | <b>-1.0</b>      | $\pm 0.5$       | <b>+1.0</b>                | LSB<br>(Note 8) |
|                                                                                                                                      |                                              | T option                                                                                                                          | <b>-0.5</b>      | $\pm 0.15$      | <b>+0.5</b>                | LSB<br>(Note 8) |

## Analog Specifications

$V_{CC} = 2.7V$  to  $5.5V$ ,  $V_{LOGIC} = 1.2V$  to  $5.5V$  over recommended operating conditions unless otherwise stated.  
**Boldface limits apply over the operating temperature range, -40 °C to +125 °C. (Continued)**

| SYMBOL                                                                                                                | PARAMETER                                           | TEST CONDITIONS                                           | MIN<br>(Note 19) | TYP<br>(Note 7) | MAX<br>(Note 19) | UNITS           |
|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------|------------------|-----------------|------------------|-----------------|
| DNL<br>(Note 11)                                                                                                      | Differential Non-linearity,<br>Guaranteed Monotonic | W option                                                  | -1               | ±0.4            | +1               | LSB<br>(Note 8) |
|                                                                                                                       |                                                     | T option                                                  | -0.4             | ±0.1            | +0.4             | LSB<br>(Note 8) |
| FSerror<br>(Note 10)                                                                                                  | Full-scale Error                                    | W option                                                  | -3.5             | -2              | 0                | LSB<br>(Note 8) |
|                                                                                                                       |                                                     | T option                                                  | -2               | -0.5            | 0                | LSB<br>(Note 8) |
| ZSerror<br>(Note 9)                                                                                                   | Zero-scale Error                                    | W option                                                  | 0                | 2               | 3.5              | LSB<br>(Note 8) |
|                                                                                                                       |                                                     | T option                                                  | 0                | 0.4             | 2                | LSB<br>(Note 8) |
| TC <sub>V</sub><br>(Note 13)                                                                                          | Ratiometric Temperature<br>Coefficient              | W option, Wiper Register set to 80 hex                    |                  | 8               |                  | ppm/°C          |
|                                                                                                                       |                                                     | T option, Wiper Register set to 80 hex                    |                  | 2.3             |                  | ppm/°C          |
|                                                                                                                       | Large Signal Wiper Settling Time                    | From code 0 to FF hex                                     |                  | 300             |                  | ns              |
| f <sub>cutoff</sub>                                                                                                   | -3dB Cutoff Frequency                               | Wiper at middle point W option                            |                  | 1200            |                  | kHz             |
|                                                                                                                       |                                                     | Wiper at middle point T option                            |                  | 120             |                  | kHz             |
| RHEOSTAT MODE (Measurements between RW and RL pins with RH not connected, or between RW and RH with RL not connected) |                                                     |                                                           |                  |                 |                  |                 |
| RINL<br>(Note 17)                                                                                                     | Integral Non-linearity, Guaranteed<br>Monotonic     | W option; V <sub>CC</sub> = 2.7V to 5.5V                  | -2.0             | ±1              | +2.0             | MI<br>(Note 14) |
|                                                                                                                       |                                                     | W option; V <sub>CC</sub> = 1.7V                          |                  | 10.5            |                  | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 2.7V to 5.5V                  | -1.0             | ±0.3            | +1.0             | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 1.7V                          |                  | 2.1             |                  | MI<br>(Note 14) |
| RDNL<br>(Note 16)                                                                                                     | Differential Non-linearity,<br>Guaranteed Monotonic | W option; V <sub>CC</sub> = 2.7V to 5.5V                  | -1               | ±0.4            | +1               | MI<br>(Note 14) |
|                                                                                                                       |                                                     | W option; V <sub>CC</sub> = 1.7V                          |                  | ±0.6            |                  | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 2.7V to 5.5V                  | -0.5             | ±0.15           | +0.5             | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 1.7V                          |                  | ±0.35           |                  | MI<br>(Note 14) |
| R <sub>offset</sub><br>(Note 15)                                                                                      | Offset, Wiper at 0 Position                         | W option; V <sub>CC</sub> = 2.7V to 5.5V                  | 0                | 3               | 5.5              | MI<br>(Note 14) |
|                                                                                                                       |                                                     | W option; V <sub>CC</sub> = 1.7V                          |                  | 6.3             |                  | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 2.7V to 5.5V                  | 0                | 0.5             | 2                | MI<br>(Note 14) |
|                                                                                                                       |                                                     | T option; V <sub>CC</sub> = 1.7V                          |                  | 1.1             |                  | MI<br>(Note 14) |
| TCR<br>(Note 18)                                                                                                      | Resistance Temperature<br>Coefficient               | W option; Wiper register set between 32<br>hex and FF hex |                  | 220             |                  | ppm/°C          |
|                                                                                                                       |                                                     | T option; Wiper register set between 32<br>hex and FF hex |                  | 75              |                  | ppm/°C          |

**Operating Specifications**

$V_{CC} = 2.7V$  to  $5.5V$ ,  $V_{LOGIC} = 1.2V$  to  $5.5V$  over recommended operating conditions unless otherwise stated.  
**Boldface limits apply over the operating temperature range,  $-40^{\circ}C$  to  $+125^{\circ}C$ .**

| SYMBOL                      | PARAMETER                                                   | TEST CONDITIONS                                                                                 | MIN<br>(Note 19) | TYP<br>(Note 7) | MAX<br>(Note 19) | UNITS   |
|-----------------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------------|-----------------|------------------|---------|
| $I_{LOGIC}$                 | $V_{LOGIC}$ Supply Current<br>(Write/Read)                  | $V_{LOGIC} = 5.5V$ , $V_{CC} = 5.5V$ ,<br>$f_{SCK} = 5MHz$ (for SPI active read and write)      |                  |                 | <b>1.5</b>       | mA      |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$ ,<br>$f_{SCK} = 1MHz$ (for SPI active read and write)      |                  |                 | <b>30</b>        | $\mu A$ |
| $I_{CC}$                    | $V_{CC}$ Supply Current<br>(Write/Read)                     | $V_{LOGIC} = 5.5V$ , $V_{CC} = 5.5V$                                                            |                  |                 | <b>100</b>       | $\mu A$ |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$                                                            |                  |                 | <b>10</b>        | $\mu A$ |
| $I_{LOGIC\ SB}$             | $V_{LOGIC}$ Standby Current                                 | $V_{LOGIC} = 5.5V$ , $V_{CC} = 5.5V$ ,<br>SPI interface in standby                              |                  |                 | <b>1.3</b>       | $\mu A$ |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$ ,<br>SPI interface in standby                              |                  |                 | <b>0.4</b>       | $\mu A$ |
| $I_{CC\ SB}$                | $V_{CC}$ Standby Current                                    | $V_{LOGIC} = 5.5V$ , $V_{CC} = 5.5V$ ,<br>SPI interface in standby                              |                  |                 | <b>1.5</b>       | $\mu A$ |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$ ,<br>SPI interface in standby                              |                  |                 | <b>1</b>         | $\mu A$ |
| $I_{LOGIC\ SHDN}$           | $V_{LOGIC}$ Shutdown Current                                | $V_{LOGIC} = 5.5V$ , $V_{CC} = 5.5V$ ,<br>SPI interface in standby                              |                  |                 | <b>1.3</b>       | $\mu A$ |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$ ,<br>SPI interface in standby                              |                  |                 | <b>0.4</b>       | $\mu A$ |
| $I_{CC\ SHDN}$              | $V_{CC}$ Shutdown Current                                   | $V_{LOGIC} = V_{CC} = 5.5V$ ,<br>SPI interface in standby                                       |                  |                 | <b>1.5</b>       | $\mu A$ |
|                             |                                                             | $V_{LOGIC} = 1.2V$ , $V_{CC} = 1.7V$ ,<br>SPI interface in standby                              |                  |                 | <b>1</b>         | $\mu A$ |
| $I_{LkgDig}$                | Leakage Current, at Pins $\overline{CS}$ ,<br>SDO, SDI, SCK | Voltage at pin from GND to $V_{LOGIC}$                                                          | <b>-0.4</b>      | <0.1            | <b>0.4</b>       | $\mu A$ |
| $t_{DCP}$                   | Wiper Response Time                                         | W option; $\overline{CS}$ rising edge to wiper new position, from<br>10% to 90% of final value. |                  | 0.4             |                  | $\mu s$ |
|                             |                                                             | T option; $\overline{CS}$ rising edge to wiper new position, from<br>10% to 90% of final value. |                  | 3.5             |                  | $\mu s$ |
| $t_{ShdnRec}$               | DCP Recall Time From<br>Shutdown Mode                       | $\overline{CS}$ rising edge to wiper recalled position and RH<br>connection                     |                  | 1.5             |                  | $\mu s$ |
| $V_{CC}, V_{LOGIC}$<br>Ramp | $V_{CC}, V_{LOGIC}$ Ramp Rate                               | Ramp monotonic at any level                                                                     | <b>0.01</b>      |                 | <b>50</b>        | V/ms    |

**Serial Interface Specification**

For SCK, SDI, SDO,  $\overline{CS}$  Unless Otherwise Noted.

