## Low Noise, Low Power, 16 Taps, Push Button Controlled Potentiometer

The Intersil ISL23512 is a three-terminal digitally-controlled potentiometer (XDCP) implemented by a resistor array composed of 15 resistive elements and a wiper switching network. The ISL23512 features a push button control, a shutdown mode, as well as an industry-leading µTQFN package.

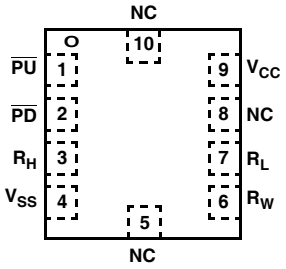
The push button control has individual $\overline{PU}$ and $\overline{PD}$ inputs for adjusting the wiper. To eliminate redundancy, the wiper position will automatically increment or decrement if one of these inputs is held longer than 1s.

Forcing both $\overline{PU}$ and $\overline{PD}$ low for more than 2s activates shutdown mode. Shutdown mode disconnects the top of the resistor chain and moves the wiper to the lowest position, minimizing power consumption.

The three terminals accessing the resistor chain naturally configure the ISL23512 as a voltage divider. A rheostat is easily formed by floating an end terminal or connecting it to the wiper.

## Pinout

**ISL23512**
**(10 LD µTQFN)**
TOP VIEW




## Features

- Solid-state volatile potentiometer
- Push button controlled
- Single or Auto increment/decrement
  - Fast Mode after 1s button press
- Shutdown Mode
- 16 wiper tap points
  - Zero scale wiper position on power-up
- Low power CMOS
  - $V_{CC}$ = 2.7V to 5.5V
  - Terminal voltage, 0 to $V_{CC}$
  - Standby current, 3µA max
- $R_{TOTAL}$ value = 10kΩ
- Packages
  - 10 Ld µTQFN (2.05mmx1.55mm)
  - Pb-free (RoHS compliant)

## Applications

- Volume Control
- LED/LCD Brightness Control
- Contrast Control
- Programming Bias Voltages
- Ladder Networks

## Ordering Information

| PART NUMBER (Notes 1, 2) | PART MARKING | $R_{TOTAL}$ (kΩ) | TEMPERATURE RANGE (°C) | PACKAGE (Pb-free) | PKG. DWG. # |
|---|---|---|---|---|---|
| ISL23512WFRU10Z-TK | GB | 10 | -40 to +125 | 10 Ld µTQFN | L10.2.1x1.6A |

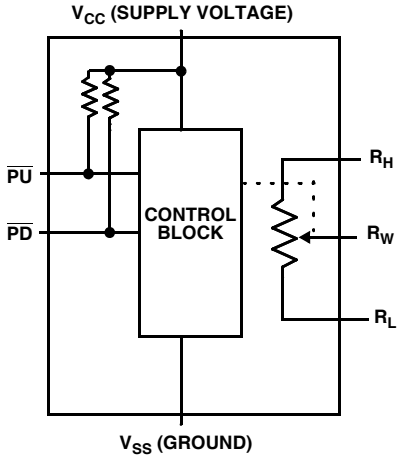
NOTES:

1. These Intersil 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. Intersil 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.
2. Please refer to TB347 for details on reel specifications.

