

PRELIMINARY



# WMS7170/1

**NONVOLATILE DIGITAL POTENTIOMETERS**

**WITH UP/DOWN (3-WIRE) INTERFACE,**

**10KOHM, 50KOHM, 100KOHM RESISTANCE**

**100 TAPS**

**WITH OPTIONAL OUTPUT BUFFER**



## 1. GENERAL DESCRIPTION

The WMS717x is a 100 non-volatile linear digital potentiometers available in 10K $\Omega$ , 50K $\Omega$  and 100K $\Omega$  resistance values. The WMS7170/1 can be used as a three-terminal potentiometer or as a two terminal variable resistor in a wide variety of applications.

The output of each potentiometer is determined by the wiper position, which varies in linearly between  $V_A$  and  $V_B$  terminal according to the content stored in the volatile Tap Register (TR) which is programmed through Up/Down (Increment/Decrement) interface. The channel has one non-volatile memory location (NVMEM0) that can be directly written to by users through the Up/Down interface. Power-on recall is also built in so the content of the NVMEM0 to Tap Register is automatically loaded.

The WMS7170/1 devices pin out the resistor wiper directly. The WMS7171 devices feature an output buffer with 3mA minimum drive capability.

All the WMS7170/1 devices are single channel devices offered in 8-pin PDIP, SOIC and MSOP packages. The WMS7170/1 devices operate over a wide operating voltage ranging from 2.7V to 5.5V.

## 2. FEATURES

- Drop-in replacements for many popular parts
- Available output buffer for WMS7171 devices
- Single linear-taper channel
- 100 taps
- 10K, 50K and 100K end-to end resistance
- $V_{SS}$  to  $V_{DD}$  terminal voltages
- Non-volatile storage of wiper positions with power-on recall
- Data storage and potentiometer control through Up/Down (3-wire) interface
- Endurance 100,000 write cycles
- Data retention 100 years
- Package options:
  - 8-pin PDIP, SOIC or MSOP
- Industrial temperature range: -40° ~ 85°C
- Single supply operation 2.7V to 5.5V



3. BLOCK DIAGRAM

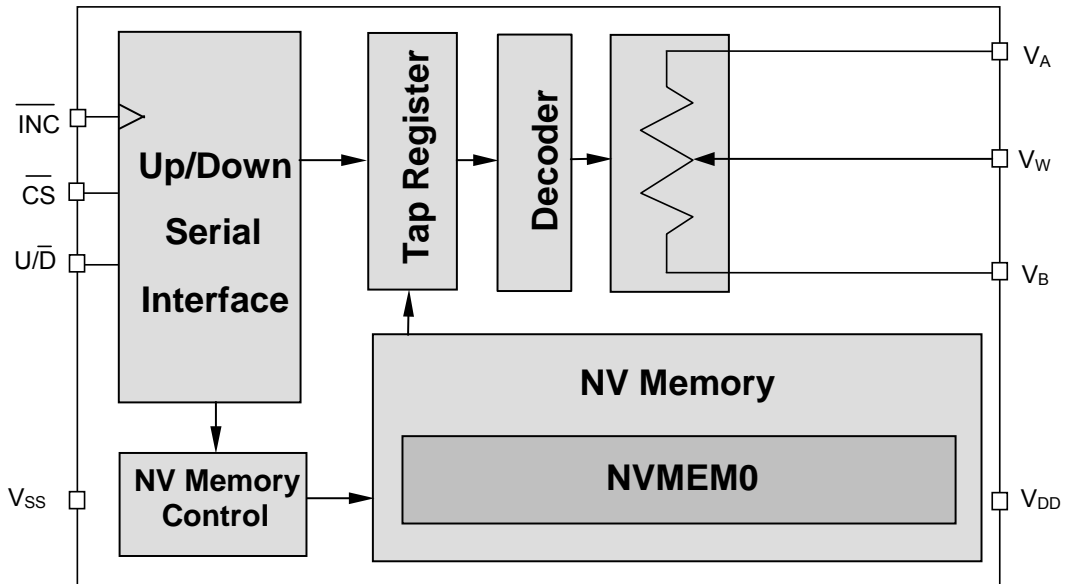


FIGURE 1 – WMS7170 BLOCK DIAGRAM (Rheostat Mode)

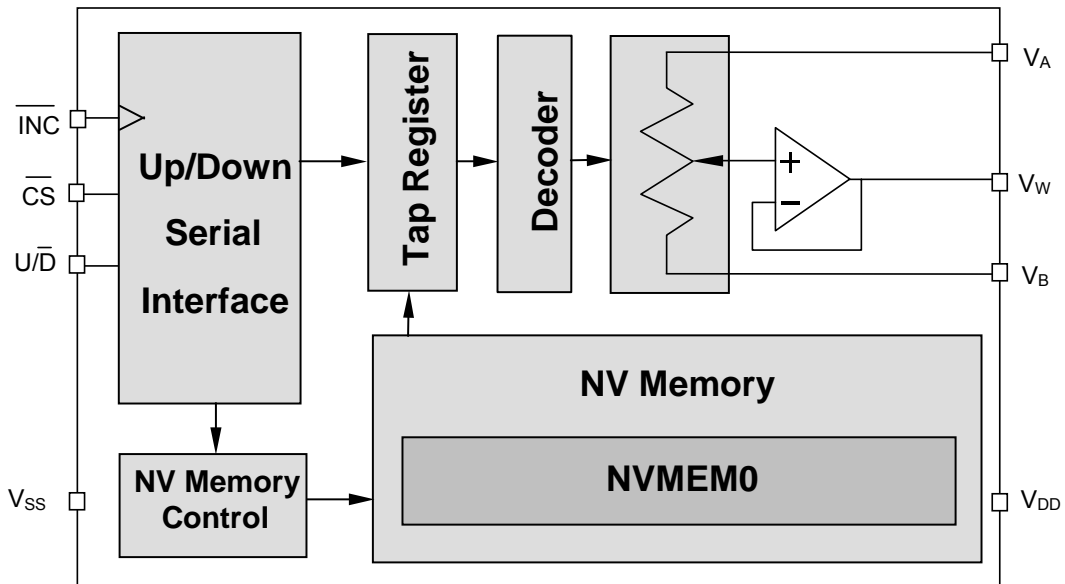


FIGURE 2 – WMS7171 BLOCK DIAGRAM (Divider Mode)