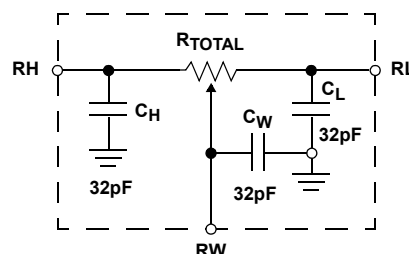
| SYMBOL                | PARAMETER                                      | TEST CONDITIONS                                                                                         | MIN<br>(Note 19)        | TYP<br>(Note 7) | MAX<br>(Note 19)       | UNITS      |
|-----------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------|-----------------|------------------------|------------|
| $V_{IL}$              | Input LOW Voltage                              |                                                                                                         | -0.3                    |                 | $0.3 \times V_{LOGIC}$ | V          |
| $V_{IH}$              | Input HIGH Voltage                             |                                                                                                         | $0.7 \times V_{LOGIC}$  |                 | $V_{LOGIC} + 0.3$      | V          |
| Hysteresis            | SDI and SCK Input Buffer Hysteresis            | $V_{LOGIC} > 2V$                                                                                        | $0.05 \times V_{LOGIC}$ |                 |                        | V          |
|                       |                                                | $V_{LOGIC} < 2V$                                                                                        | $0.1 \times V_{LOGIC}$  |                 |                        |            |
| $V_{OL}$              | SDO Output Buffer LOW Voltage                  | $I_{OL} = 3mA$ , $V_{LOGIC} > 2V$                                                                       | 0                       |                 | 0.4                    | V          |
|                       |                                                | $I_{OL} = 1.5mA$ , $V_{LOGIC} < 2V$                                                                     |                         |                 | $0.2 \times V_{LOGIC}$ | V          |
| $R_{pu}$<br>(Note 18) | SDO Pull-up Resistor Off-chip                  | Maximum is determined by $t_{R0}$ and $t_{F0}$ with<br>maximum bus load $C_b = 30pF$ , $f_{SCK} = 5MHz$ |                         |                 | 1.5                    | k $\Omega$ |
| $C_{pin}$             | SCK, SDO, SDI, $\overline{CS}$ Pin Capacitance |                                                                                                         |                         | 10              |                        | pF         |

**Serial Interface Specification** For SCK, SDI, SDO,  $\overline{\text{CS}}$  Unless Otherwise Noted. (Continued)

| SYMBOL            | PARAMETER                                            | TEST CONDITIONS                                             | MIN<br>(Note 19) | TYP<br>(Note 7) | MAX<br>(Note 19) | UNITS         |
|-------------------|------------------------------------------------------|-------------------------------------------------------------|------------------|-----------------|------------------|---------------|
| $f_{\text{SCK}}$  | SCK Frequency                                        | $V_{\text{LOGIC}} = 1.7\text{V to } 5.5\text{V}$            |                  |                 | 5                | MHz           |
|                   |                                                      | $V_{\text{LOGIC}} = 1.2\text{V to } 1.6\text{V}$            |                  |                 | 1                | MHz           |
| $t_{\text{CYC}}$  | SPI Clock Cycle Time                                 | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 200              |                 |                  | ns            |
| $t_{\text{WH}}$   | SPI Clock High Time                                  | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 100              |                 |                  | ns            |
| $t_{\text{WL}}$   | SPI Clock Low Time                                   | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 100              |                 |                  | ns            |
| $t_{\text{LEAD}}$ | Lead Time                                            | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 250              |                 |                  | ns            |
| $t_{\text{LAG}}$  | Lag Time                                             | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 250              |                 |                  | ns            |
| $t_{\text{SU}}$   | SDI, SCK and $\overline{\text{CS}}$ Input Setup Time | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 50               |                 |                  | ns            |
| $t_{\text{H}}$    | SDI, SCK and $\overline{\text{CS}}$ Input Hold Time  | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 50               |                 |                  | ns            |
| $t_{\text{RI}}$   | SDI, SCK and $\overline{\text{CS}}$ Input Rise Time  | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 10               |                 |                  | ns            |
| $t_{\text{FI}}$   | SDI, SCK and $\overline{\text{CS}}$ Input Fall Time  | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 10               |                 | 20               | ns            |
| $t_{\text{DIS}}$  | SDO Output Disable Time                              | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 0                |                 | 100              | ns            |
| $t_{\text{SO}}$   | SDO Output Setup Time                                | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 50               |                 |                  | ns            |
| $t_{\text{V}}$    | SDO Output Valid Time                                | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 150              |                 |                  | ns            |
| $t_{\text{HO}}$   | SDO Output Hold Time                                 | $V_{\text{LOGIC}} \geq 1.7\text{V}$                         | 0                |                 |                  | ns            |
| $t_{\text{RO}}$   | SDO Output Rise Time                                 | $R_{\text{pu}} = 1.5\text{k}, C_{\text{bus}} = 30\text{pF}$ |                  |                 | 60               | ns            |
| $t_{\text{FO}}$   | SDO Output Fall Time                                 | $R_{\text{pu}} = 1.5\text{k}, C_{\text{bus}} = 30\text{pF}$ |                  |                 | 60               | ns            |
| $t_{\text{CS}}$   | $\overline{\text{CS}}$ Deselect Time                 |                                                             | 2                |                 |                  | $\mu\text{s}$ |

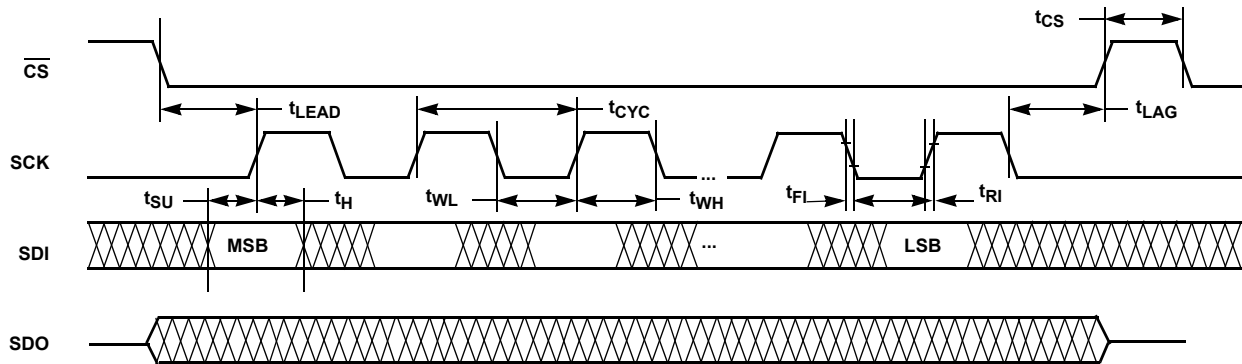
## NOTES:

- Typical values are for  $T_A = +25^\circ\text{C}$  and 3.3V supply voltages.
- $\text{LSB} = [V(\text{RW})_{255} - V(\text{RW})_0]/255$ .  $V(\text{RW})_{255}$  and  $V(\text{RW})_0$  are  $V(\text{RW})$  for the DCP register set to FF hex and 00 hex respectively. LSB is the incremental voltage when changing from one tap to an adjacent tap.
- ZS error =  $V(\text{RW})_0/\text{LSB}$ .
- FS error =  $[V(\text{RW})_{255} - V_{\text{CC}}]/\text{LSB}$ .
- $\text{DNL} = [V(\text{RW})_i - V(\text{RW})_{i-1}]/\text{LSB} - 1$ , for  $i = 1$  to 255.  $i$  is the DCP register setting.
- $\text{INL} = [V(\text{RW})_i - i \cdot \text{LSB} - V(\text{RW})_0]/\text{LSB}$  for  $i = 1$  to 255
- $C_V = \frac{\text{Max}(V(\text{RW})_i) - \text{Min}(V(\text{RW})_i)}{V(\text{RW}_i(+25^\circ\text{C}))} \times \frac{10^6}{+165^\circ\text{C}}$  for  $i = 16$  to 255 decimal,  $T = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .  $\text{Max}()$  is the maximum value of the wiper voltage and  $\text{Min}()$  is the minimum value of the wiper voltage over the temperature range.
- $\text{MI} = |RW_{255} - RW_0|/255$ . MI is a minimum increment.  $RW_{255}$  and  $RW_0$  are the measured resistances for the DCP register set to FF hex and 00 hex respectively.
- $\text{Roffset} = RW_0/\text{MI}$ , when measuring between RW and RL.  
 $\text{Roffset} = RW_{255}/\text{MI}$ , when measuring between RW and RH.
- $\text{RDNL} = (RW_i - RW_{i-1})/\text{MI} - 1$ , for  $i = 16$  to 255.
- $\text{RINL} = [RW_i - (\text{MI} \cdot i) - RW_0]/\text{MI}$ , for  $i = 16$  to 255.
- $C_R = \frac{[\text{Max}(R_i) - \text{Min}(R_i)]}{R_i(+25^\circ\text{C})} \times \frac{10^6}{+165^\circ\text{C}}$  for  $i = 16$  to 255,  $T = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .  $\text{Max}()$  is the maximum value of the resistance and  $\text{Min}()$  is the minimum value of the resistance over the temperature range.
- Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.

