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# **WMS7170 / 7171**

**NON-VOLATILE DIGITAL POTENTIOMETERS**

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

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

**100 TAPS**

**WITHOUT / WITH OUTPUT BUFFER**



## 1. GENERAL DESCRIPTION

The WMS7170/7171 is a single channel 100-tap non-volatile linear digital potentiometer available in 10K $\Omega$ , 50K $\Omega$  and 100K $\Omega$  resistance. The device consists of Up/Down serial interface, tap register, decoder, resistor array, wiper switches, NV memory and control logics.

The WMS7170 device can be configured as a two-terminal variable resistor or a three-terminal voltage divider without an output buffer, but the WMS7171 device, which has a built-in output buffer, can only be configured as a three-terminal voltage divider. Both devices can be used in a wide variety of applications.

The output of the potentiometer is determined by its wiper position, which varies linearly between its end terminals,  $R_A/V_A$  and  $R_B/V_B$ . The wiper position,  $R_w/V_w$ , is controlled by Up/Down serial interface ( $\overline{CS}$ ,  $\overline{INC}$  and  $\overline{U/D}$ ) through the Tap Register (TR). In addition, the wiper position can also be stored into a non-volatile memory location (NVMEM0), which is then automatically recalled upon power up.

## 2. FEATURES

- Drop-in replacement for many popular parts
- Single linear-taper channel
- 100 taps
- 10K, 50K and 100K end-to-end resistance
- $V_{SS}$  to  $V_{DD}$  terminal voltages
- Automatic recall of wiper position when power-on
- Potentiometer control through Up/Down (3-wire) serial interface
- Endurance 100,000 cycles
- Data retention 100 years
- Package options:
  - 8-pin PDIP, SOIC or MSOP
- Industrial temperature range: -40° to 85°C
- Single supply operation : 2.7V to 5.5V



3. BLOCK DIAGRAM

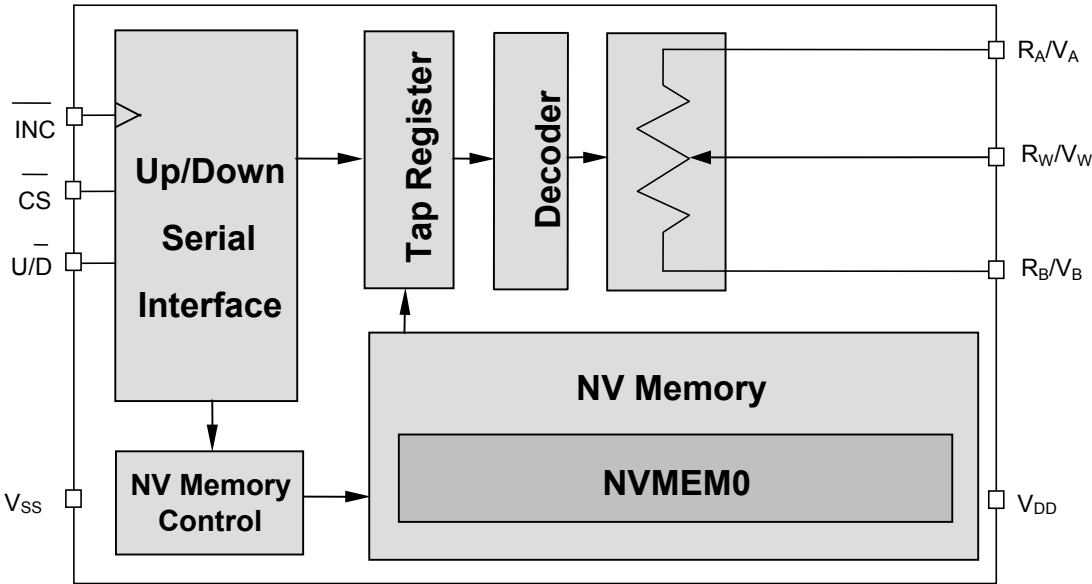


FIGURE 1 – WMS7170 BLOCK DIAGRAM (Rheostat/Divider Mode)