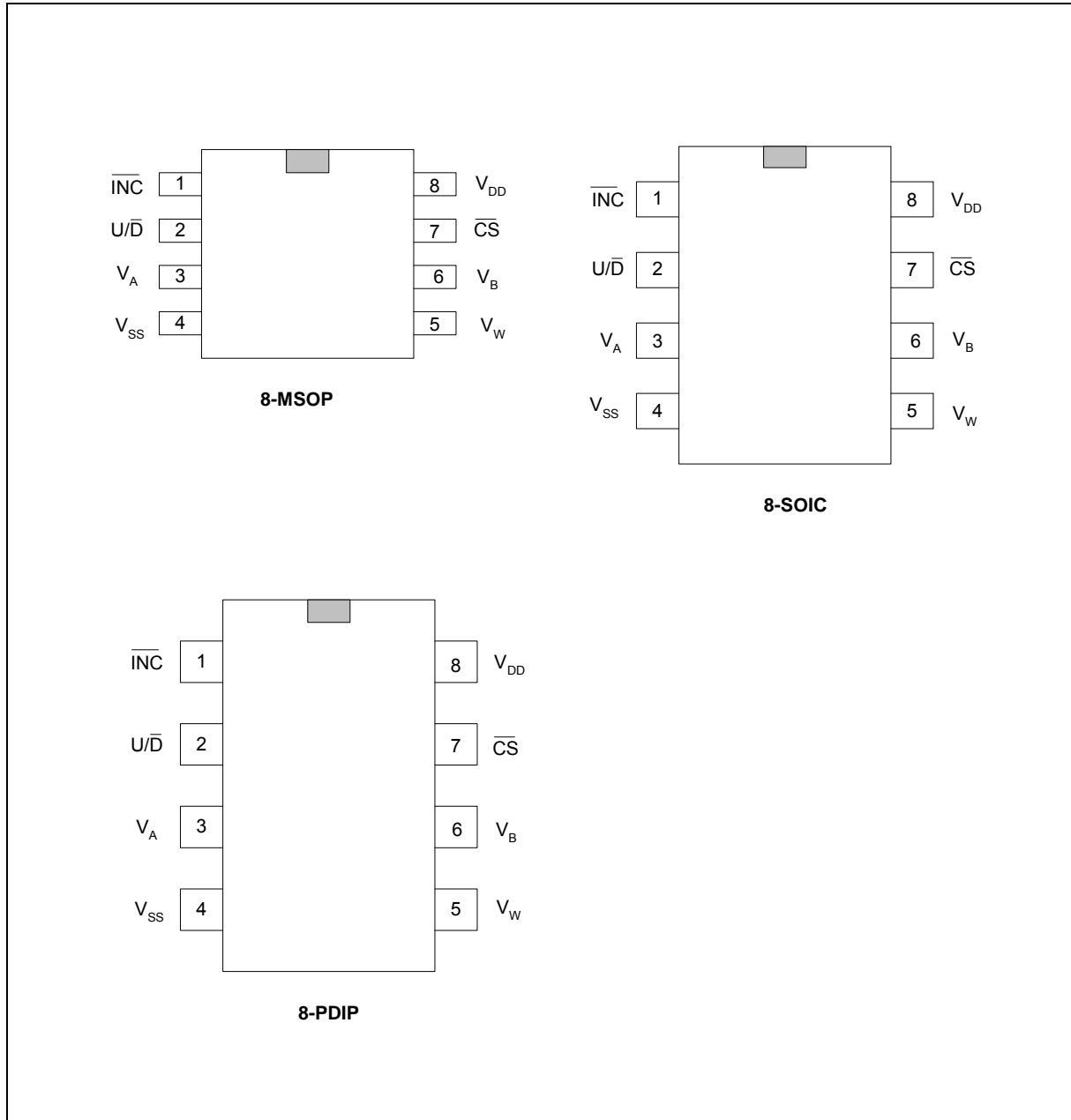


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## 5. PIN CONFIGURATION





## 6. PIN DESCRIPTION

TABLE 1 – PIN DESCRIPTION

| Pin Name                       | I/O | Description   |
|--------------------------------|-----|---|
| $\overline{\text{INC}}$        | I   | Increment Control. A High-Low transition of $\overline{\text{INC}}$ when $\overline{\text{CS}}$ is low will move the wiper up or down for one increment based on the $\text{U}/\overline{\text{D}}$ input |
| $\text{U}/\overline{\text{D}}$ | I   | Up/Down control Input. High state will cause the wiper to move to the $\text{V}_\text{B}$ terminal, Low state to the $\text{V}_\text{A}$ terminal   |
| $\text{V}_\text{A}$            | -   | High terminal of WinPot   |
| $\text{V}_\text{SS}$           | -   | Ground pin, logic ground reference  |
| $\text{V}_\text{DD}$           | -   | Power Supply  |
| $\overline{\text{CS}}$         | I   | Chip Select. When $\overline{\text{CS}}$ is HIGH, the part is deselected and the device will be in the standby mode. $\overline{\text{CS}}$ LOW enables the part, placing it in the active power mode     |
| $\text{V}_\text{B}$            | -   | Low terminal of WinPot  |
| $\text{V}_\text{W}$            | O   | Wiper terminal of WinPot (can be buffered), its position on the resistor array is controlled by the inputs on $\overline{\text{INC}}$ , $\text{U}/\overline{\text{D}}$ , and $\overline{\text{CS}}$       |



## **7. FUNCTIONAL DESCRIPTION**

The WMS7170/1, a nonvolatile digitally programmable potentiometers with 100 taps, with or without output buffer, is designed to operate as both a potentiometer or a variable resistor depending upon the output configuration selected.

The chip can store up to one 8-bit word in a nonvolatile memory (NVMEM0) in order to set the tap register value when the device is powered up.

The WMS7170/1 is controlled by a serial Up-Down (3-wire) interface that allows setting the tap register value as well as storing data in the nonvolatile memory.

### **7.1. POTENTIOMETER AND RHEOSTAT MODES**

The WMS7170/1 can operate as either a rheostat or as a potentiometer (voltage divider). When in the potentiometer configuration there are two possible modes. One is done using WMS7170 Winpot device without the output buffer and the other mode is done with WMS7171 WinPot device with the output buffer.

#### **7.1.1. Rheostat Configuration**

The WMS7170/1 acts as a two terminal resistive element in the rheostat configuration where one terminal can be connected to either the end point pins of the resistor ( $V_A$  and  $V_B$ ) and the other terminal is the wiper ( $V_W$ ) pin. This configuration controls the resistance between the two terminals and the resistance can be adjusted by sending the corresponding tap register setting to the WMS7170/1 or can also be set by loading a pre-set tap register value from nonvolatile memory NVMEM0 upon power up.

#### **7.1.2. Potentiometer Configuration**

In potentiometer configuration an input voltage is applied to either one of the end point pins ( $V_A$  or  $V_B$ ). The voltage on the wiper pin will be proportional to the voltage difference between  $V_A$  and  $V_B$  and the wiper setting. The resistance cannot be directly measured in this configuration.

### **7.2. NON-VOLATILE MEMORY (NVMEM)**

The WMS7170/1 has one NVMEM position available for storing the potentiometer setting. The NVMEM position can be directly written via the Up/Down interface. The potentiometer is loaded with the value stored in the NVMEM0 on power up.



### 7.3. SERIAL DATA INTERFACE

The Up/Down family has a 3-wire Serial Data Interface consisting of  $\overline{CS}$ ,  $\overline{INC}$ ,  $\overline{U/D}$  pins. Only UP/DOWN operations can be performed. The key features of this interface include:

- Increment/Decrement operations on the tap register (TR)
- Direct refresh of tap register (TR) from internal NVMEM
- Nonvolatile storage of the present tap register value into the NVMEM and automatic recall at power up
- For WMS7171 devices, output buffer amplifier

### 7.4. OPERATION OVERVIEW

The wiper position or the Tap Register(TR) setting can only be changed by the UP/DOWN operation with the combination of  $\overline{CS}$ ,  $\overline{U/D}$ , and  $\overline{INC}$  signals. When  $\overline{CS}$  is low, the part will be activated and the TR setting can be changed by toggling  $\overline{INC}$ , and TR will move up when  $\overline{U/D}$  is High and move down when  $\overline{U/D}$  is Low. The TR setting will be stored into the user NVMEM automatically each time  $\overline{CS}$  goes high while  $\overline{INC}$  holds high. Otherwise, if  $\overline{INC}$  is low when  $\overline{CS}$  goes high, the TR setting will not be stored. The NVMEM content will be automatically loaded into TR at Power On. The user NVMEM can be tested through the voltage measurement on the wiper pin after saving TR setting into the NVMEM and reloading into the TR. When the TR setting is already at LOW, further DOWN operations won't change the setting. Similarly, when TR setting is at HIGH, further UP operations won't change the setting.