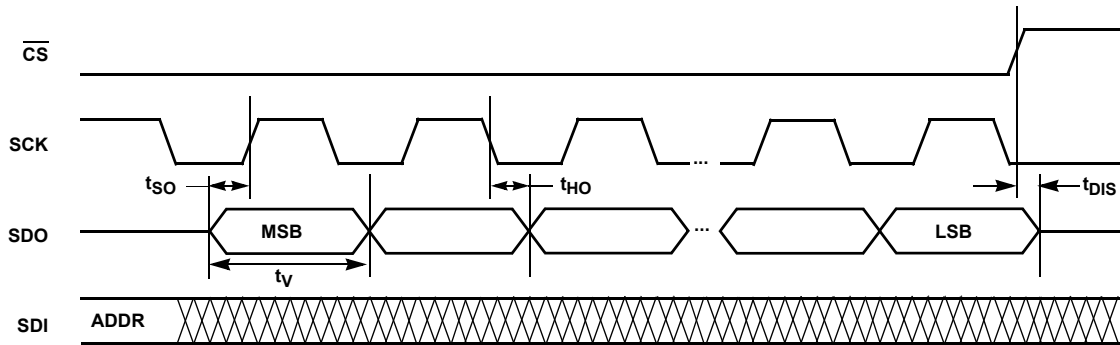
**DCP Macro Model**

# Timing Diagrams

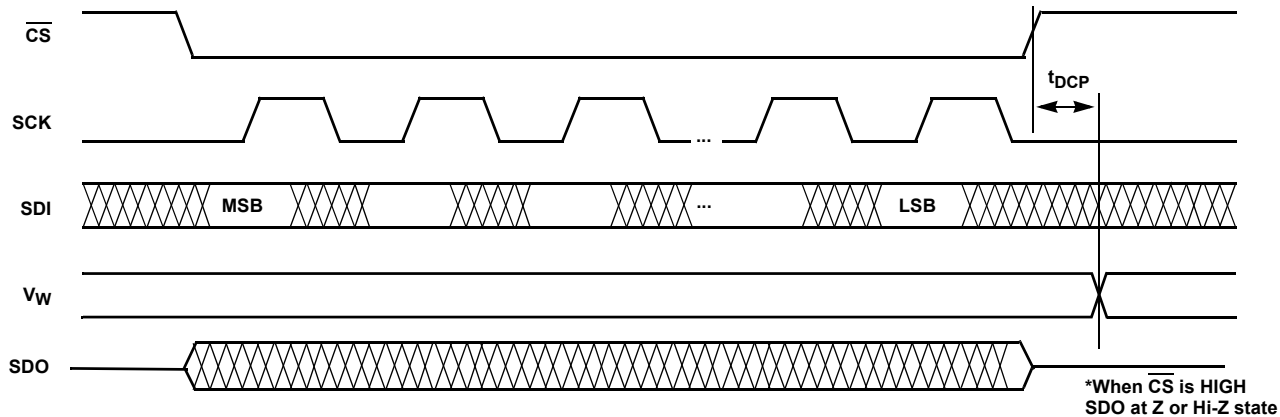
## Input Timing



## Output Timing



## XDCP™ Timing (for All Load Instructions)



## Typical Performance Curves

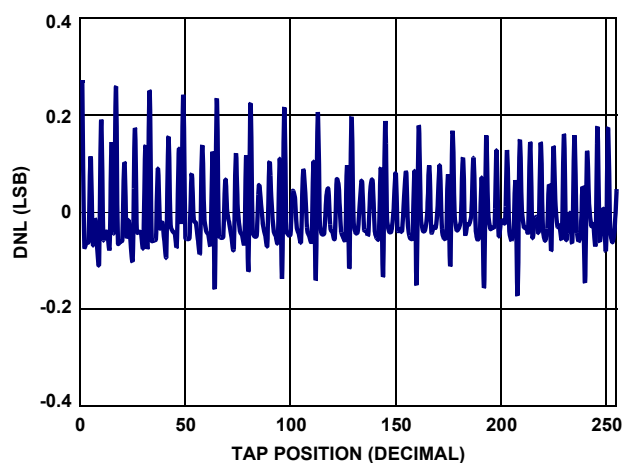
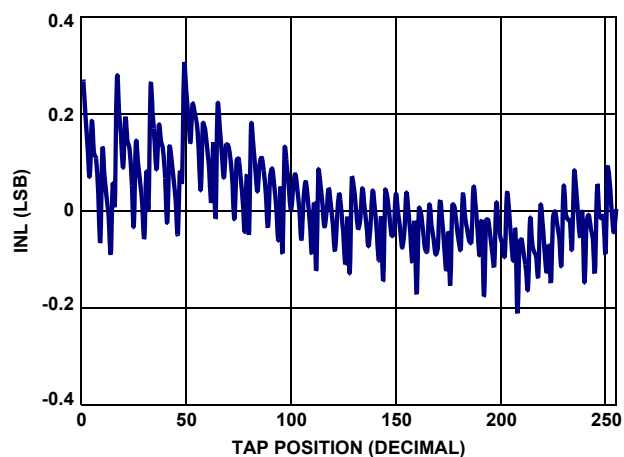
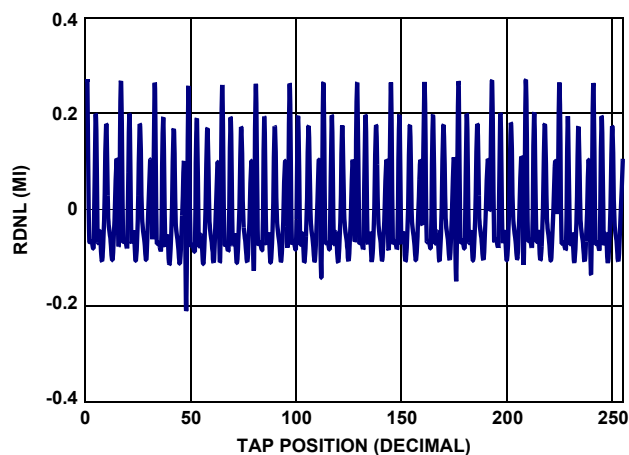
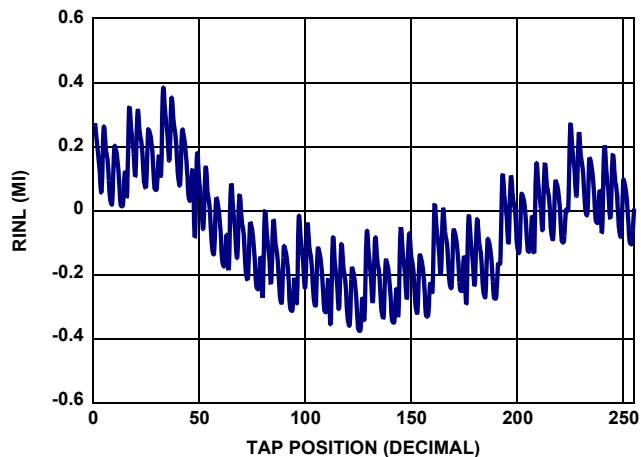
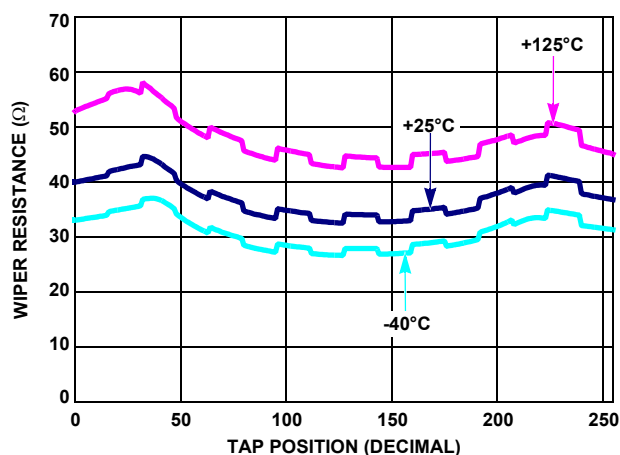
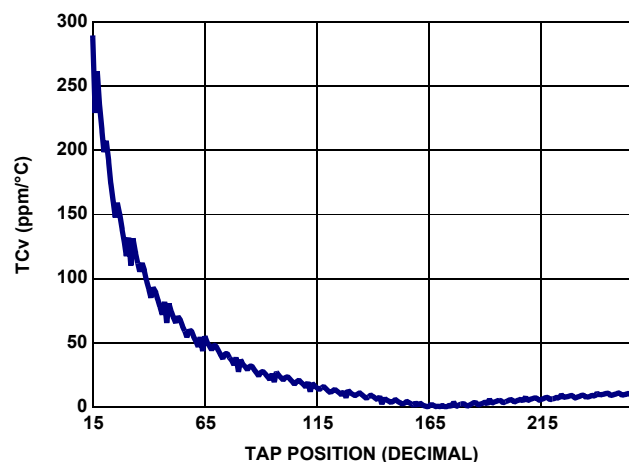
FIGURE 3. 10k DNL vs TAP POSITION,  $V_{CC} = 5V$ FIGURE 4. 10k INL vs TAP POSITION,  $V_{CC} = 5V$ FIGURE 5. 10k RDNL vs TAP POSITION,  $V_{CC} = 5V$ FIGURE 6. 10k RINL vs TAP POSITION,  $V_{CC} = 5V$ FIGURE 7. 10k WIPER RESISTANCE vs TAP POSITION,  $V_{CC} = 5V$ 