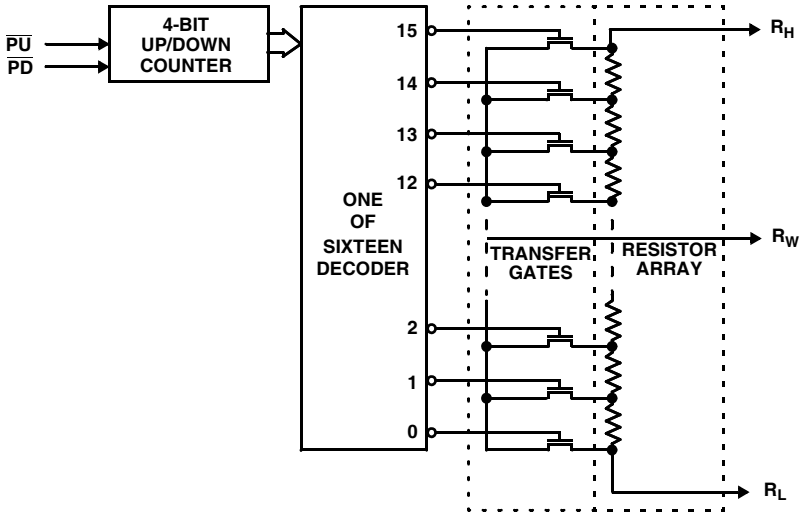
## Pin Descriptions

| µTQFN PIN | SYMBOL | BRIEF DESCRIPTION |
|---|---|---|
| 1 | $\overline{PU}$ | The $\overline{PU}$ is a negative-edge triggered input with internal pull-up. Toggling $\overline{PU}$ will move the wiper close to $R_H$ terminal. |
| 2 | $\overline{PD}$ | The $\overline{PD}$ is a negative-edge triggered input with internal pull-up. Toggling $\overline{PD}$ will move the wiper close to $R_L$ terminal. |
| 3 | $R_H$ | The $R_H$ and $R_L$ pins of the ISL23512 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is $V_{SS}$ and the maximum is $V_{CC}$. The terminology of $R_H$ and $R_L$ references the relative position of the terminal in relation to wiper movement direction selected by the $\overline{PU}/\overline{PD}$ input. |
| 4 | $V_{SS}$ | Ground |
| 6 | $R_W$ | The $R_W$ pin is the wiper terminal of the potentiometer, which is equivalent to the movable terminal of a mechanical potentiometer. |
| 7 | $R_L$ | The $R_H$ and $R_L$ pins of the ISL23512 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is $V_{SS}$ and the maximum is $V_{CC}$. The terminology of $R_H$ and $R_L$ references the relative position of the terminal in relation to wiper movement direction selected by the $\overline{PU}/\overline{PD}$ input. |
| 5, 8, 10 | NC | No connection. |
| 9 | $V_{CC}$ | Supply Voltage. |

## Block Diagrams




GENERAL




DETAILED

## Absolute Maximum Ratings

Storage Temperature . . . . . .-65°C to +150°C
Voltage at $\overline{PU}$ and $\overline{PD}$ Pin with Respect to GND . . -0.3V to $V_{CC}$+0.3
$V_{CC}$ . . . . . .-0.3V to +6V
Voltage at any DCP Pin with Respect to GND. . . . . .-0.3V to $V_{CC}$
$I_W$ (10s) . . . . . ±6mA
Latchup . . . . . Class II, Level A @ +125°C
ESD Rating
Human Body Model . . . . . .3kV
Machine Model. . . . . .250V

## Thermal Information

| Thermal Resistance (Typical, Notes 3, 4) | $\theta_{JA}$ (°C/W) | $\theta_{JC}$ (°C/W) |
|---|---|---|
| 10 Ld µTQFN . . . . . | 150 | 48.3 |

Maximum Junction Temperature (Plastic Package). . . . . .+150°C
Pb-free Reflow Profile . . . . . .see link below
http://www.intersil.com/pbfree/Pb-FreeReflow.asp

## Recommended Operating Conditions

Temperature Range (Extended Industrial). . . . . .-40°C to +125°C
$V_{CC}$ . . . . . 2.7V to 5.5V
Power Rating . . . . . .15mW
Wiper Current . . . . . .±3.0mA

*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.*

NOTE:

3. $\theta_{JA}$ is measured with the component mounted on a high effective thermal conductivity test board in free air. See Tech Brief TB379 for details.
4. For $\theta_{JC}$, the “case temp” location is the center of the exposed metal pad on the package underside.

## Potentiometer Specifications

Over recommended operating conditions, unless otherwise specified.

| SYMBOL | PARAMETER | TEST CONDITIONS | MIN (Note 18) | TYP (Note 5) | MAX (Note 18) | UNIT |
|---|---|---|---|---|---|---|
| $R_{TOTAL}$ | $R_H$ to $R_L$ Resistance | W option | | 10 | | kΩ |
| | $R_H$ to $R_L$ Resistance Tolerance | | -20 | | +20 | % |
| | End-to-End Temperature Coefficient | W option | | ±80 | | ppm/°C (Note 16) |
| $R_W$ | Wiper Resistance | Wiper current = $V_{CC}/R_{TOTAL}$ | | 130 | 400 | Ω |
| $V_{RH}$, $V_{RL}$ | $V_{RH}$ and $V_{RL}$ Terminal Voltages | $V_{RH}$ and $V_{RL}$ to GND | 0 | | $V_{CC}$ | V |
| $C_H/C_L/C_W$ (Note 17) | Potentiometer Capacitance | | | 10/10/25 | | pF |
| $I_{LkgDCP}$ | Leakage on DCP Pins | Voltage at pin from GND to $V_{CC}$ | | 0.1 | 1 | µA |
| **VOLTAGE DIVIDER MODE (0V @ $R_L$; $V_{CC}$ @ $R_H$; measured at $R_W$ unloaded)** | | | | | | |
| INL (Note 10) | Integral Non-linearity | | -1 | | 1 | LSB (Note 6) |
| DNL (Note 9) | Differential Non-linearity | Monotonic over all tap positions | -0.5 | | 0.5 | LSB (Note 6) |
| ZSerror (Note 7) | Zero-scale Error | W option | 0 | 0.3 | 3 | LSB (Note 6) |
| FSerror (Note 8) | Full-scale Error | W option | -3 | -0.3 | 0 | LSB (Note 6) |
| $TC_V$ (Note 11) | Ratiometric Temperature Coefficient | DCP register set to 8 hex | | ±4 | | ppm/°C |
| **RESISTOR MODE (Measurements between $R_W$ and $R_L$ with $R_H$ not connected, or between $R_W$ and $R_H$ with $R_L$ not connected)** | | | | | | |
| RINL (Note 15) | Integral Non-linearity | DCP register set between 1 hex and F hex; monotonic over all tap positions | -1.5 | | 1.5 | MI (Note 12) |
| RDNL (Note 14) | Differential Non-linearity | W option | -1 | | 1 | MI (Note 12) |
| Roffset (Note 13) | Offset | W option | 0 | 1 | 3 | MI (Note 12) |