When  $\overline{CS}$  is held HIGH, the part will be in Standby mode and the TR setting will not be changed.

The operating modes of Up/Down are summarized below.

| $\overline{CS}$ | $\overline{U/D}$ | $\overline{INC}$ | Operation                   |
|-----------------|------------------|------------------|-----------------------------|
| Low             | High             | High to Low      | Wiper toward $V_A$          |
| Low             | Low              | High to Low      | Wiper toward $V_B$          |
| Low to High     | x                | High             | Store Wiper Position        |
| Low to High     | x                | Low              | No Store, Return to Standby |
| High            | x                | x                | Standby                     |

Note: x means don't care





## 8. TIMING DIAGRAMS

Conditions:  $V_{DD} = +2.7V$  to  $5.5V$ ,  $V_A = V_{DD}$ ,  $V_B = 0V$ ,  $T = 25^\circ C$

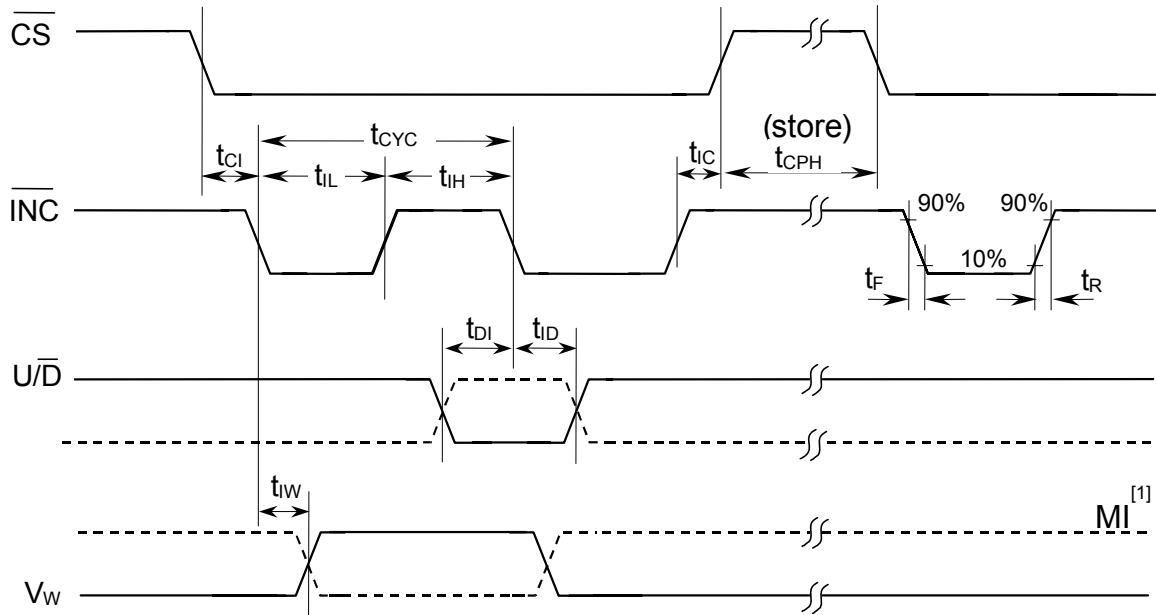


FIGURE 3 –WMS7170/1 TIMING DIAGRAM

Note:

[1] MI in the AC Timing diagram (Figure 3) refers to the minimum incremental change in the wiper output due to a change in the wiper position.



TABLE 10 – TIMING PARAMETERS

| PARAMETERS  | SYMBOL                       | MIN.                    | MAX.                               | UNITS         |
|---|------------------------------|-------------------------|------------------------------------|---------------|
| $\overline{\text{CS}}$ to $\overline{\text{INC}}$ Setup             | $t_{\text{CI}}$              | 100                     |                                    | ns            |
| U/ $\overline{\text{D}}$ to $\overline{\text{INC}}$ Setup           | $t_{\text{DI}}$              | 50                      |                                    | ns            |
| U/ $\overline{\text{D}}$ to $\overline{\text{INC}}$ Hold            | $t_{\text{ID}}$              | 100                     |                                    | ns            |
| $\overline{\text{INC}}$ LOW Period                                  | $t_{\text{IL}}$              | 250                     |                                    | ns            |
| $\overline{\text{INC}}$ HIGH Period                                 | $t_{\text{IH}}$              | 250                     |                                    | ns            |
| $\overline{\text{INC}}$ Inactive to $\overline{\text{CS}}$ Inactive | $t_{\text{IC}}$              | 1                       |                                    | $\mu\text{s}$ |
| $\overline{\text{CS}}$ Deselect Time (NO STORE)                     | $t_{\text{CPH}}$             | 100                     |                                    | ns            |
| $\overline{\text{CS}}$ Deselect Time (STORE)                        | $t_{\text{CPH}}$             | 15 (2.7V)               |                                    | ms            |
| $\overline{\text{INC}}$ to $V_{\text{W}}$ Change                    | $t_{\text{IW}}$              |                         | 5                                  | $\mu\text{s}$ |
| $\overline{\text{INC}}$ Cycle Time                                  | $t_{\text{CYC}}$             | 1                       |                                    | $\mu\text{s}$ |
| $\overline{\text{INC}}$ Input Rise and Fall Time                    | $t_{\text{R}}, t_{\text{F}}$ |                         | 500                                | $\mu\text{s}$ |
| Power-Up to Wiper Stable  | $t_{\text{PU}}$              |                         | 1                                  | ms            |
| $V_{\text{CC}}$ Power-Up rate                                       | $t_{\text{R}} V_{\text{CC}}$ | 0.2<br>(13ms<br>0-2.7V) | 50<br>(54 $\mu\text{s}$<br>0-2.7V) | V/ms          |



## 9. ABSOLUTE MAXIMUM RATINGS

TABLE 11 – ABSOLUTE MAXIMUM RATINGS (PACKAGED PARTS)<sup>[1]</sup>

| Conditions                        | Values   |
|-----------------------------------|--|
| Junction temperature              | 150°C  |
| Storage temperature               | -65° to +150°C                                       |
| Voltage applied to any pad        | (V <sub>SS</sub> – 0.3V) to (V <sub>DD</sub> + 0.3V) |
| V <sub>DD</sub> – V <sub>SS</sub> | -0.3 to 7.0V   |

TABLE 12 – OPERATING CONDITIONS (PACKAGED PARTS)

| Conditions                             | Values         |
|--|----------------|
| Commercial operating temperature range | 0°C to +70°C   |
| Extended operating temperature         | -20°C to +70°C |
| Industrial operating temperature       | -40°C to +85°C |
| Supply voltage (V <sub>DD</sub> )      | +2.7V to +5.5V |
| Ground voltage (V <sub>SS</sub> )      | 0V             |

<sup>[1]</sup> Stresses above those listed may cause permanent damage to the device. Exposure to the absolute maximum ratings may affect device reliability. Functional operation is not implied at these conditions