FIGURE 8. 10k TCv vs TAP POSITION

## Typical Performance Curves (Continued)

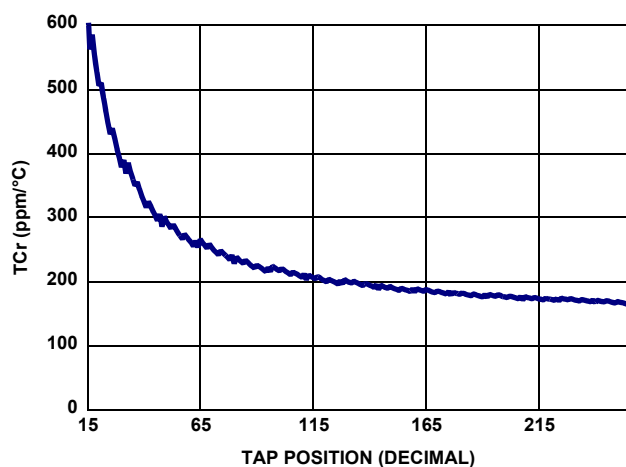


FIGURE 9. 10k TCr vs TAP POSITION

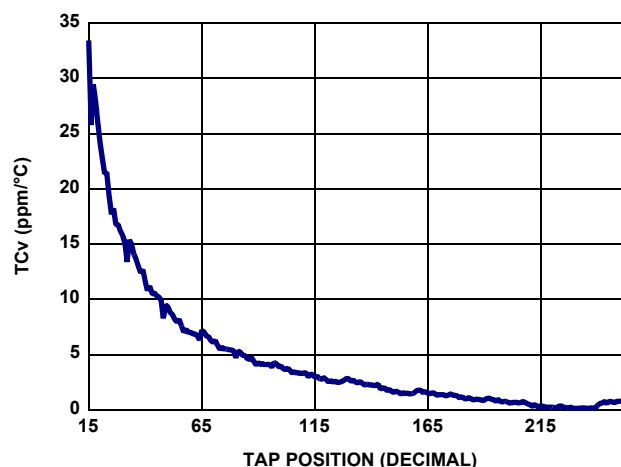


FIGURE 10. 100k TCv vs TAP POSITION

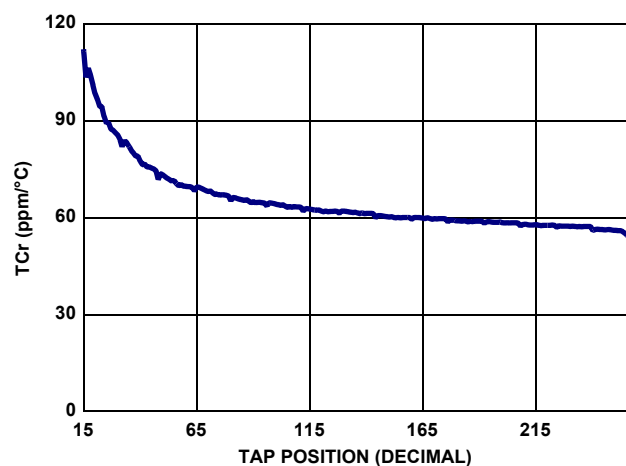


FIGURE 11. 100k TCr vs TAP POSITION

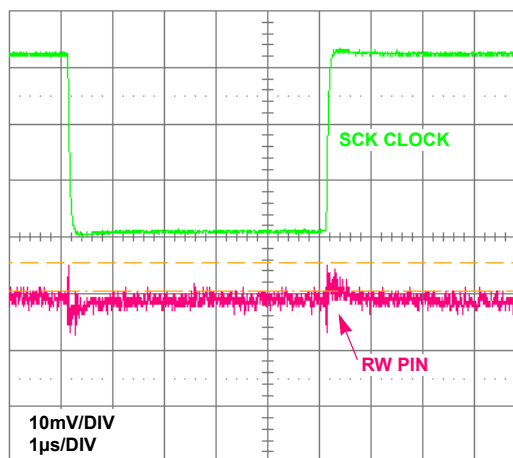


FIGURE 12. WIPER DIGITAL FEEDTHROUGH

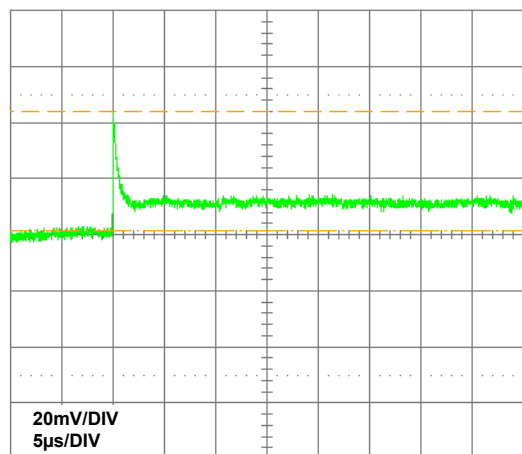


FIGURE 13. WIPER TRANSITION GLITCH

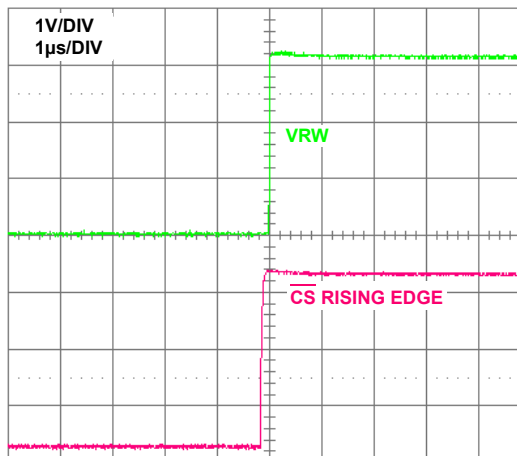


FIGURE 14. WIPER LARGE SIGNAL SETTLING TIME

## Typical Performance Curves (Continued)

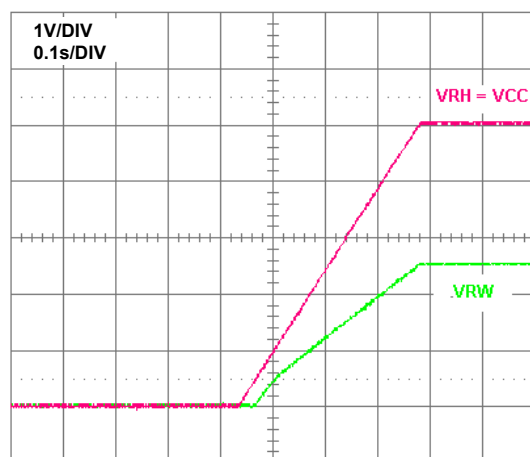


FIGURE 15. POWER-ON START-UP IN VOLTAGE DIVIDER MODE

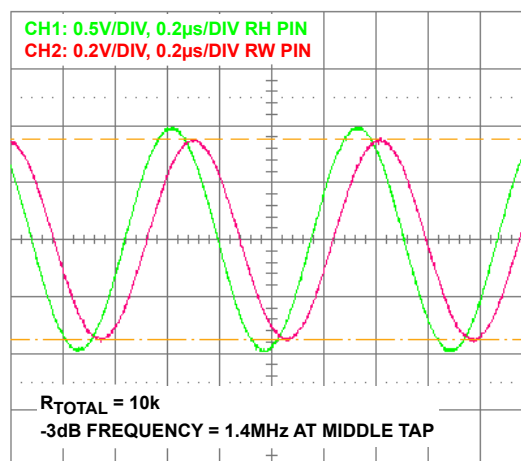


FIGURE 16. 10k -3dB CUT OFF FREQUENCY

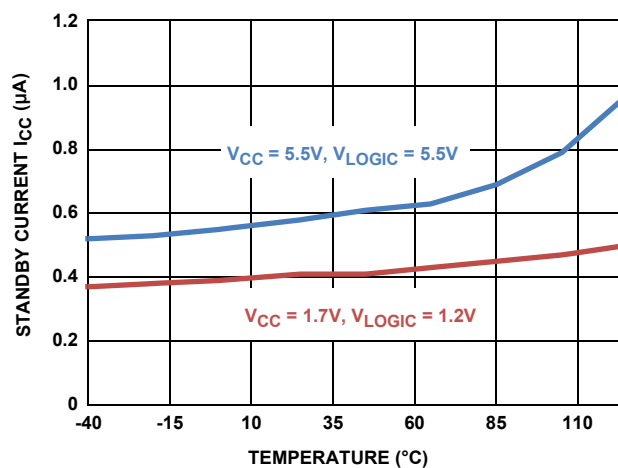


FIGURE 17. STANDBY CURRENT vs TEMPERATURE

## Functional Pin Description

### Potentiometers Pins

#### RH AND RL

The high (RH) and low (RL) terminals of the ISL23415 are equivalent to the fixed terminals of a mechanical potentiometer. The RH and RL are referenced to the relative position of the wiper and not the voltage potential on the terminals. With the WR register set to 255 decimal, the wiper will be closest to RH, and with the WR register set to 0, the wiper is closest to RL.

#### RW

The RW is the wiper terminal, and it is equivalent to the moveable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the WR register.

### Power Pins

#### V<sub>CC</sub>

Power terminal for the potentiometer section analog power source. Can be any value needed to support voltage range of DCP pins, from 1.7V to 5.5V, independent of the V<sub>LOGIC</sub> voltage.

### Bus Interface Pins

#### SERIAL CLOCK (SCL)

This input is the serial clock of the SPI serial interface.

#### SERIAL DATA INPUT (SDI)

The SDI is a serial data input pin for SPI interface. It receives operation code, wiper address and data from the SPI remote host device. The data bits are shifted in at the rising edge of the serial clock SCK, while the CS input is low.

#### SERIAL DATA OUTPUT (SDO)

The SDO is a serial data output pin. During a read cycle, the data bits are shifted out on the falling edge of the serial clock SCK and will be available to the master on the following rising edge of SCK.

The output type is configured through ACR[1] bit for Push-Pull or Open Drain operation. Default setting for this pin is Push-Pull. An external pull-up resistor is required for Open Drain output operation. When CS is HIGH, the SDO pin is in tri-state (Z) or high-tri-state (Hi-Z) depends on the selected configuration.

#### CHIP SELECT ( $\overline{\text{CS}}$ )

$\overline{\text{CS}}$  LOW enables the ISL23415, placing it in the active power mode. A HIGH to LOW transition on  $\overline{\text{CS}}$  is required prior to the start of any operation after power-up. When  $\overline{\text{CS}}$  is HIGH, the ISL23415 is deselected and the SDO pin is at high impedance, and the device will be in the standby state.

#### V<sub>LOGIC</sub>

Digital power source for the logic control section. It supplies an internal level translator for 1.2V to 5.5V serial bus operation. Use the same supply as the I<sup>2</sup>C logic source.

## Principles of Operation

The ISL23415 is an integrated circuit incorporating one DCP with its associated registers and an SPI serial interface providing direct communication between a host and the potentiometer. The resistor array is comprised of individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper.

The electronic switches on the device operate in a “make before break” mode when the wiper changes tap positions.

Voltage at any DCP pins, RH, RL or RW, should not exceed V<sub>CC</sub> level at any conditions during power-up and normal operation.