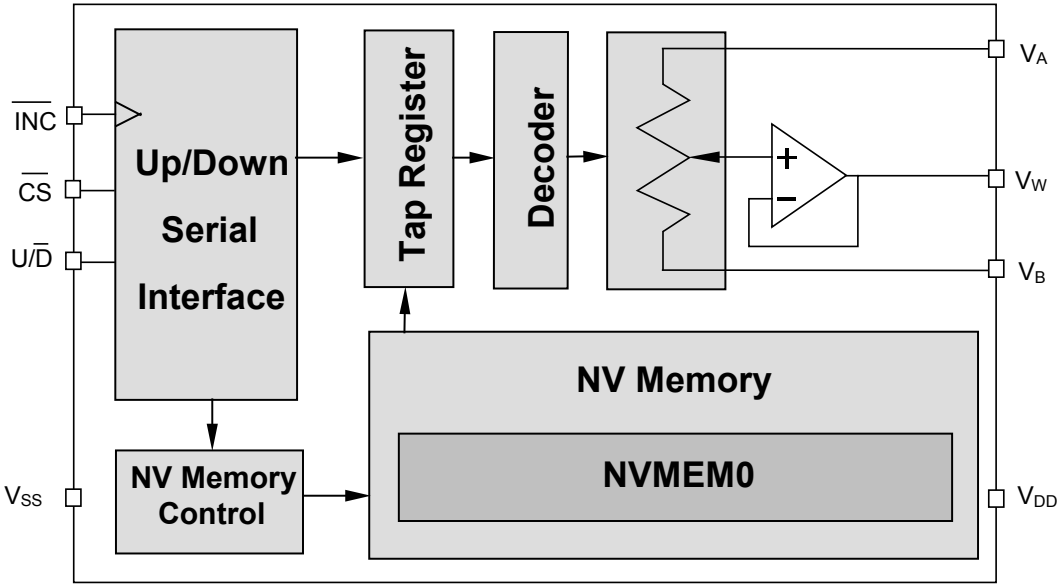


FIGURE 2 – WMS7171 BLOCK DIAGRAM (Divider Mode)