## 10. ELECTRICAL CHARACTERISTICS

TABLE 12 – ELECTRICAL CHARACTERISTICS (Packaged parts)

| PARAMETERS                                    | SYMBOL   | MIN.               | TYP. | MAX.               | UNITS  | CONDITIONS  |
|---|--|--------------------|------|--------------------|--------|---|
| <b>Rheostat Mode</b>                          |  |                    |      |                    |        |   |
| Nominal Resistance                            | R  | -20                |      | +20                | %      | T=25°C, V <sub>W</sub> open   |
| Different Non Linearity <sup>[2]</sup>        | DNL  | -1                 |      | +1                 | LSB    |   |
| Integral Non Linearity <sup>[2]</sup>         | INL  | -1                 |      | +1                 | LSB    |   |
| Tempo <sup>1</sup>                            | $\Delta R_{AB}/\Delta T$                         |                    | 300  |                    | ppm/°C |   |
| Wiper Resistance <sup>[2]</sup>               | R <sub>W</sub>                                   |                    | 50   |                    | Ω      | V <sub>DD</sub> =5V, I=V <sub>DD</sub> /R <sub>Total</sub>                            |
|   |  |                    | 80   |                    | Ω      | V <sub>DD</sub> =2.7V, I=V <sub>DD</sub> /R <sub>Total</sub>                          |
| Wiper Current                                 | I <sub>W</sub>                                   | -1                 |      | 1                  | mA     |   |
| <b>Divider Mode</b>                           |  |                    |      |                    |        |   |
| Resolution                                    | N  | 8                  |      |                    | Bits   |   |
| Different Non Linearity <sup>[2]</sup>        | DNL  | -1                 | ±0.2 | +1                 | LSB    |   |
| Integral Non Linearity <sup>[2]</sup>         | INL  | -1                 | ±0.1 | +1                 | LSB    |   |
| Temperature Coefficient <sup>[1]</sup>        | $\Delta V_w/\Delta T$                            |                    | +20  |                    | ppm/°C | Code = 80h  |
| Full Scale Error                              | V <sub>FSE</sub>                                 | -1                 |      | 0                  | LSB    | Code = Full Scale   |
| Zero Scale Error                              | V <sub>ZSE</sub>                                 | 0                  |      | 1                  | LSB    | Code = Zero Scale   |
| <b>Resistor Terminal</b>                      |  |                    |      |                    |        |   |
| Voltage Range                                 | V <sub>A</sub> , V <sub>B</sub> , V <sub>W</sub> | V <sub>SS</sub>    |      | V <sub>DD</sub>    | V      |   |
| Terminal Capacitance <sup>[1]</sup>           | C <sub>A</sub> , C <sub>B</sub>                  |                    | 30   |                    | pF     |   |
| Wiper Capacitance <sup>[1]</sup>              |  |                    | 30   |                    | pF     |   |
| <b>Dynamic Characteristics <sup>[1]</sup></b> |  |                    |      |                    |        |   |
| Bandwidth –3dB                                | BW <sub>10K</sub>                                |                    | 1.5  |                    | MHz    | V <sub>DD</sub> =5V, V <sub>B</sub> =V <sub>SS</sub>                                  |
|   | BW <sub>50K</sub>                                |                    | 300  |                    | KHz    | Code = 80h  |
|   | BW <sub>100K</sub>                               |                    | 200  |                    | KHz    |   |
| Settling Time to 1 LSB                        | T <sub>S</sub>                                   |                    | 80   | 100                | uS     |   |
| <b>Analog Output (Buffer enables)</b>         |  |                    |      |                    |        |   |
| Amp Output Current                            | I <sub>OUT</sub>                                 | 3                  |      |                    | mA     | V <sub>O</sub> =1/2 scale   |
| Amp Output Resistance                         | R <sub>out</sub>                                 |                    | 1    | 10                 | Ω      | I <sub>L</sub> = 100uA  |
| Total Harmonic Distortion <sup>[1]</sup>      | THD  |                    |      | 0.08               | %      | V <sub>A</sub> =2.5V, V <sub>DD</sub> =5V, f=1kHz, V <sub>IN</sub> =1V <sub>RMS</sub> |
| <b>Digital Inputs/Outputs</b>                 |  |                    |      |                    |        |   |
| Input High Voltage                            | V <sub>IH</sub>                                  | 0.7V <sub>DD</sub> |      |                    | V      |   |
| Input Low Voltage                             | V <sub>IL</sub>                                  |                    |      | 0.3V <sub>DD</sub> | V      |   |



| PARAMETERS                        | SYMBOL                  | MIN. | TYP. | MAX. | UNITS   | CONDITIONS                                     |
|-----------------------------------|-------------------------|------|------|------|---------|--|
| Output Low Voltage                | $V_{OL}$                |      |      | 0.4  | V       | $I_{OL}=2mA$                                   |
| Input Leakage Current             | $I_{LI}$                | -1   |      | +1   | $\mu A$ | $\overline{CS}=V_{DD}, Vin=V_{SS} \sim V_{DD}$ |
| Output Leakage Current            | $I_{Lo}$                | -1   |      | +1   | $\mu A$ | $\overline{CS}=V_{DD}, Vin=V_{SS} \sim V_{DD}$ |
| Input Capacitance <sup>[1]</sup>  | $C_{IN}$                |      | 25   |      | pF      | $V_{DD}=5V, fc = 1Mhz$                         |
| Output Capacitance <sup>[1]</sup> | $C_{OUT}$               |      | 25   |      | pF      | $V_{DD}=5V, fc = 1Mhz$                         |
| <b>Power Requirements</b>         |                         |      |      |      |         |  |
| Operating Voltage                 | $V_{DD}$                | 2.7  |      | 5.5  | V       |  |
| Operating Current                 | $I_{DDR}$               |      | 0.5  | 1    | mA      | All ops except NVMEM program                   |
| Operating Current                 | $I_{DDW}$               |      | 1    | 2    | mA      | During Non-volatile memory program             |
| Standby Current                   | $I_{SA}$ <sup>[3]</sup> |      | 0.5  | 1    | mA      | Buffer is active, NOP, no load                 |
|                                   | $I_{SB}$ <sup>[4]</sup> |      | 0.1  | 1    | $\mu A$ | Buffer is inactive, Power Down, No load        |
| Power Supply Rejection Ratio      | PSRR                    |      |      | 1    | LSB/V   | $V_{DD}=5V \pm 10\%, Code=80H$                 |

## Notes:

[1] Not subject to production test.

[2]  $LSB = (V_A - V_B) / (T - 1)$ ;  $DNL = (V_{i+1} - V_i) / LSB$ ;  $INL = (V_i - i * LSB) / LSB$ ;  
where  $i = [0, (T - 1)]$  and  $T = \#$  of taps of the device.

[3] WMS71x1 only.

[4] WMS71x0 only.