The V<sub>LOGIC</sub> pin needs to be connected to the SPI bus supply which allows reliable communication with the wide range of microcontrollers and independent of the V<sub>CC</sub> level. This is extremely important in systems where the digital supply has lower levels than the analog supply.

### DCP Description

Each DCP is implemented with a combination of resistor elements and CMOS switches. The physical ends of DCP are equivalent to the fixed terminals of a mechanical potentiometer (RH and RL pins). The RW pin of the DCP is connected to intermediate nodes, and is equivalent to the wiper terminal of a mechanical potentiometer. The position of the wiper terminal within the DCP is controlled by the 8-bit volatile Wiper Register (WR). When the WR of a DCP contains all zeroes (WR[7:0] = 00h), its wiper terminal (RW) is closest to its “Low” terminal (RL). When the WR register of a DCP contains all ones (WR[7:0] = FFh), its wiper terminal (RW) is closest to its “High” terminal (RH). As the value of the WR increases from all zeroes (0) to all ones (255 decimal), the wiper moves monotonically from the position closest to RL to the position closest to RH. At the same time, the resistance between RW and RL increases monotonically, while the resistance between RH and RW decreases monotonically.

While the ISL23415 is being powered up, the WR is reset to 80h (128 decimal), which locates RW roughly at the center between RL and RH.

The WR can be read or written to directly using the SPI serial interface as described in the following sections.

### Memory Description

The ISL23415 contains two volatile 8-bit registers: the Wiper Register (WR) and the Access Control Register (ACR). Memory map of ISL23415 is in Table 1. The Wiper Register WR at address 0 contains current wiper position of the DCP. The Access Control Register (ACR) at address 10h contains information and control bits described in Table 2.

TABLE 1. MEMORY MAP

| ADDRESS (hex) | VOLATILE | DEFAULT SETTING (hex) |
|---------------|----------|-----------------------|
| 10            | ACR      | 40                    |
| 0             | WR       | 80                    |

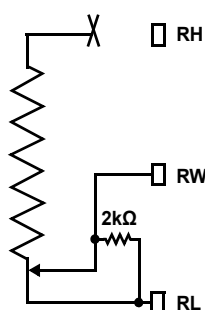
**TABLE 2. ACCESS CONTROL REGISTER (ACR)**

| BIT # | 7 | 6    | 5 | 4 | 3 | 2 | 1   | 0 |
|-------|---|------|---|---|---|---|-----|---|
| NAME  | 0 | SHDN | 0 | 0 | 0 | 0 | SDO | 0 |

The SDO bit (ACR[1]) configures type of SDO output pin. The default value of SDO bit is 0 for Push-Pull output. The SDO pin can be configured as Open Drain output for some applications. In this case, an external pull-up resistor is required, reference the “Serial Interface Specification” on page 6.

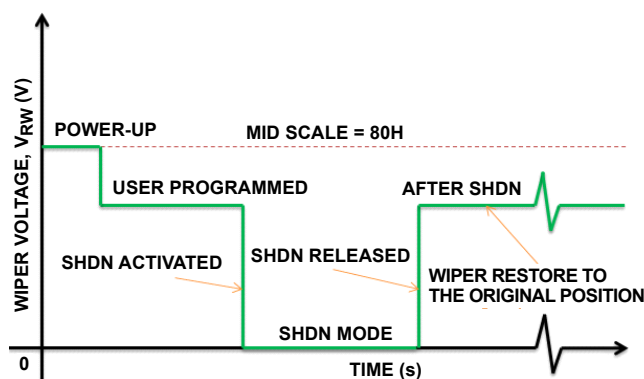
## Shutdown Function

The SHDN bit (ACR[6]) disables or enables shutdown mode for all DCP channels simultaneously. When this bit is 0, i.e., each DCP is forced to end-to-end open circuit and each RW shorted to RL through a 2kΩ serial resistor, as shown in Figure 18. Default value of the SHDN bit is 1.

**FIGURE 18. DCP CONNECTION IN SHUTDOWN MODE**

When the device enters shutdown, all current DCP WR settings are maintained. When the device exits shutdown, the wipers will

return to the previous WR settings after a short settling time (see Figure 26).

**FIGURE 19. SHUTDOWN MODE WIPER RESPONSE**

## SPI Serial Interface

The ISL23415 supports an SPI serial protocol, mode 0. The device is accessed via the SDI input and SDO output with data clocked in on the rising edge of SCK, and clocked out on the falling edge of SCK.  $\overline{CS}$  must be LOW during communication with the ISL23415. The SCK and  $\overline{CS}$  lines are controlled by the host or master. The ISL23415 operates only as a slave device.

All communication over the SPI interface is conducted by sending the MSB of each byte of data first.