## DC Electrical Specifications

Over recommended operating conditions, unless otherwise specified.

| SYMBOL | PARAMETER | TEST CONDITIONS | MIN (Note 18) | TYP (Note 5) | MAX (Note 18) | UNIT |
|---|---|---|---|---|---|---|
| $I_{CC}$ | $V_{CC}$ Active Current | $V_{CC}$ = 5.5V, perform wiper move operation | | | 150 | µA |
| $I_{SB}$ | Stand-by Current | Monotonic over all tap positions | | 0.6 | 3 | µA |
| $I_{Lkg}$ | $\overline{PU}$, $\overline{PD}$ Input Leakage Current | $V_{IN}$ = $V_{SS}$ to $V_{CC}$ | -2 | | +2 | µA |
| $V_{IH}$ | $\overline{PU}$, $\overline{PD}$ Input HIGH Voltage | | $V_{CC}$ x 0.7 | | | V |
| $V_{IL}$ | $\overline{PU}$, $\overline{PD}$ Input LOW Voltage | | | | $V_{CC}$ x 0.1 | V |
| $C_{IN}$ (Note 17) | $\overline{PU}$, $\overline{PD}$ Input Capacitance | $V_{CC}$ = 3.3V, $T_A$ = +25°C, f = 1MHz | | 10 | | pF |
| Rpull_up (Note 17) | Pull-up Resistor for $\overline{PU}$ and $\overline{PD}$ | | | 1 | | MΩ |

## AC Electrical Specifications

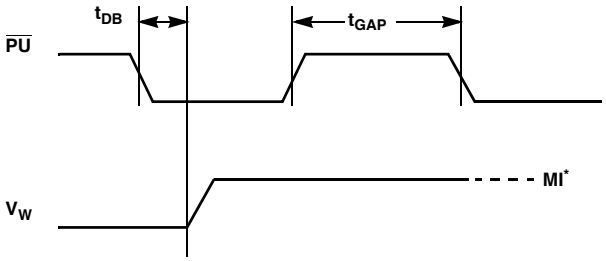
Over recommended operating conditions, unless otherwise specified. Limits are established by characterization.

| SYMBOL | PARAMETER | MIN (Note 18) | TYP (Note 5) | MAX (Note 18) | UNIT |
|---|---|---|---|---|---|
| $t_{GAP}$ | Time Between Two Separate Push Button Events | 2 | | | ms |
| $t_{DB}$ | Debounce Time | | 15 | 30 | ms |
| $t_{S\ SLOW}$ | Wiper Change on a Slow Mode | 100 | 250 | 375 | ms |
| $t_{S\ FAST}$ | Wiper Change on a Fast Mode | 25 | 50 | 75 | ms |
| $t_{stdn}$ (Note 17) | Time to Enter Shutdown Mode (Keep $\overline{PU}$ and $\overline{PD}$ Low) | | 2 | | s |
| $t_R$ $V_{CC}$ | $V_{CC}$ Power-up Rate | 0.2 | | 50 | V/ms |

NOTES:

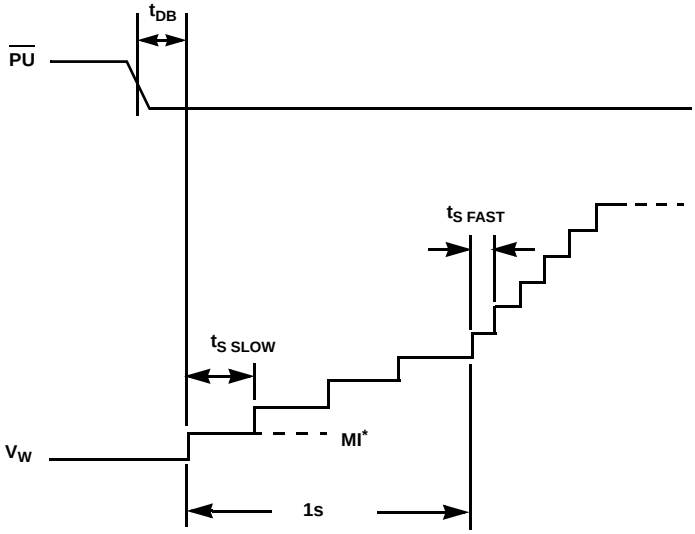
5. Typical values are for $T_A$ = +25°C and 3.3V supply voltage.
6. LSB: $[V(RW)_{15} – V(RW)_0]/15$. $V(RW)_{15}$ and $V(RW)_0$ are voltage on RW pin for the DCP register set to F hex and 0 hex respectively. LSB is the incremental voltage when changing from one tap to an adjacent tap.
7. ZS error = $V(RW)_0$/LSB.
8. FS error = $[V(RW)_{15} – V_{CC}]$/LSB.
9. DNL = $[V(RW)_i – V(RW)_{i-1}]$/LSB -1, for i = 1 to 15; i is the DCP register setting.
10. INL = $[V(RW)_i – i • LSB – V(RW)]$/LSB for i = 1 to 15
11. $TC_V = \frac{Max(V(RW)_i) - Min(V(RW)_i)}{[Max(V(RW)_i) + Min(V(RW)_i)]/2} \times \frac{10^6}{+165°C}$ for i = 5 to 15 decimal, T = -40°C to +125°C. Max( ) is the maximum value of the wiper voltage and Min ( ) is the minimum value of the wiper voltage over the temperature range.
12. MI = $|RW_{15} – RW_0|/15$. MI is a minimum increment. $RW_{15}$ and $RW_0$ are the measured resistances for the DCP register set to 0F hex and 00 hex respectively.
13. Roffset = $RW_0$/MI, when measuring between $R_W$ and $R_L$.
    Roffset = $RW_{15}$/MI, when measuring between $R_W$ and $R_H$.
14. RDNL = $(RW_i – RW_{i-1})$/MI, for i = 1 to 15.
15. RINL = $[RW_i – (MI • i) – RW_0]$/MI, for i = 1 to 15.
16. $TC_R = \frac{[Max(Ri) - Min(Ri)]}{[Max(Ri) + Min(Ri)]/2} \times \frac{10^6}{+165°C}$ for i = 5 to 15, T = -40°C to +125°C. Max( ) is the maximum value of the resistance and Min ( ) is the minimum value of the resistance over the temperature range.
17. Limits should be considered typical and are not production tested.
18. Parts are 100% tested at +25°C. Over-temperature limits established by characterization and are not production tested.

## Slow Mode Timing



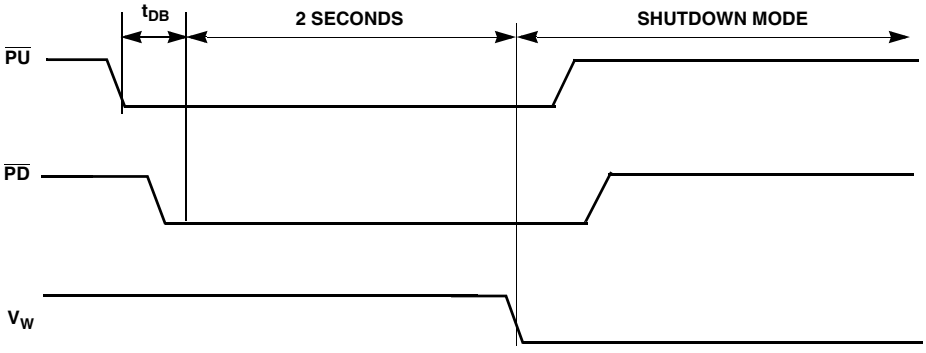

*MI in the AC timing diagram refers to the minimum incremental change in the wiper voltage.

## Fast Mode Timing




*MI in the AC timing diagram refers to the minimum incremental change in the wiper voltage.

## Shutdown Mode Timing



## Typical Performance Curves

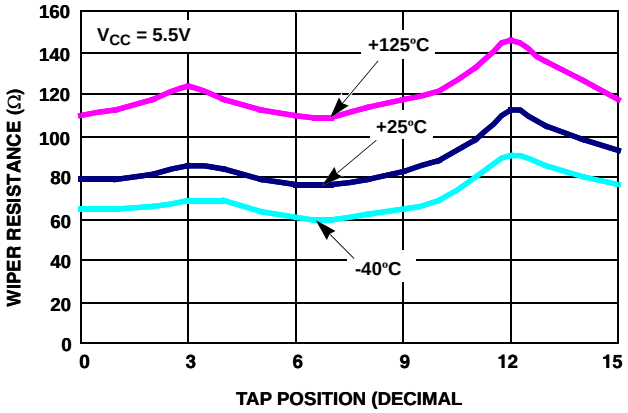



FIGURE 1. WIPER RESISTANCE vs TAP POSITION [ I(RW) = $V_{CC}/R_{TOTAL}$ ] FOR 10kΩ (W)