10.1 TEST CIRCUITS

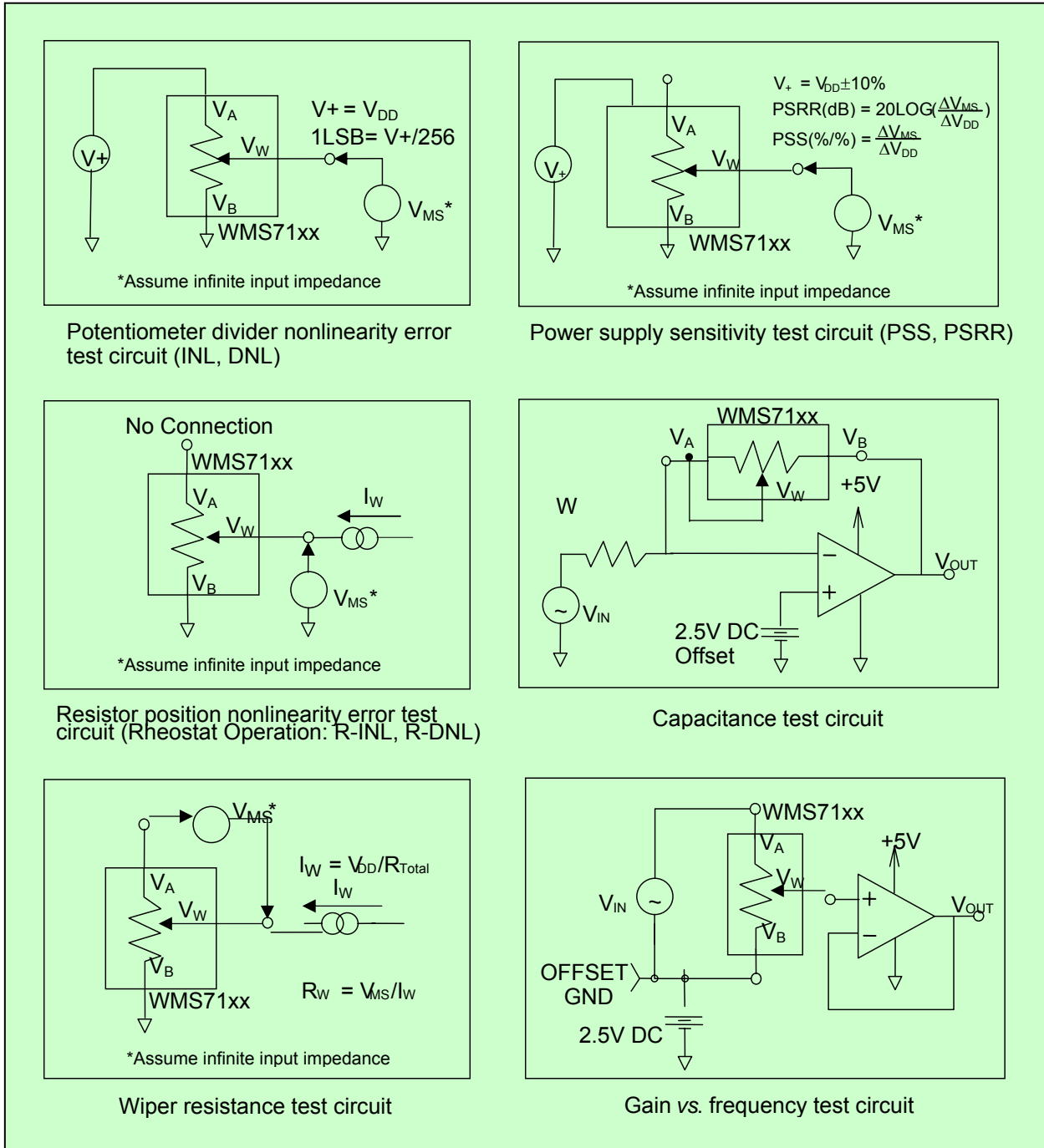


FIGURE 4 – TEST CIRCUITS



## 11. TYPICAL APPLICATION CIRCUITS

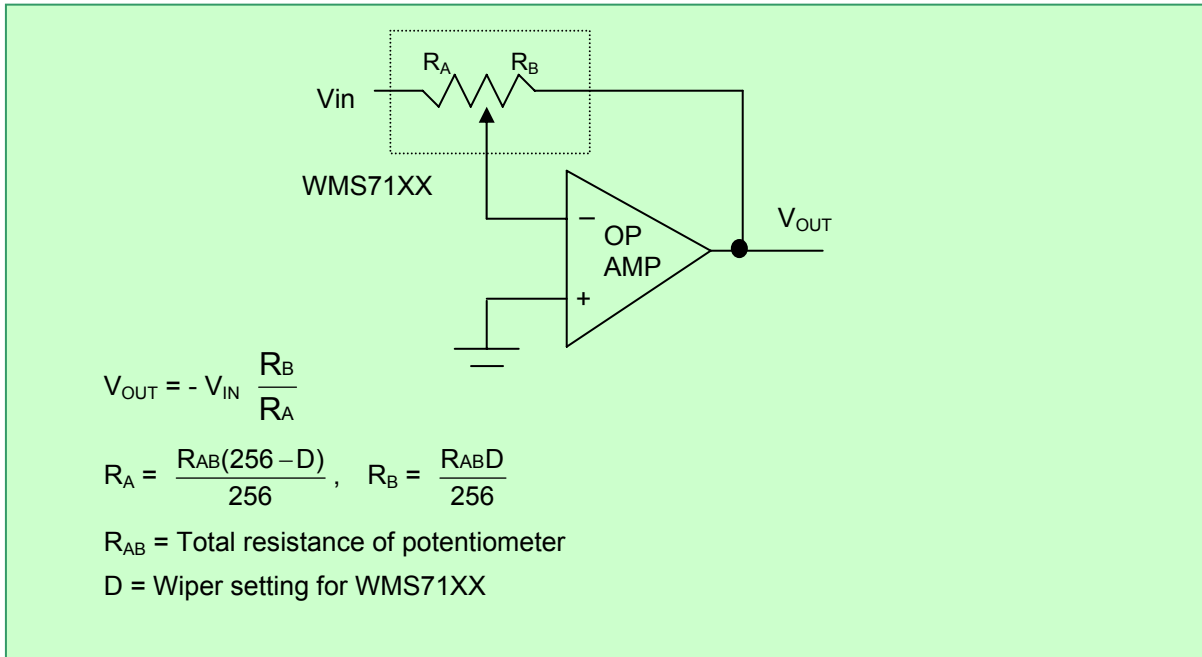


FIGURE 5 – PROGRAMMABLE INVERTING GAIN AMPLIFIER USING THE WMS7170/1

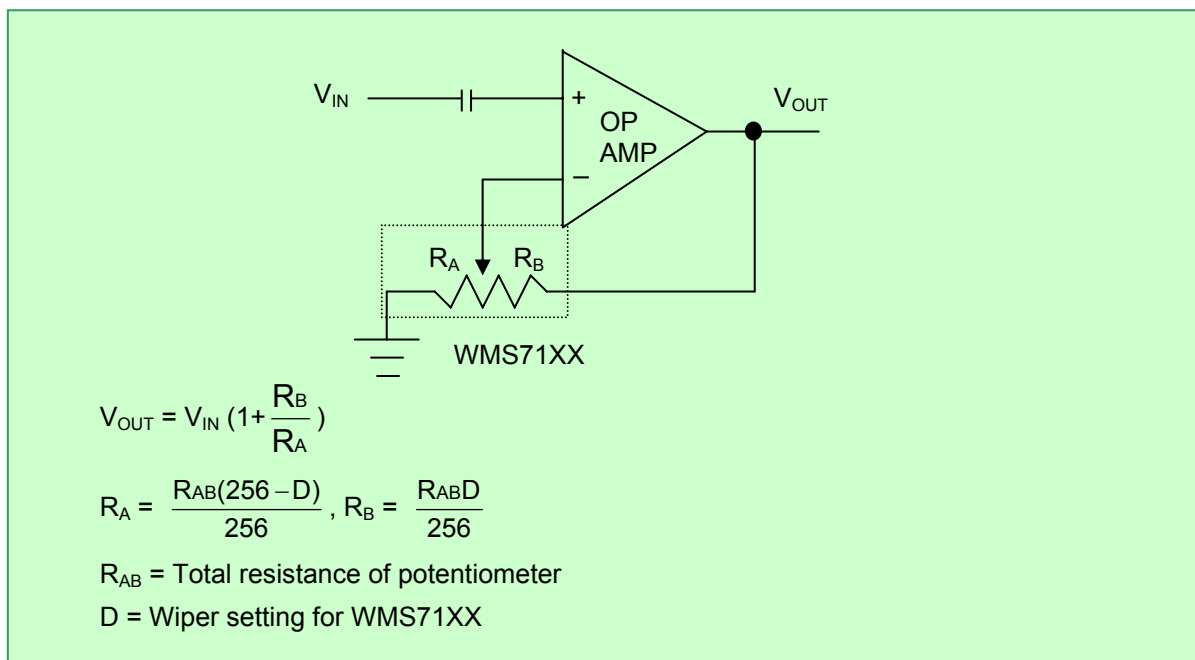


FIGURE 6 – PROGRAMMABLE NON-INVERTING GAIN AMPLIFIER USING THE WMS7170/1

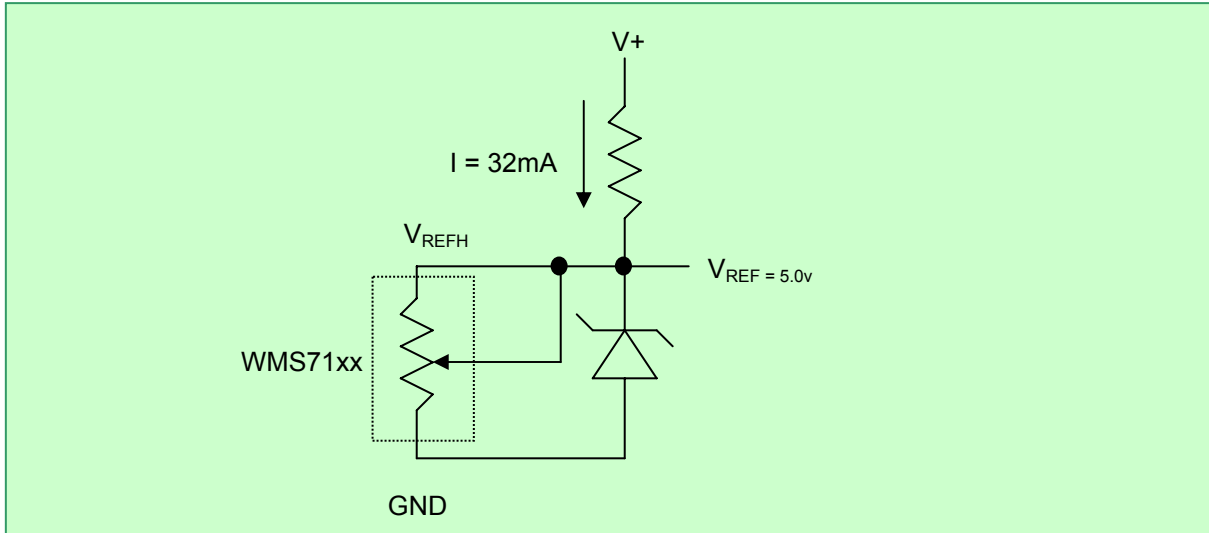


FIGURE 7 – WMS7170/1 TRIMMING VOLTAGE REFERENCE

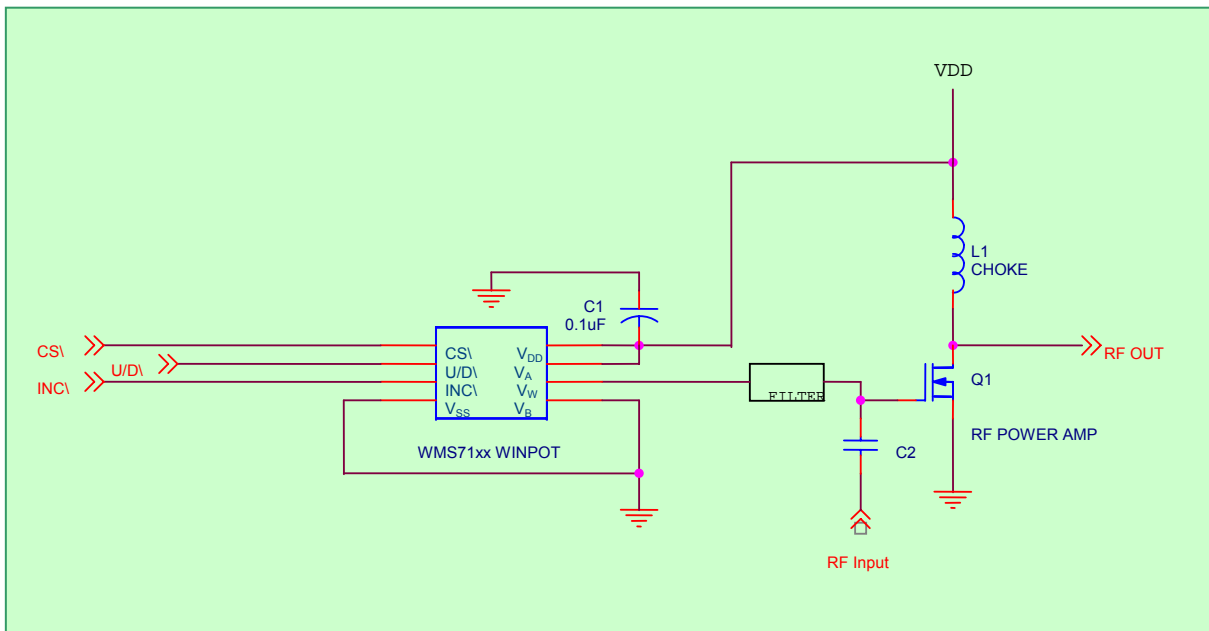


FIGURE 8 – WMS7170/1 RF AMP CONTROL





### 11.1. LAYOUT CONSIDERATIONS

Use a 0.1 $\mu$ F bypass capacitor as close as possible to the  $V_{DD}$  pin. This is recommended for best performance. Often this can be done by placing the surface mount capacitor on the bottom side of the PC board, directly between the  $V_{DD}$  and  $V_{SS}$  pins. Care should be taken to separate the analog and digital traces. Sensitive traces should not run under the device or close to the bypass capacitors.

A dedicated plane for analog ground helps in reducing ground noise for sensitive analog signals.