## Protocol Conventions

The SPI protocol contains Instruction Byte followed by one or more Data Bytes. A valid Instruction Byte contains instruction as the three MSBs, with the following five register address bits (see Table 3).

The next byte sent to the ISL23415 is the Data Byte.

**TABLE 3. INSTRUCTION BYTE FORMAT**

| BIT # | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-------|----|----|----|----|----|----|----|----|
|       | I2 | I1 | I0 | R4 | R3 | R2 | R1 | R0 |

Table 4 contains a valid instruction set for ISL23415.

If the [R4:R0] bits are zero or one, then the read or write is to the WRi register. If the [R4:R0] are 10000, then the operation is to the ACR.

**TABLE 4. INSTRUCTION SET**

| INSTRUCTION SET |    |    |    |    |    |    |    | OPERATION       |
|-----------------|----|----|----|----|----|----|----|-----------------|
| I2              | I1 | I0 | R4 | R3 | R2 | R1 | R0 |                 |
| 0               | 0  | 0  | X  | X  | X  | X  | X  | NOP             |
| 0               | 0  | 1  | X  | X  | X  | X  | X  | ACR READ        |
| 0               | 1  | 1  | X  | X  | X  | X  | X  | ACR WRTE        |
| 1               | 0  | 0  | R4 | R3 | R2 | R1 | R0 | WRi or ACR READ |
| 1               | 1  | 0  | R4 | R3 | R2 | R1 | R0 | WRi or ACR WRTE |

Where X means “do not care”.

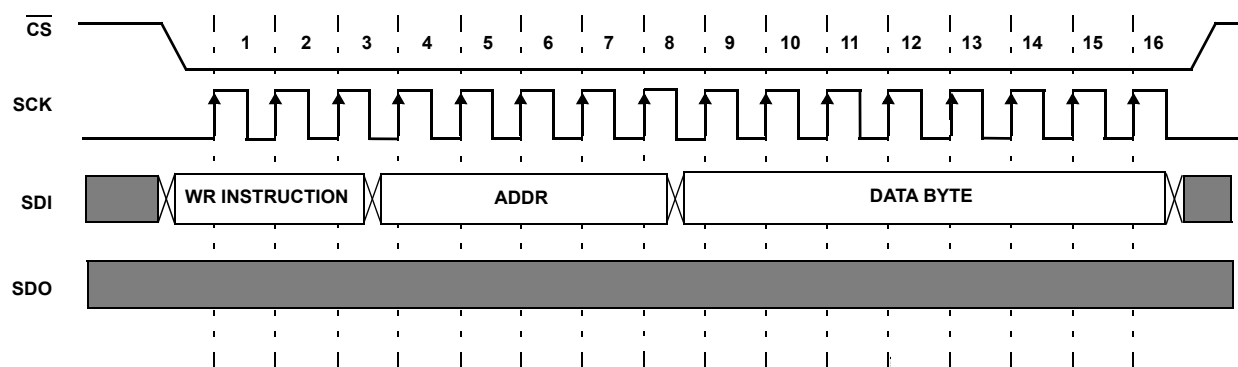


FIGURE 20. TWO BYTE WRITE SEQUENCE

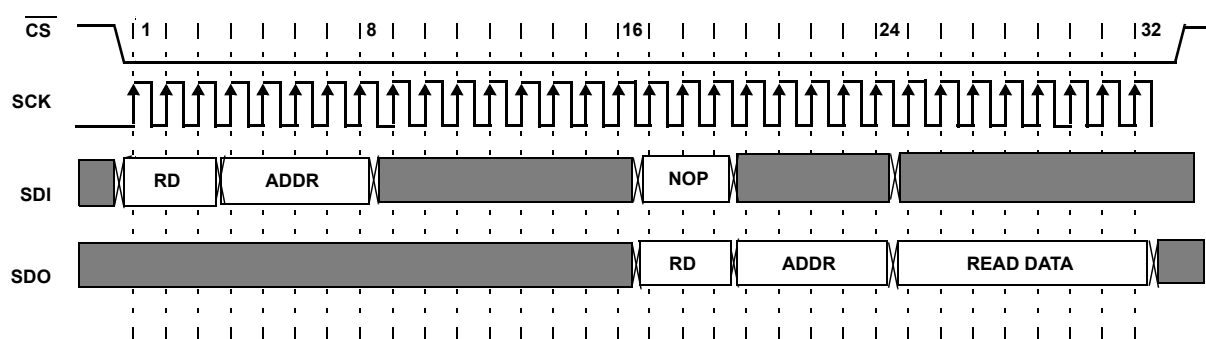


FIGURE 21. FOUR BYTE READ SEQUENCE

## Write Operation

A write operation to the ISL23415 is a two or more bytes operation. It requires first, the  $\overline{\text{CS}}$  transition from HIGH-to-LOW. Then the host sends a valid Instruction Byte, followed by one or more Data Bytes to the SDI pin. The host terminates the write operation by pulling the  $\overline{\text{CS}}$  pin from LOW-to-HIGH. Instruction is executed on the rising edge of  $\overline{\text{CS}}$  (see Figure 20).

## Read Operation

A Read operation to the ISL23415 is a four byte operation. It requires first, the  $\overline{\text{CS}}$  transition from HIGH-to-LOW. Then the host sends a valid Instruction Byte, followed by a “dummy” Data Byte, NOP Instruction Byte and another “dummy” Data Byte to SDI pin. The SPI host receives the Instruction Byte (instruction code + register address) and requested Data Byte from SDO pin on the rising edge of SCK during third and fourth bytes, respectively. The host terminates the read by pulling the  $\overline{\text{CS}}$  pin from LOW-to-HIGH (see Figure 21).

## Applications Information

### Communicating with ISL23415

Communication with ISL23415 proceeds using SPI interface through the ACR (address 10000b) and WR (addresses 00000b) registers.

The wiper of the potentiometer is controlled by the WR register. Writes and reads can be made directly to these register to control and monitor the wiper position.

### Daisy Chain Configuration

When application needs more than one ISL23415, it can communicate with all of them without additional  $\overline{\text{CS}}$  lines by daisy chaining the DCPs as shown on Figure 22. In Daisy Chain configuration, the SDO pin of the previous chip is connected to the SDI pin of the following chip, and each  $\overline{\text{CS}}$  and SCK pins are connected to the corresponding microcontroller pins in parallel, like regular SPI interface implementation. The Daisy Chain configuration can also be used for simultaneous setting of multiple DCPs. Note, the number of daisy chained DCPs is limited only by the driving capabilities of SCK and  $\overline{\text{CS}}$  pins of microcontroller; for larger number of SPI devices buffering of SCK and  $\overline{\text{CS}}$  lines is required.

### Daisy Chain Write Operation

The write operation starts by HIGH-to-LOW transition on  $\overline{\text{CS}}$  line, followed by N number of two bytes write instructions on SDI line with reversed chain access sequence: the instruction byte + data byte for the last DCP in chain is going first, as shown in Figure 23, where N is a number of DCPs in chain. The serial data is going through DCPs from DCP0 to DCP(N-1) as follow: DCP0 → DCP1 → DCP2 → ... → DCP(N-1). The write instruction is executed on the rising edge of  $\overline{\text{CS}}$  for all N DCPs simultaneously.

## Daisy Chain Read Operation

The read operation consists of two parts: first, send the read instructions (N two bytes operation) with valid address; second, read the requested data while sending NOP instructions (N two bytes operation) as shown in Figures 24 and 25.

The first part starts by HIGH-to-LOW transition on  $\overline{CS}$  line, followed by N two bytes read instruction on SDI line with reversed chain access sequence: the instruction byte + dummy data byte for the last DCP in chain is going first, followed by LOW-to-HIGH transition on  $\overline{CS}$  line. The read instructions are executed during second part of read sequence. It also starts by HIGH-to-LOW transition on  $\overline{CS}$  line, followed by N number of two bytes NOP instructions on SDI line and LOW-to-HIGH transition of  $\overline{CS}$ . The data is read on every even byte during second part of read sequence while every odd byte contains code 111b followed by address from which the data is being read.

## Wiper Transition

When stepping up through each tap in voltage divider mode, some tap transition points can result in noticeable voltage transients, or overshoot/undershoot, resulting from the sudden transition from a very low impedance “make” to a much higher impedance “break within a short period of time (<1μs). There are

several code transitions such as 0Fh to 10h, 1Fh to 20h, ..., EFh to FFh, which have higher transient glitch. Note, that all switching transients will settle well within the settling time as stated in the datasheet. A small capacitor can be added externally to reduce the amplitude of these voltage transients, but that will also reduce the useful bandwidth of the circuit, thus may not be a good solution for some applications. It may be a good idea, in that case, to use fast amplifiers in a signal chain for fast recovery.