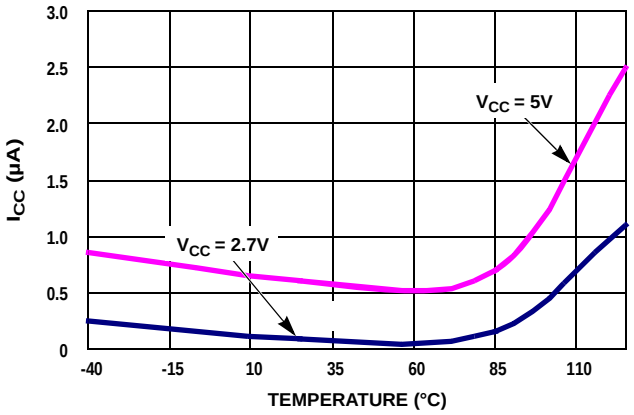



FIGURE 2. STANDBY $I_{CC}$ vs TEMPERATURE

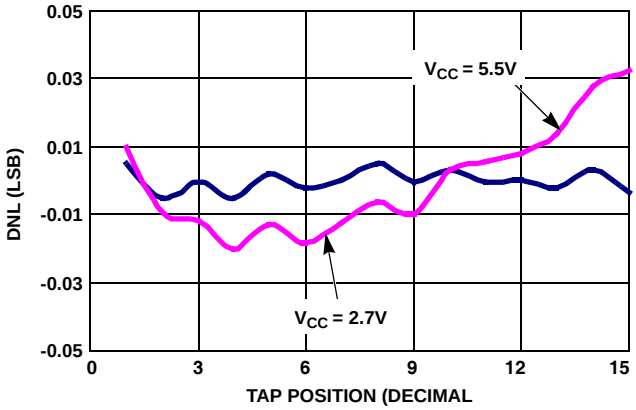



FIGURE 3. DNL vs TAP POSITION IN VOLTAGE DIVIDER MODE FOR 10kΩ (W)

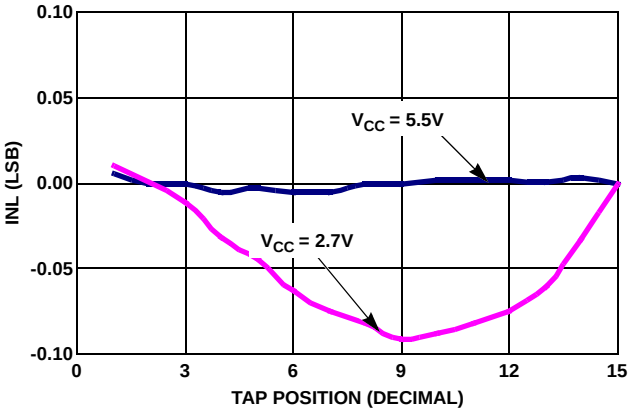



FIGURE 4. INL vs TAP POSITION IN VOLTAGE DIVIDER MODE FOR 10kΩ (W)