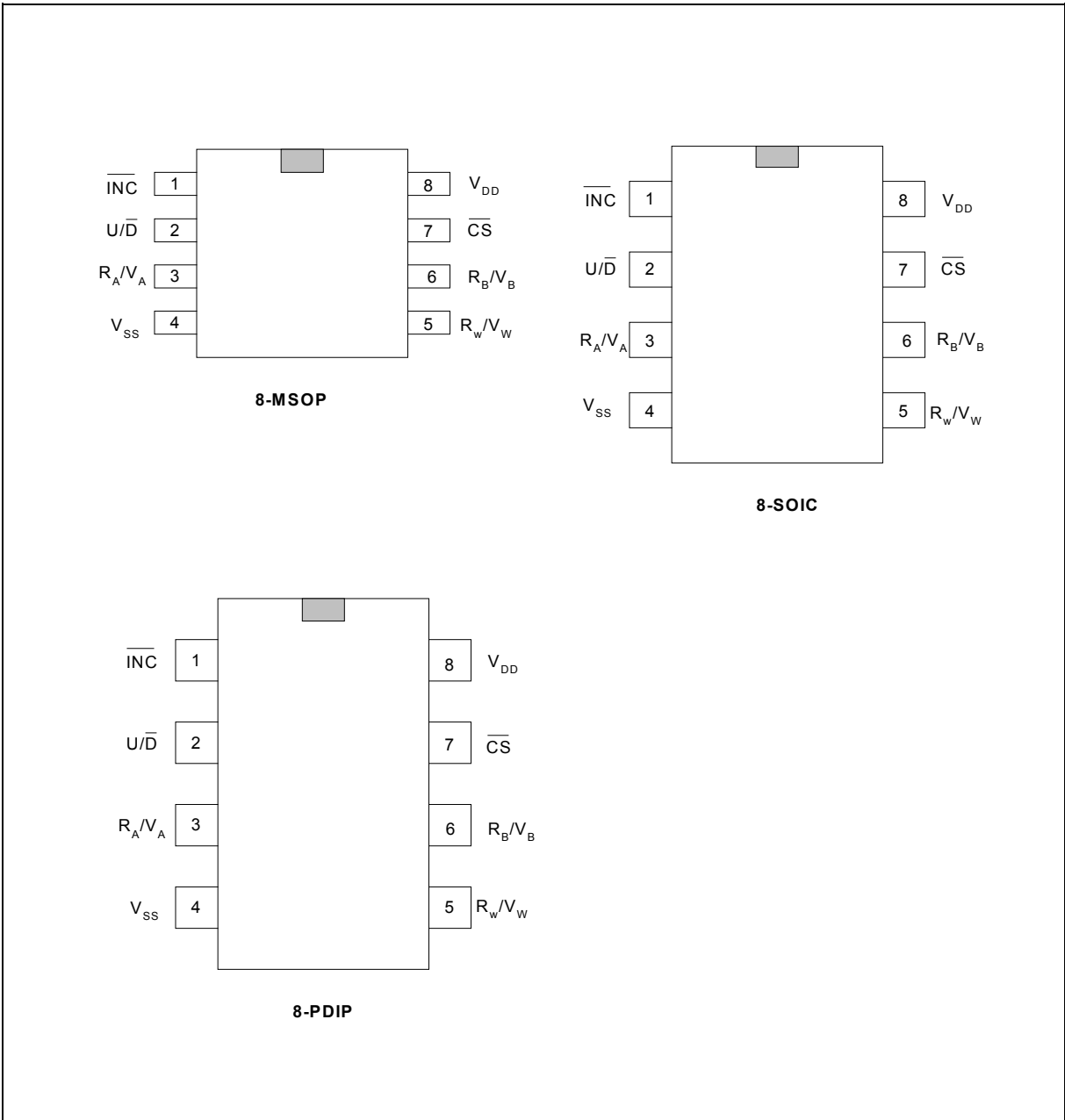


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5. PIN CONFIGURATION



## 6. PIN DESCRIPTION

TABLE 1 – PIN DESCRIPTION

Pin Name	Description
$\overline{CS}$	<b>Chip Select:</b> When $\overline{CS}$ is LOW, the device is enabled. When $\overline{CS}$ is HIGH, the part is deselected and is in standby mode
$U/\overline{D}$	<b>Up/Down Control:</b> HIGH state enables the wiper to move towards the $R_A / V_A$ terminal, while LOW state implies the wiper moves towards the $R_B / V_B$ terminal
$\overline{INC}$	<b>Increment Control:</b> When $\overline{CS}$ is LOW, a HIGH-LOW transition on $\overline{INC}$ will move the wiper one increment either up or down based on the $U/\overline{D}$ input
$R_A/V_A$	<b>High terminal</b> of the device
$R_B/V_B$	<b>Low terminal</b> of the device
$R_W/V_W$	<b>Wiper Terminal:</b> Output of the resistor array is determined by the $\overline{INC}$ , $U/\overline{D}$ and $\overline{CS}$ inputs
$V_{SS}$	Ground pin, logic ground reference
$V_{DD}$	Power Supply

Notes: The terminology of high and low terminals above references to the relative position of the terminal with respect to the wiper moving direction and not the voltage potential of the terminal.



## 7. FUNCTIONAL DESCRIPTION

### 7.1. RHEOSTAT AND DIVIDER OPERATIONS

The WMS7170 device can operate as either a two-terminal variable resistor or a three-terminal voltage divider without an output buffer. However, the WMS7171 can only operate in a three-terminal voltage divider with an output buffer.