## V<sub>LOGIC</sub> Requirements

It is recommended to keep V<sub>LOGIC</sub> powered all the time during normal operation. In a case where turning V<sub>LOGIC</sub> OFF is necessary, it is recommended to ground the V<sub>LOGIC</sub> pin of the ISL23415. Grounding the V<sub>LOGIC</sub> pin or both V<sub>LOGIC</sub> and V<sub>CC</sub> does not affect other devices on the same bus. It is good practice to put a 1μF capacitor in parallel with 0.1μF decoupling capacitor close to the V<sub>LOGIC</sub> pin.

## V<sub>CC</sub> Requirements and Placement

It is recommended to put a 1μF capacitor in parallel with 0.1μF decoupling capacitor close to the V<sub>CC</sub> pin.

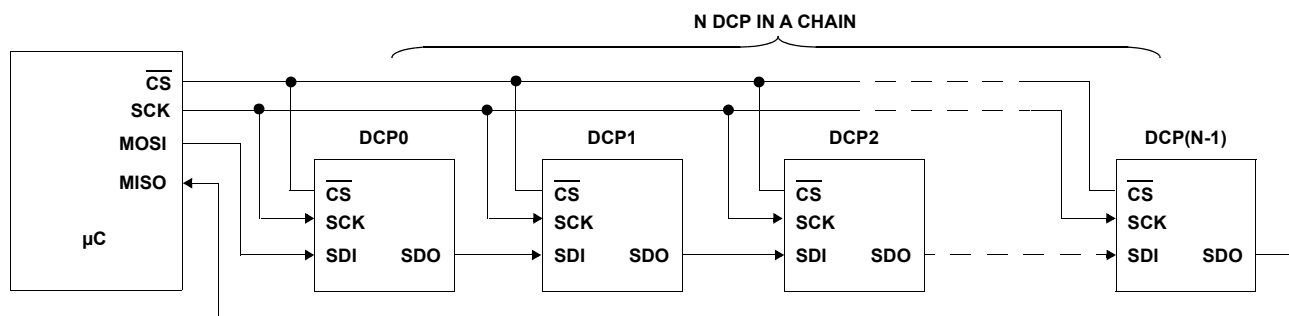


FIGURE 22. DAISY CHAIN CONFIGURATION

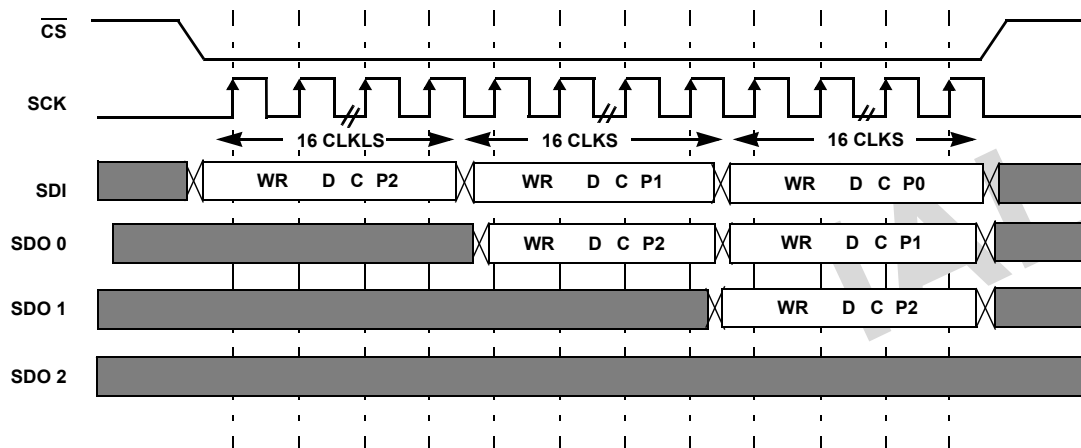


FIGURE 23. DAISY CHAIN WRITE SEQUENCE OF N = 3 DCP

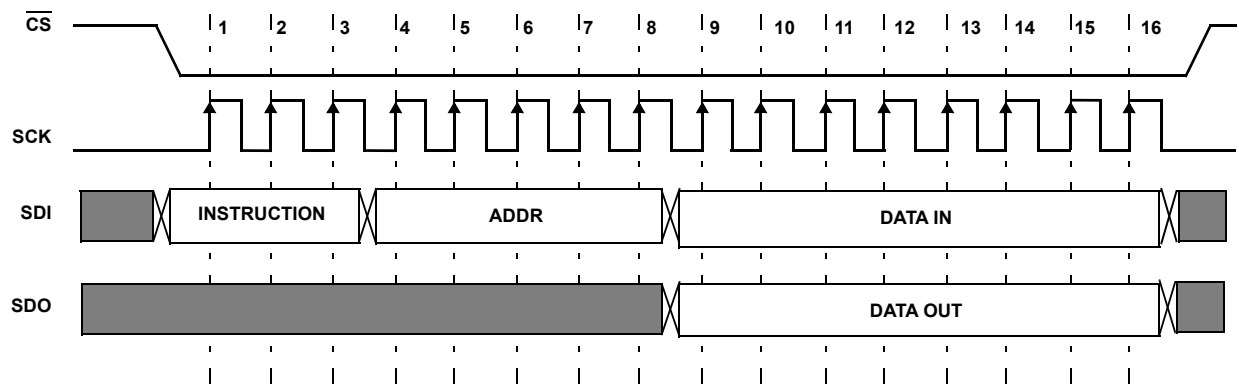


FIGURE 24. TWO BYTE READ INSTRUCTION

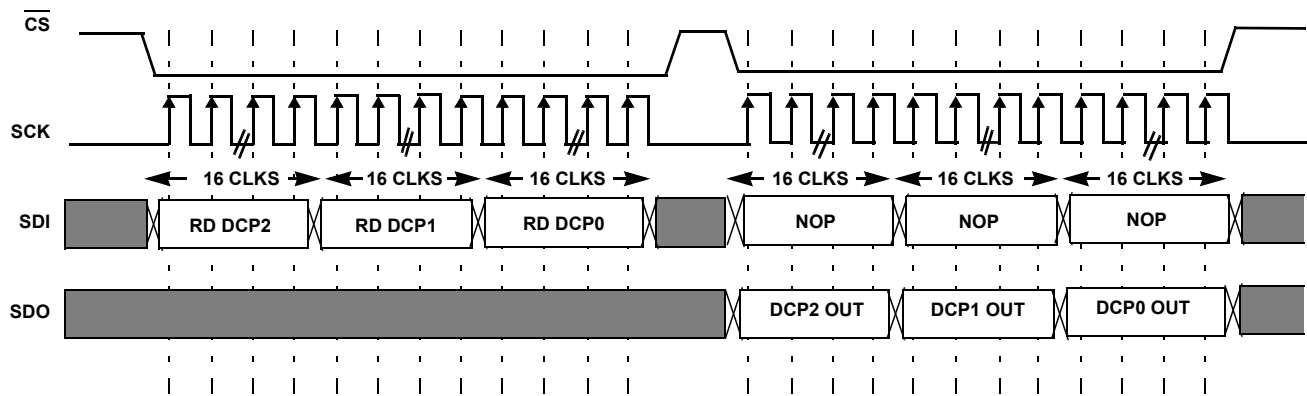


FIGURE 25. DAISY CHAIN READ SEQUENCE OF N = 3 DCP

## Revision History

The revision history provided is for informational purposes only and is believed to be accurate, but not warranted. Please go to web to make sure you have the latest Rev

| DATE         | REVISION | CHANGE                                                                                                                                                                                                                                                                                                                                   |
|--------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mar 17, 2022 | 3.00     | Removed About Intersil section.<br>Removed 50k $\Omega$ option information throughout datasheet.<br>Updated the Ordering Information table formatting.<br>Updated POD M10.118 to the latest revision, changes are as follows:<br>-Corrected typo in the side view 1 updating package thickness tolerance from $\pm 0.10$ to $\pm 0.10$ . |
| Sep 14, 2015 | 2.00     | Updated Ordering Information on page 3.<br>Updated Products to About Intersil Verbiage.<br>Updated POD M10.118 to most current revision. Revision change is as follows:<br>Updated to new POD template. Added land pattern                                                                                                               |
| Jul 28, 2011 | 1.00     | Added "Shutdown Function" section and revised " $V_{\text{LOGIC}}$ Standby Current" and " $V_{\text{CC}}$ Shutdown Current" limits on page 6.<br>On page 6, split "Wiper Response Time" up into 3 separate conditions for each option (W, U, T).                                                                                         |
| Dec 15, 2010 | 0.00     | Initial Release.                                                                                                                                                                                                                                                                                                                         |

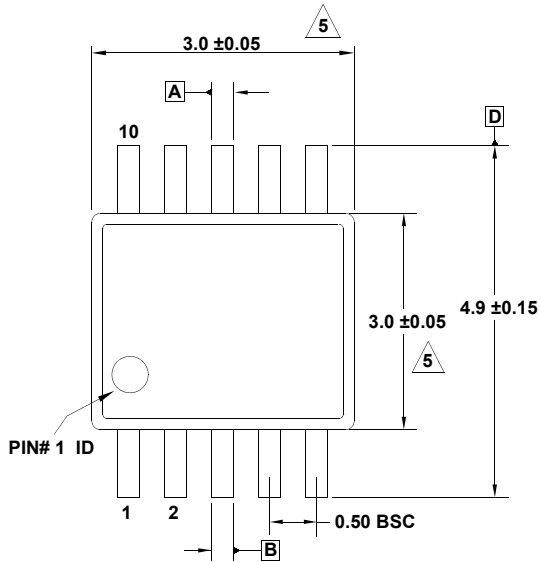
## Package Outline Drawings

For the most recent package outline drawing, see [M10.118](#).