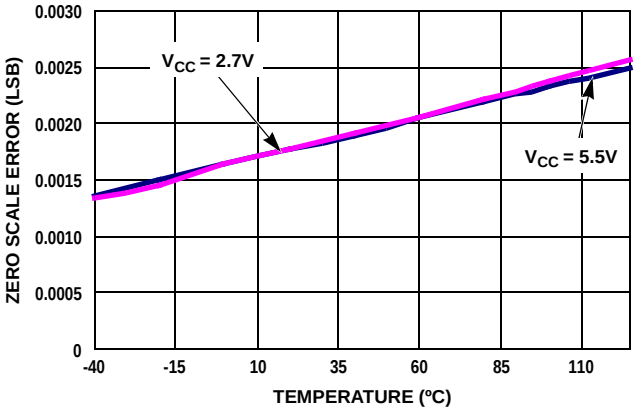



FIGURE 5. ZS ERROR vs TEMPERATURE

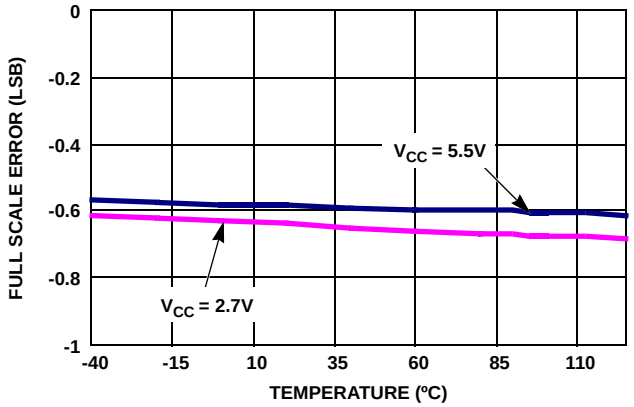



FIGURE 6. FS ERROR vs TEMPERATURE

## Typical Performance Curves (Continued)

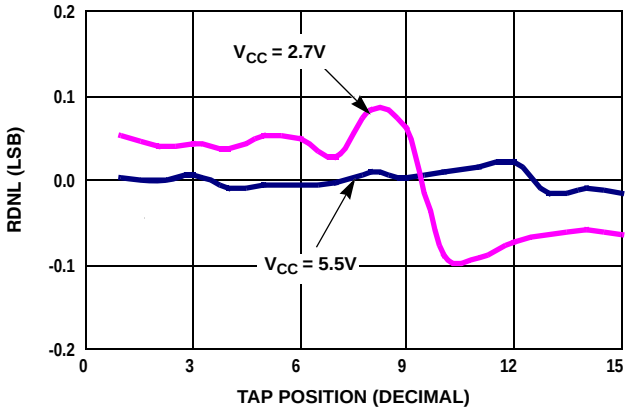



FIGURE 7. DNL vs TAP POSITION IN RHEOSTAT MODE FOR 10kΩ (W)

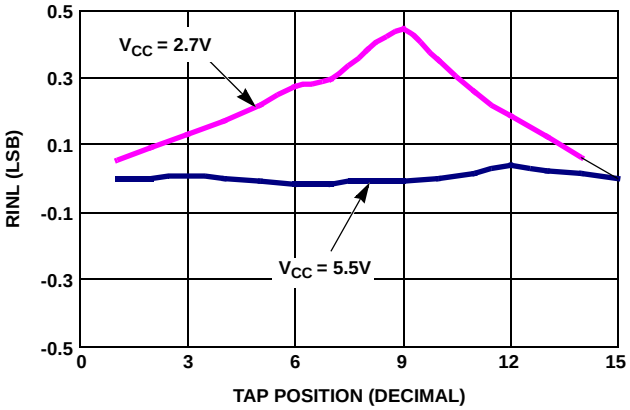



FIGURE 8. INL vs TAP POSITION IN RHEOSTAT MODE FOR 10kΩ (W)