#### 7.1.1. Rheostat Configuration

In the rheostat mode, the WMS7170 can be configured as a two-terminal resistive element, where one terminal is connected to one end of the resistor ( $R_A$  or  $R_B$ ) and the other terminal is the wiper ( $R_W$ ). The moving direction of the wiper depends upon the setting of  $\overline{U/D}$  control signal. When the  $\overline{U/D}$  is set to Up, then the wiper moves towards  $R_A$ . Conversely, when the  $\overline{U/D}$  is set to Down, then the wiper moves towards  $R_B$ . The wiper movement to either direction is controlled by toggling the  $\overline{INC}$  signal from HIGH to LOW.

This configuration controls the resistance between the wiper and either end. The wiper resistance can be adjusted by either changing the wiper position or loading a stored wiper position value from NVMEM0 upon power up.

#### 7.1.2. Divider Configuration

Additionally, the WMS7170 can also be configured as a voltage divider. With an input voltage applied to one end (usually  $V_A$ ), the ground is connected to the other end (usually  $V_B$ ). These input voltages cannot exceed the  $V_{DD}$  level or go below the  $V_{SS}$  level. The voltage on the wiper,  $V_W$ , is proportional to the wiper position with respect to the voltage difference between  $V_A$  and  $V_B$ . The moving direction of the wiper depends upon the setting of the  $\overline{U/D}$  control signal. When the  $\overline{U/D}$  is set to Up, then the wiper moves towards  $V_A$ . Conversely, when the  $\overline{U/D}$  is set to Down, then the wiper moves towards  $V_B$ . The wiper movement to either direction is controlled by toggling the  $\overline{INC}$  signal from HIGH to LOW.

Nevertheless, the WMS7171 can only be configured as a voltage divider and operate similarly as the WMS7170 device. The only difference is WMS7171 has an output buffer, but WMS7170 doesn't have. Besides, the resistance cannot be directly measured in this configuration.

### 7.2. NON-VOLATILE MEMORY (NVMEM0)

The WMS7170/7171 has one NVMEM0 location available for storing the current wiper position via the Up/Down serial interface. This stored value is automatically recalled and loaded into the tap register upon power up.





**7.3. SERIAL DATA INTERFACE**

The WMS7170/7171 device has a 3-wire Up/Down Serial Interface consisting of  $\overline{CS}$ ,  $\overline{INC}$  and  $\overline{U/D}$  control signals. The key features of this interface include:

- Enabling the device
- Determining the moving direction of the wiper
- Increment/Decrement operation on the wiper
- Non-volatile storage of the present wiper position into the NVMEM0 for automatic recall at power up
- Entering into the standby mode

**7.4. OPERATION OVERVIEW**

The wiper position can be changed either up or down by operating the  $\overline{CS}$ ,  $\overline{U/D}$  and  $\overline{INC}$  control signals.

When  $\overline{CS}$  is LOW, the device is selected and the wiper can be moved by toggling the  $\overline{INC}$ . As a result, the wiper moves up when  $\overline{U/D}$  is HIGH and moves down when  $\overline{U/D}$  is LOW. The status of the  $\overline{U/D}$  can be changed even though the  $\overline{CS}$  remains LOW. This allows the system to enable the device and then move the wiper position either up or down until the desired position is reached.

When the wiper is already at the lowest position, further Down operation won't change the wiper position. Similarly, when the wiper is at the highest position, further Up operation won't change the wiper position too.

The current wiper position can be automatically stored into the NVMEM0 each time the  $\overline{CS}$  goes from LOW to HIGH while the  $\overline{INC}$  remains HIGH. Adversely, if the  $\overline{INC}$  is LOW when the  $\overline{CS}$  goes HIGH, the wiper position cannot be stored. Meanwhile, the NVMEM0 content is automatically loaded into the wiper during power on.

When the  $\overline{CS}$  is held HIGH, the device enters into Standby mode and the wiper position cannot be changed. Changing the  $\overline{CS}$  to LOW exits the Standby mode and enables the device again.