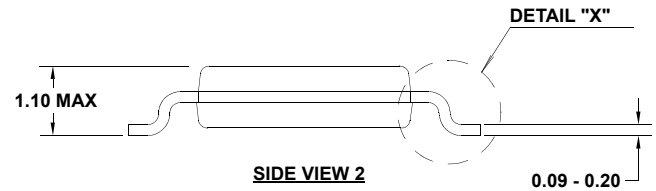
M10.118

10 Lead Mini Small Outline Plastic Package

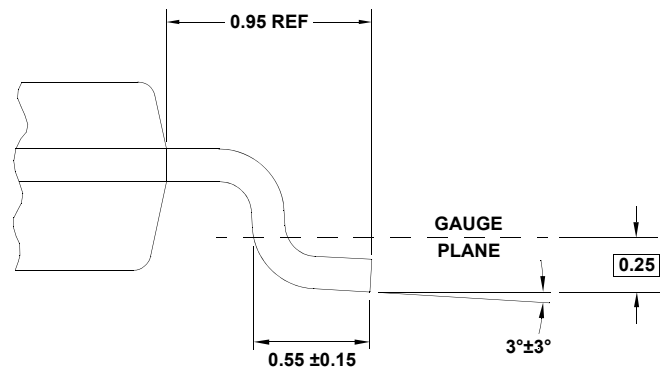
Rev 2, 5/2021



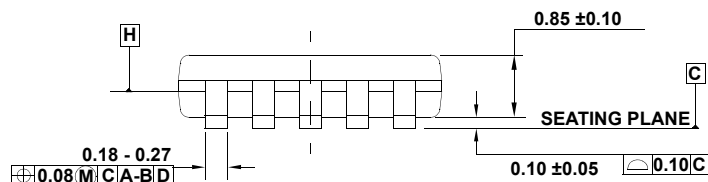
**TOP VIEW**



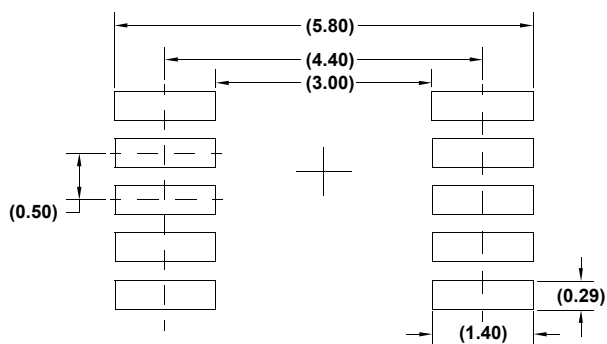
**SIDE VIEW 2**



**DETAIL "X"**



**SIDE VIEW 1**



**TYPICAL RECOMMENDED LAND PATTERN**

### NOTES:

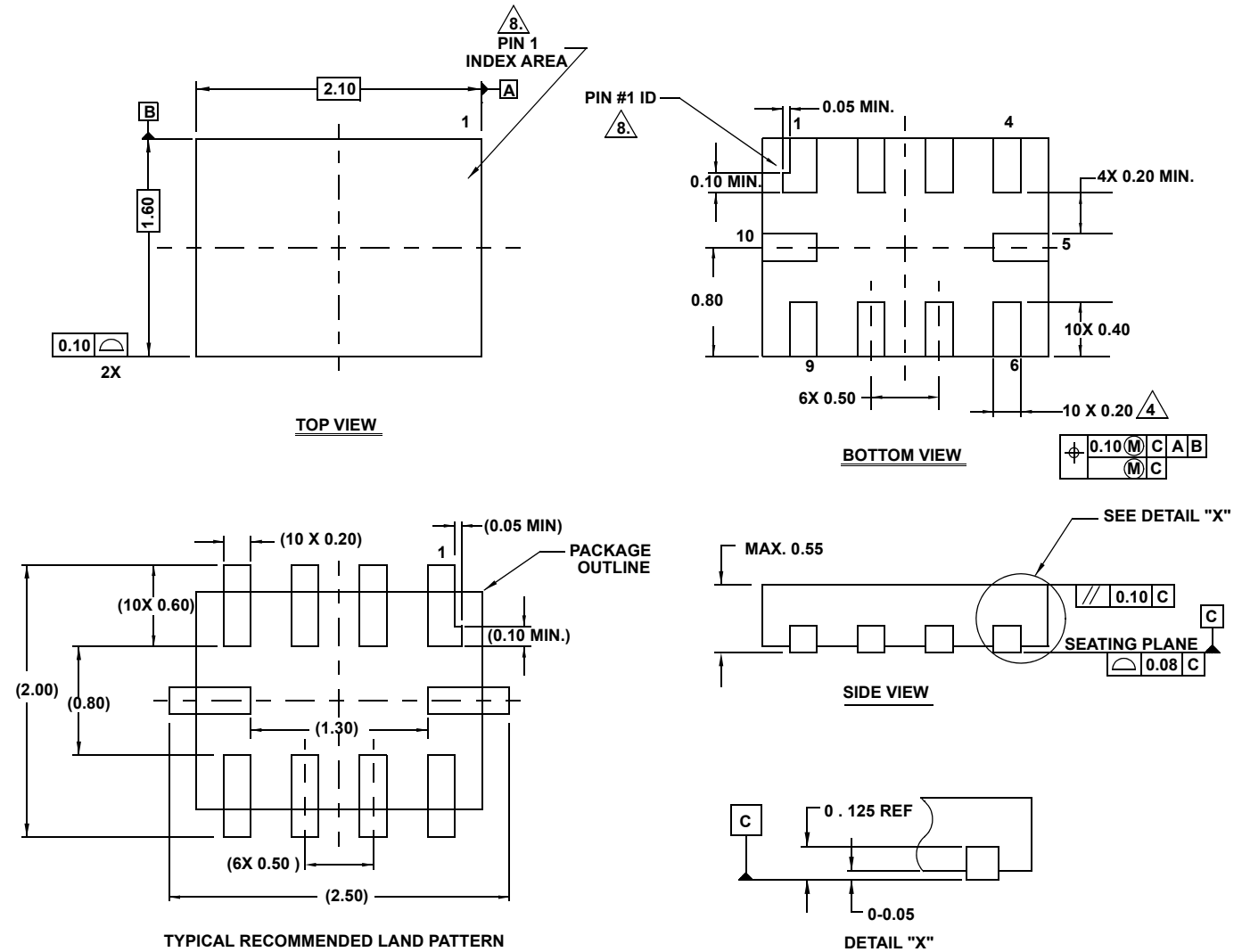
1. Dimensions are in millimeters.
2. Dimensioning and tolerancing conform to JEDEC MO-187-BA and AMSEY14.5m-1994.
3. Plastic or metal protrusions of 0.15mm max per side are not included.
4. Plastic interlead protrusions of 0.15mm max per side are not included.
5. Dimensions are measured at Datum Plane "H".
6. Dimensions in ( ) are for reference only.

For the most recent package outline drawing, see [L10.2.1x1.6A](#).

# L10.2.1x1.6A

## 10 Lead Ultra Thin Quad Flat No-Lead Plastic Package

Rev 5, 3/10



### NOTES:

1. Dimensioning and tolerancing conform to ASME Y14.5M-1994.
2. All Dimensions are in millimeters. Angles are in degrees. Dimensions in ( ) for Reference Only.
3. Unless otherwise specified, tolerance : Decimal  $\pm 0.05$



Lead width dimension applies to the metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip.

5. Maximum package warpage is 0.05mm.
6. Maximum allowable burrs is 0.076mm in all directions.

7. Same as JEDEC MO-255UABD except:  
No lead-pull-back, MIN. Package thickness = 0.45 not 0.50mm  
Lead Length dim. = 0.45mm max. not 0.42mm.



The configuration of the pin #1 identifier is optional, but must be located within the zone indicated. The pin #1 identifier may be either a mold or mark feature.

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