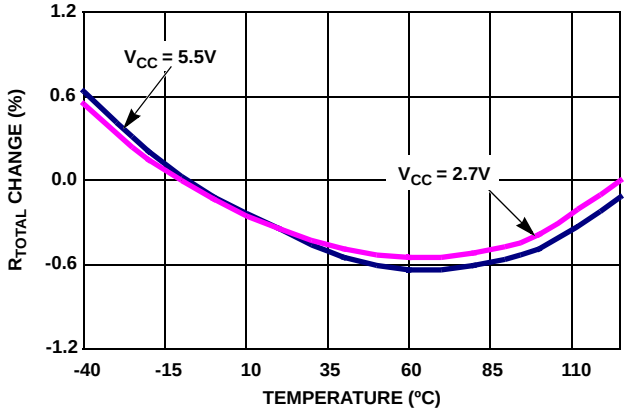



FIGURE 9. END TO END $R_{TOTAL}$ % CHANGE vs TEMPERATURE

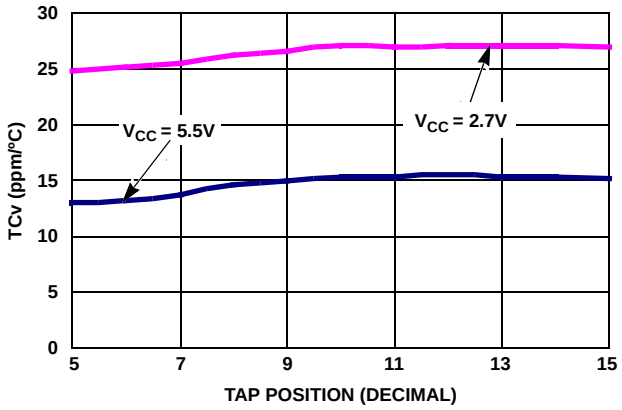



FIGURE 10. TC FOR VOLTAGE DIVIDER MODE IN ppm

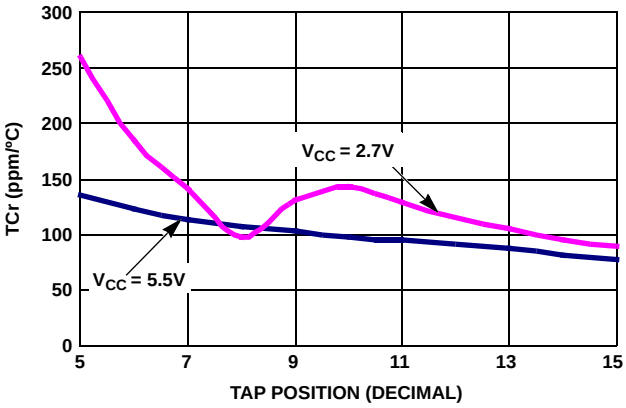



FIGURE 11. TC FOR RHEOSTAT MODE IN ppm

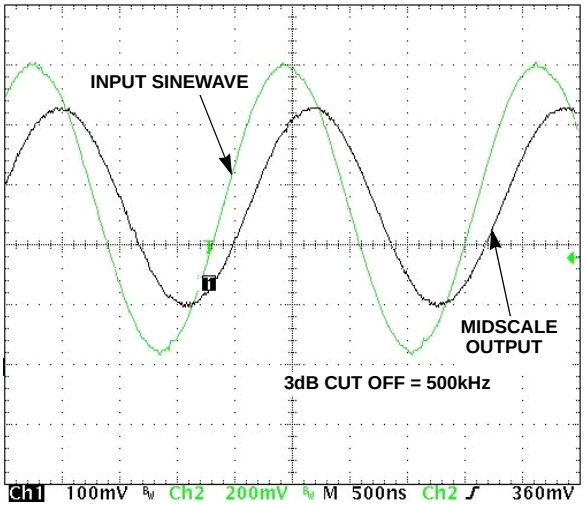



FIGURE 12. FREQUENCY RESPONSE (500kHz)

## Power-up and Power-down Requirements

There are no restrictions on the power-up or power-down conditions of $V_{cc}$ and the voltages applied to the potentiometer pins provided that $V_{cc}$ is always more positive than or equal to $V_{RH}$ and $V_{RL}$, i.e., $V_{cc} \geq V_{RH}, V_{RL}$. The $V_{cc}$ ramp rate specification is always in effect.

## Pin Descriptions

### $R_H$ and $R_L$

The $R_H$ and $R_L$ pins of the ISL23512 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is $V_{SS}$ and the maximum is $V_{CC}$. The terminology of $R_H$ and $R_L$ references the relative position of the terminal in relation to wiper movement direction.

### $R_W$

The $R_W$ pin is the wiper terminal of the potentiometer, which is equivalent to the movable terminal of a mechanical potentiometer. The default wiper position at power-up is at 0 tap.

### $\overline{PU}$

The debounced $\overline{PU}$ input is used to increment the wiper position. An on-chip pull-up holds the $\overline{PU}$ input HIGH. A switch closure to ground or a LOW logic level will, after a debounce time, move the wiper to the next adjacent higher tap position.

### $\overline{PD}$

The debounced $\overline{PD}$ input is used to decrement the wiper position. An on-chip pull-up holds the $\overline{PD}$ input HIGH. A switch closure to ground or a LOW logic level will, after a debounce time, move the wiper to the next adjacent lower tap position.

## Device Operation

There are three sections of the ISL23512: the input control, the counter and decode section and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch, connecting a point on the resistor array to the wiper output. The resistor array is comprised of 15 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 ISL23512 is designed to interface directly to two push button switches for effectively moving the wiper up or down. The $\overline{PU}$ and $\overline{PD}$ inputs increment or decrement a 4-bit counter respectively. The output of this counter is decoded to select one of the sixteen wiper positions along the resistive array. The wiper increment input, $\overline{PU}$ and the wiper decrement input, $\overline{PD}$ are both connected to an internal pull-up so that they normally remain HIGH. When pulled LOW by an external push button switch or a logic LOW level input, the wiper will be switched to the next adjacent tap position.

Internal debounce circuitry prevents inadvertent switching of the wiper position if $\overline{PU}$ or $\overline{PD}$ remain LOW for less than 15ms, typical. Each of the buttons can be pushed either once for a single increment/decrement or continuously for multiple increments/decrements. The number of increments/decrements of the wiper position depend on how long the button is being pushed. When making a continuous push, after the first second, the increment/decrement speed increases. For the first second, the device will be in the slow scan mode. Then, if the button is held for longer than 1s, the device will go into the fast scan mode. As soon as the button is released, the ISL23512 will return to a stand-by condition.

If both $\overline{PU}$ and $\overline{PD}$ buttons are pulled low more than 15ms from each other, all commands are ignored upon release of ALL buttons.

The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme.

### Shutdown Mode

The ISL23512 enters into Shutdown Mode if both $\overline{PU}$ and $\overline{PD}$ inputs are kept LOW for 2s. In this mode, the resistors array is totally disconnected from its $R_H$ pin and the wiper is moved to the position closest to the $R_L$ pin, as shown in Figure 13.

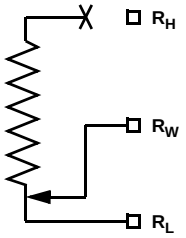



**FIGURE 13. DCP CONNECTION IN SHUTDOWN MODE**

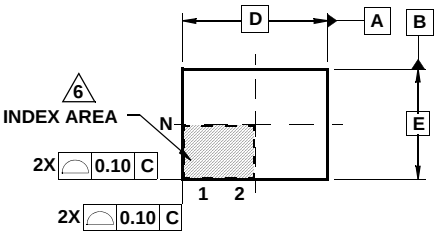
Note that $\overline{PU}$ and $\overline{PD}$ inputs must be pulled LOW within $t_{DB}$ time window of 15ms (see “Shutdown Mode Timing” on page 5) otherwise all commands will be ignored until both inputs are released.