The operating modes of Up/Down interface are summarized in the table below:

$\overline{CS}$	$\overline{U/D}$	$\overline{INC}$	Operation
LOW	HIGH	HIGH to LOW	Move Wiper toward $R_A/V_A$
LOW	LOW	HIGH to LOW	Move Wiper toward $R_B/V_B$
LOW to HIGH	x	HIGH	Store Current 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:

- <sup>[1]</sup> This only applies to the Power-Up sequence.
- <sup>[2]</sup> 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
$\overline{CS}$ to $\overline{INC}$ Setup	$t_{CI}$	100		ns
U/D to $\overline{INC}$ Setup	$t_{DI}$	50		ns
U/D to $\overline{INC}$ Hold	$t_{ID}$	100		ns
$\overline{INC}$ LOW Period	$t_{iL}$	250		ns
$\overline{INC}$ HIGH Period	$t_{iH}$	250		ns
$\overline{INC}$ Inactive to $\overline{CS}$ Inactive	$t_{iC}$	1		$\mu$ s
$\overline{CS}$ Deselect Time (NO STORE)	$t_{CPH}$	100		ns
$\overline{CS}$ Deselect Time (STORE)	$t_{CPH}$	15 (2.7V) 30 (5.5V)		ms
$\overline{INC}$ to Wiper Change	$t_{iW}$		5	$\mu$ s
$\overline{INC}$ Cycle Time	$t_{CYC}$	1		$\mu$ s
$\overline{INC}$ Input Rise and Fall Time	$t_R, t_F$		500	$\mu$ s
Power-Up Delay	$t_{PUD}$		1	ms
$V_{CC}$ Power-Up rate	$t_R V_{CC}$	0.2 (13ms 0-2.7V)	50 (54 $\mu$ s 0-2.7V)	V/ms



## 9. ABSOLUTE MAXIMUM RATINGS & OPERATING CONDITIONS

**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	( $V_{SS} - 0.3V$ ) to ( $V_{DD} + 0.3V$ )
Lead temperature (soldering – 10 seconds)	300°C
$V_{SS} - V_{DD}$	-0.3 to 7.0V

**TABLE 12 – OPERATING CONDITIONS (PACKAGED PARTS)**

Conditions	Values
Industrial operating temperature	-40°C to +85°C
Supply voltage ( $V_{DD}$ )	+2.7V to +5.5V
Ground voltage ( $V_{SS}$ )	0V

<sup>[1]</sup> Stresses above those listed may cause permanent damage to the device. Exposure to the absolute maximum ratings may affect device performance and 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 <sup>[5]</sup>
<b>Rheostat Mode</b>						
Nominal Resistance	R	-20		+20	%	T=25°C, Wiper open
Different Non Linearity <sup>[2]</sup>	R-DNL	-1	±0.3	+1	LSB	<sup>[6]</sup>
Integral Non Linearity <sup>[2]</sup>	R-INL	-1	±0.5	+1	LSB	<sup>[6]</sup>
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> <sup>[7]</sup>
			80		Ω	V <sub>DD</sub> =2.7V, I=V <sub>DD</sub> /R <sub>Total</sub> <sup>[7]</sup>
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>	$\Delta W / \Delta T$		+20		ppm/°C	Wiper at center
Full Scale Error	V <sub>FSE</sub>	-1		0	LSB	Wiper at highest position
Zero Scale Error	V <sub>ZSE</sub>	0		1	LSB	Wiper at lowest position
<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, B =VSS
	BW <sub>50K</sub>		300		KHz	Wiper at center
	BW <sub>100K</sub>		200		KHz	
<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	%	A =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>	0.7xV <sub>DD</sub>			V	
Input Low Voltage	V <sub>IL</sub>			0.3xV <sub>DD</sub>	V	
Output Low Voltage	V <sub>OL</sub>			0.4	V	I <sub>OL</sub> =2mA

**TABLE 12 – ELECTRICAL CHARACTERISTICS (Packaged parts) – Cont'd**

PARAMETERS	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS <sup>[5]</sup>
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	$I_{DDR}, I_{DDW}$		1	2	mA	All operations
Standby Current	$I_{SA}$ <sup>[3]</sup>		0.5	1	mA	Buffer = ON $\overline{CS} = HIGH, no load$
	$I_{SB}$ <sup>[4]</sup>		0.1	1	$\mu A$	Buffer = OFF $\overline{CS} = HIGH, no load$
Power Supply Rejection Ratio	PSRR			1	LSB/V	$V_{DD}=5V \pm 10\%$ , Wiper at center

Notes:

<sup>[1]</sup> Not subject to production test.