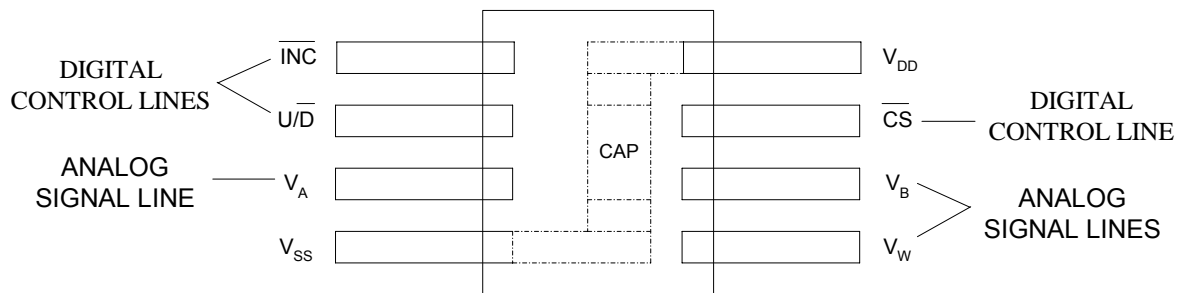


FIGURE 9 – WMS7170/1 LAYOUT



12. PACKAGE DRAWINGS AND DIMENSIONS

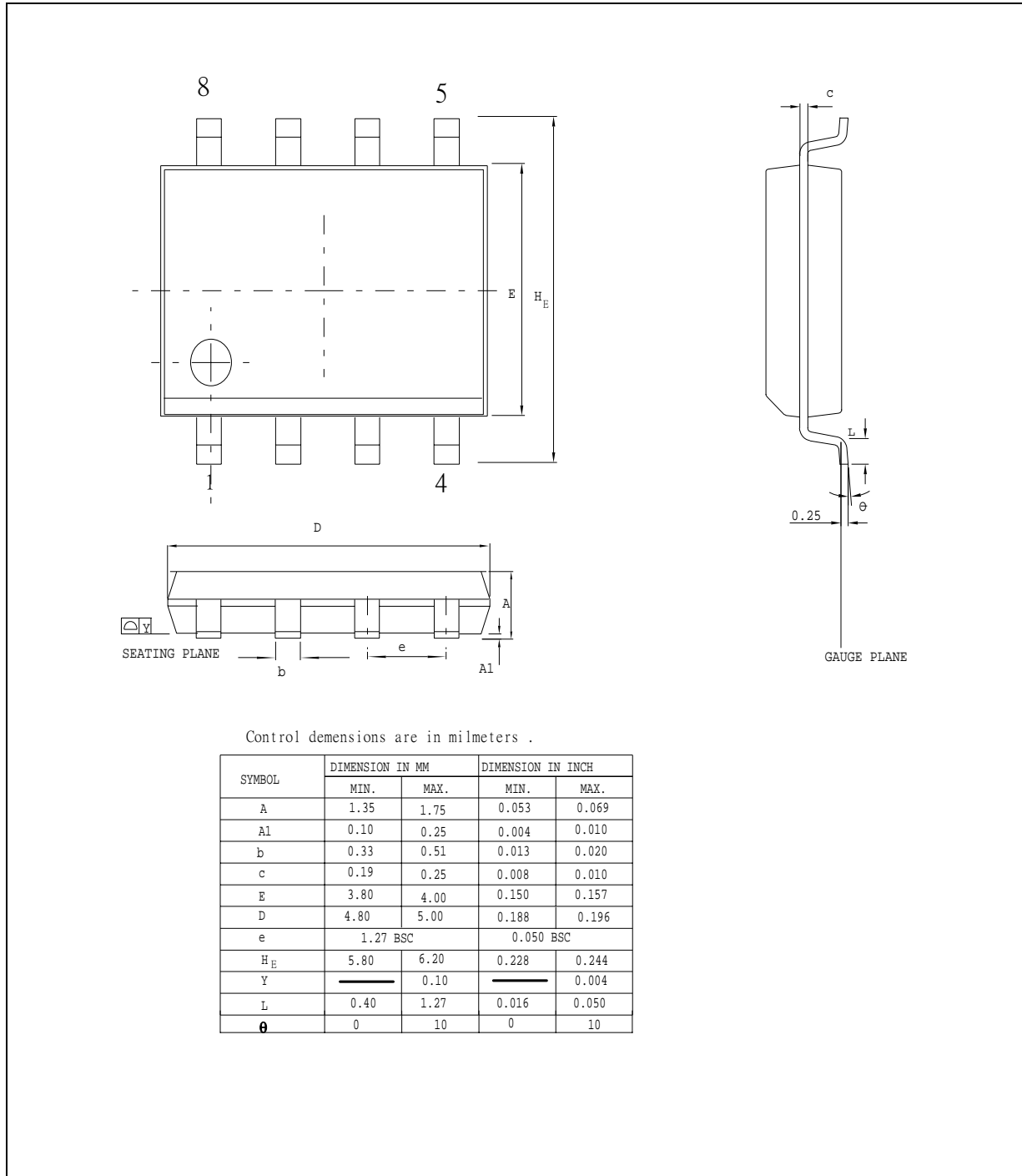


FIGURE 10: 8L 150MIL SOIC

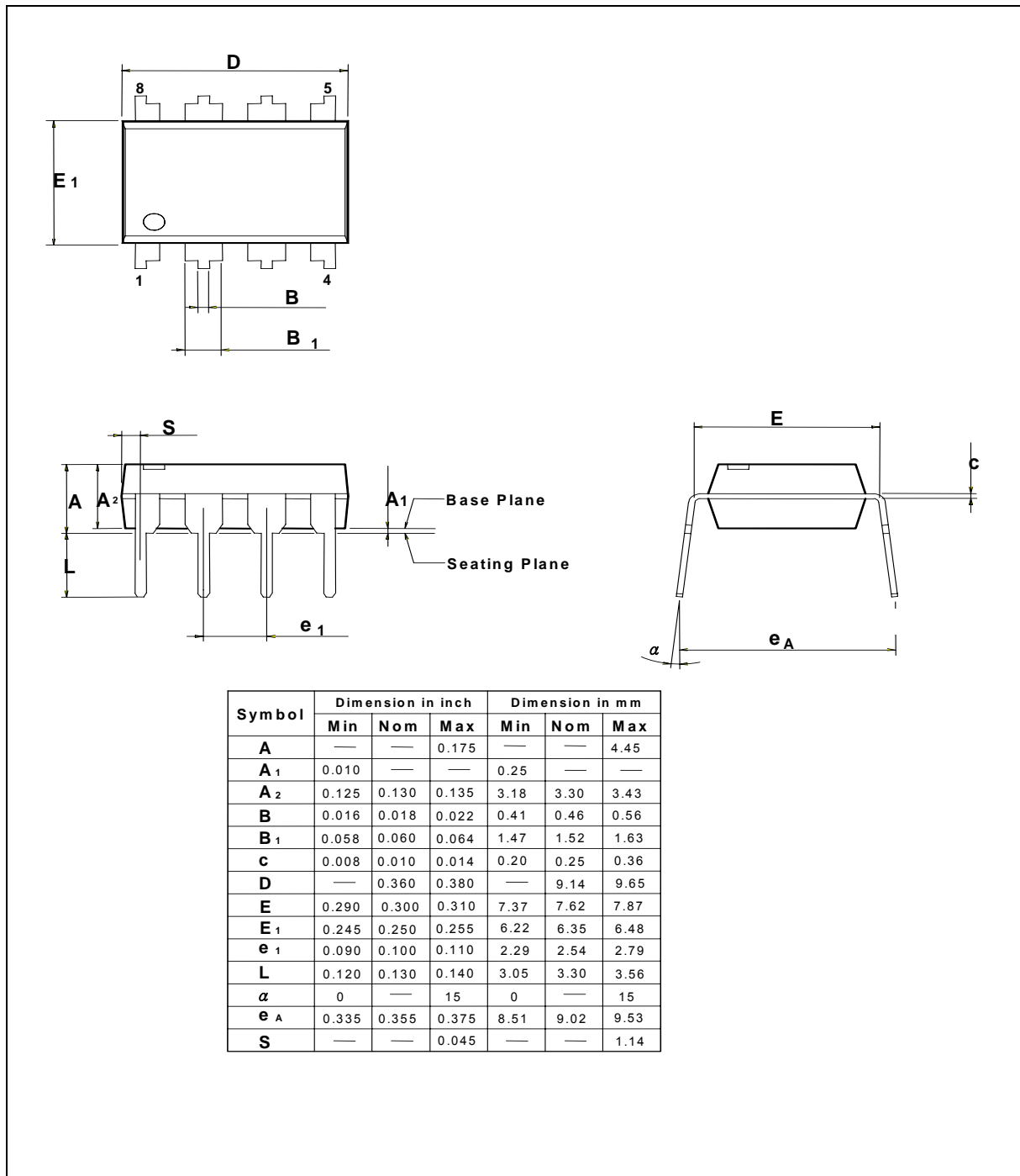


FIGURE 11: 8L 300MIL PDIP

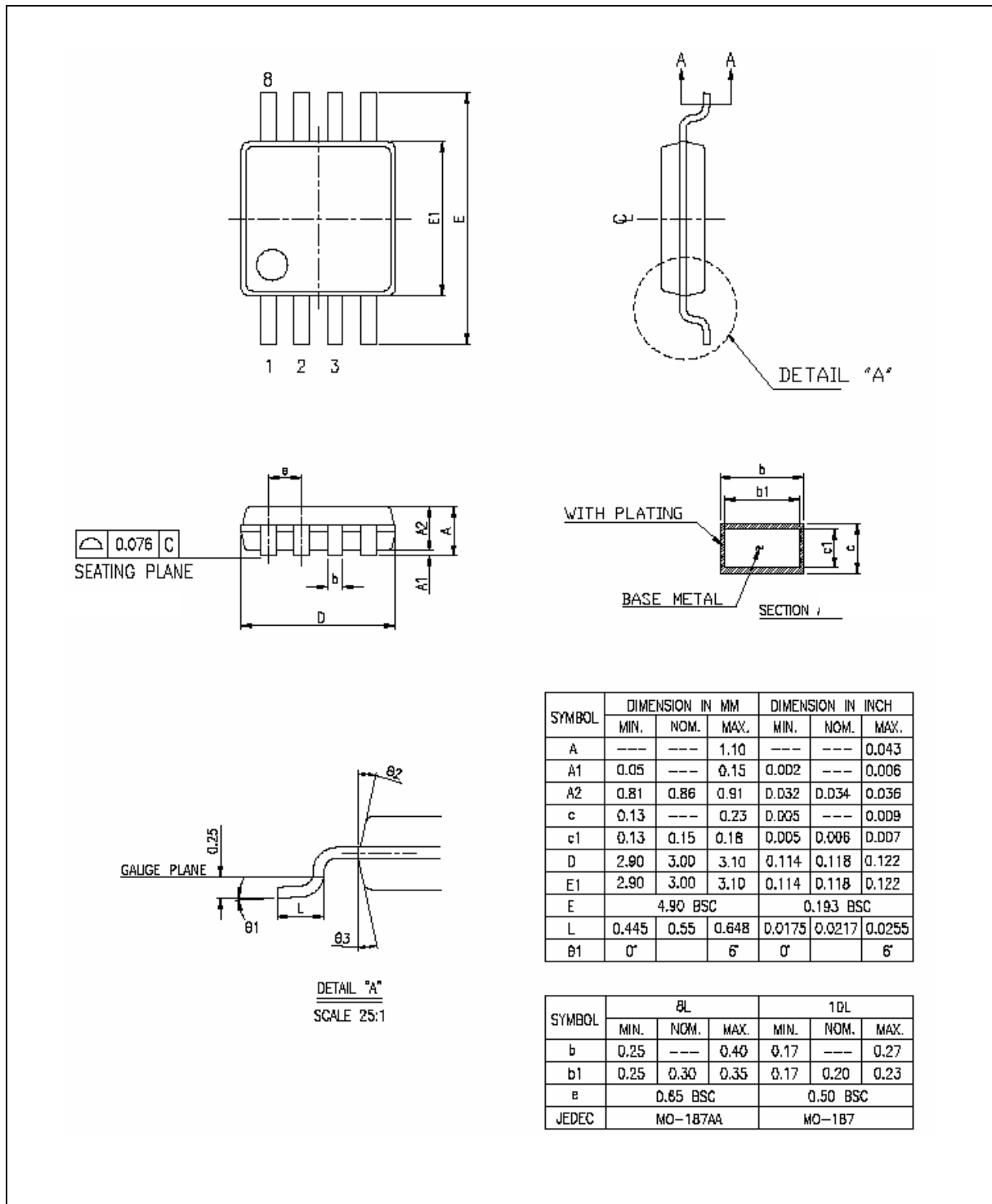
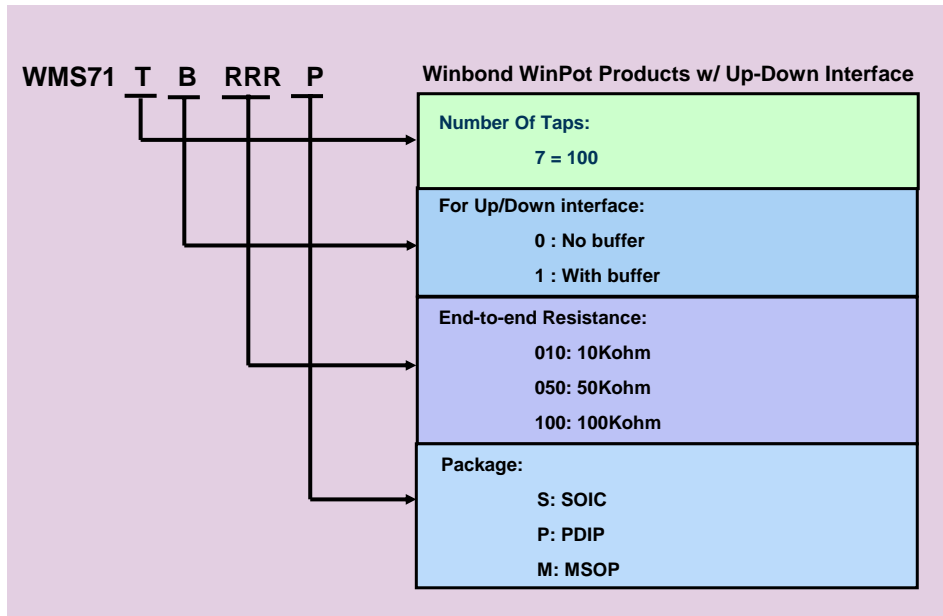


FIGURE 12: 8L 3MM MSOP



**13. ORDERING INFORMATION**

Winbond's WinPot Part Number Description:



| Output Buffer | End-to-End Resistance | SOIC                 | PDIP                 | MSOP                 |
|---------------|-----------------------|----------------------|----------------------|----------------------|
| NO            | 10K                   | WMS71700 <b>10S</b>  | WMS71700 <b>10P</b>  | WMS71700 <b>10M</b>  |
|               | 50K                   | WMS71700 <b>50S</b>  | WMS71700 <b>50P</b>  | WMS71700 <b>50M</b>  |
|               | 100K                  | WMS71700 <b>100S</b> | WMS71700 <b>100P</b> | WMS71700 <b>100M</b> |
| YES           | 10K                   | WMS71710 <b>10S</b>  | WMS71710 <b>10P</b>  | WMS71710 <b>10M</b>  |
|               | 50K                   | WMS71710 <b>50S</b>  | WMS71710 <b>50P</b>  | WMS71710 <b>50M</b>  |
|               | 100K                  | WMS71710 <b>100S</b> | WMS71710 <b>100P</b> | WMS71710 <b>100M</b> |

For the latest product information, access Winbond's worldwide website at <http://www.winbond-usa.com>



#### 14. VERSION HISTORY

| VERSION | DATE       | DESCRIPTION             |
|---------|------------|-------------------------|
| 1.0     | June 2003  | Initial issue           |
| 1.1     | April 2005 | Revise disclaim section |



Winbond products are not designed, intended, authorized or warranted for use as components in systems or equipment intended for surgical implantation, atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, or for other applications intended to support or sustain life. Furthermore, Winbond products are not intended for applications wherein failure of Winbond products could result or lead to a situation wherein personal injury, death or severe property or environmental damage could occur.

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