Holding either $\overline{PU}$ or $\overline{PD}$ input LOW for more than 15ms will exit shutdown mode and return wiper to prior shutdown position. If $\overline{PU}$ or $\overline{PD}$ will be held LOW for more than 250ms, the ISL23512 will start auto-increment or auto-decrement of wiper position.

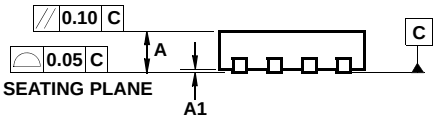
### $R_{TOTAL}$ with $V_{CC}$ Removed

The end-to-end resistance of the array will fluctuate once $V_{CC}$ is removed.

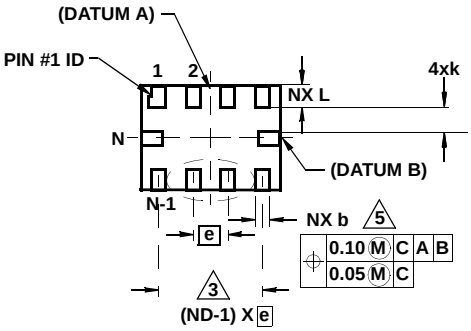
## Ultra Thin Quad Flat No-Lead Plastic Package (UTQFN)



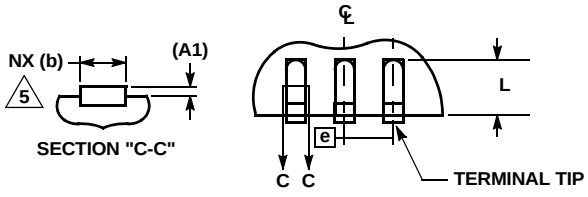

TOP VIEW



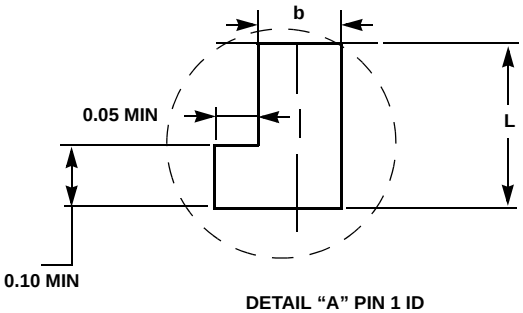

SIDE VIEW




BOTTOM VIEW




FOR ODD TERMINAL/SIDE




DETAIL "A" PIN 1 ID

### L10.2.1x1.6A

**10 LEAD ULTRA THIN QUAD FLAT NO-LEAD PLASTIC PACKAGE**

| SYMBOL | MILLIMETERS | | | NOTES |
|---|---|---|---|---|
| | MIN | NOMINAL | MAX | |
| A | 0.45 | 0.50 | 0.55 | - |
| A1 | - | - | 0.05 | - |
| A3 | | 0.127 REF | | - |
| b | 0.15 | 0.20 | 0.25 | 5 |
| D | 2.05 | 2.10 | 2.15 | - |
| E | 1.55 | 1.60 | 1.65 | - |
| e | | 0.50 BSC | | - |
| k | 0.20 | - | - | - |
| L | 0.35 | 0.40 | 0.45 | - |
| N | | 10 | | 2 |
| Nd | | 4 | | 3 |
| Ne | | 1 | | 3 |
| θ | 0 | - | 12 | 4 |

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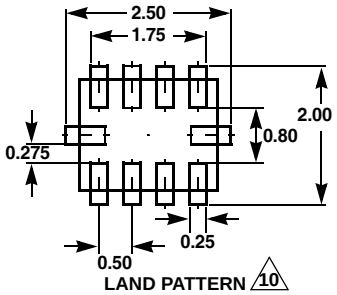
NOTES:

1. Dimensioning and tolerancing conform to ASME Y14.5-1994.
2. N is the number of terminals.
3. Nd and Ne refer to the number of terminals on D and E side, respectively.
4. All dimensions are in millimeters. Angles are in degrees.
5. Dimension b applies to the metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip.
6. 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.
7. Maximum package warpage is 0.05mm.
8. Maximum allowable burrs is 0.076mm in all directions.
9. Same as JEDEC MO-255UABD except:
   No lead-pull-back, "A" MIN dimension = 0.45 not 0.50mm
   "L" MAX dimension = 0.45 not 0.42mm.
10. For additional information, to assist with the PCB Land Pattern Design effort, see Intersil Technical Brief TB389.

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