<sup>[2]</sup>  $LSB = (R_A/V_A - R_B/V_B) / (T - 1)$ ;  $DNL = (V_i - V_{i+1}) / LSB + 1$  (if increment) or  $= (V_i - V_{i+1}) / LSB - 1$  (if decrement);  $INL = (V_i - i*LSB) / LSB$ ; where  $i = [0, (T - 1)]$  and  $T = \#$  of taps of the device.

<sup>[3]</sup> WMS7171 only.

<sup>[4]</sup> WMS7170 only.

<sup>[5]</sup> Conditions:  $V_{CC} = 2.7$  to  $5.5V$ ,  $T = 25^\circ C$  and timing measured at 50% level, unless stated.

<sup>[6]</sup> Only guarantee by design.

<sup>[7]</sup>  $R_{total}$  = end-to-end resistance.

10.1 TEST CIRCUITS

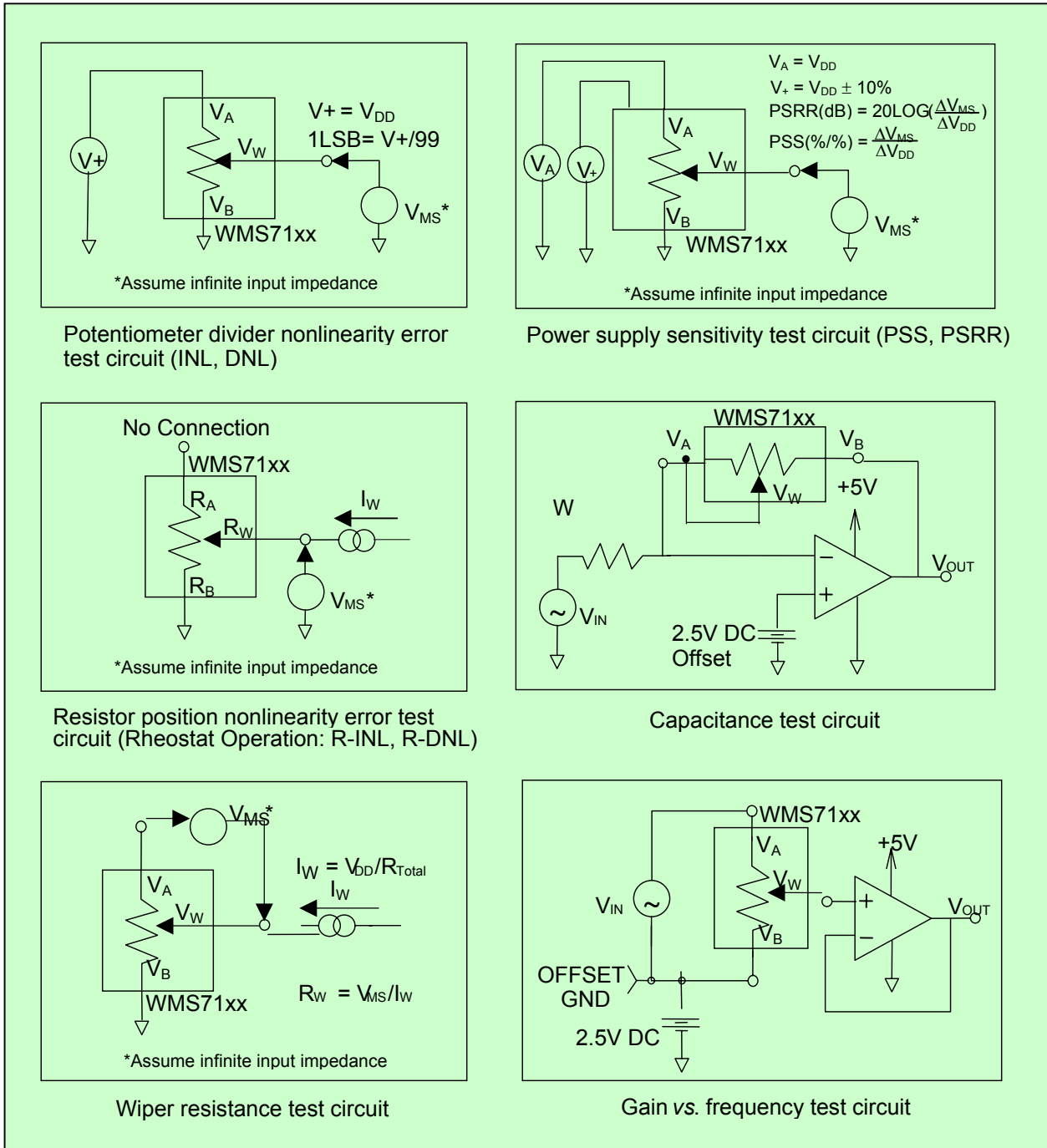


FIGURE 4 – TEST CIRCUITS



11. TYPICAL APPLICATION CIRCUITS

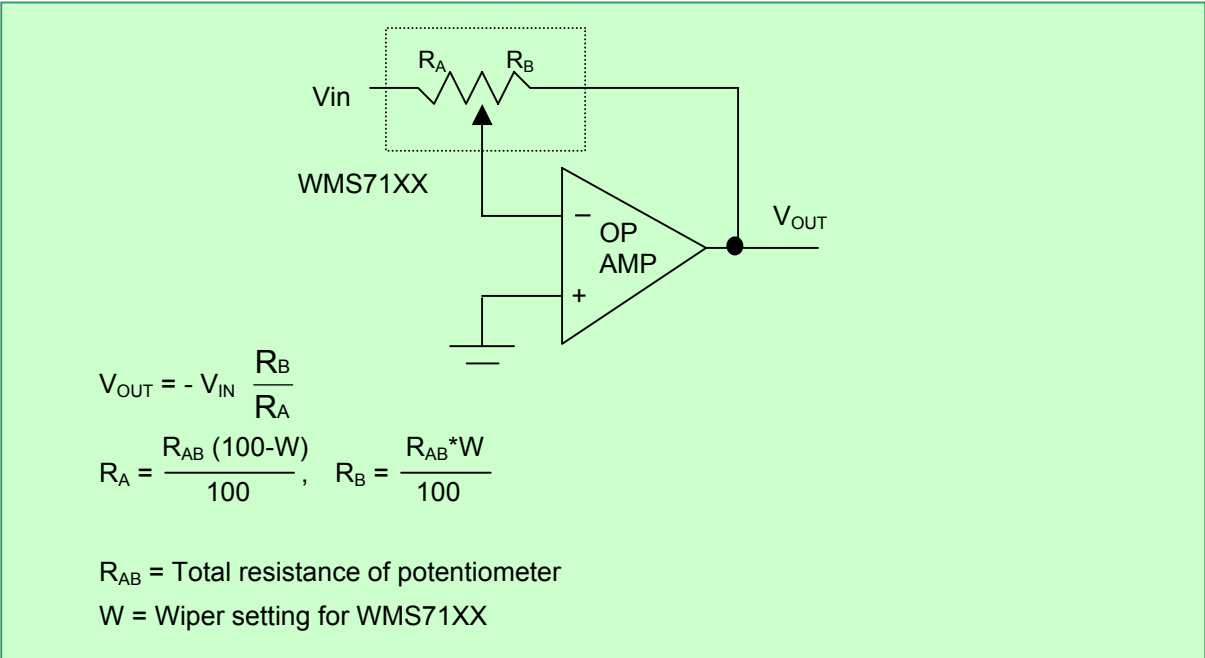


FIGURE 5 – PROGRAMMABLE INVERTING GAIN AMPLIFIER USING THE WMS7170/7171

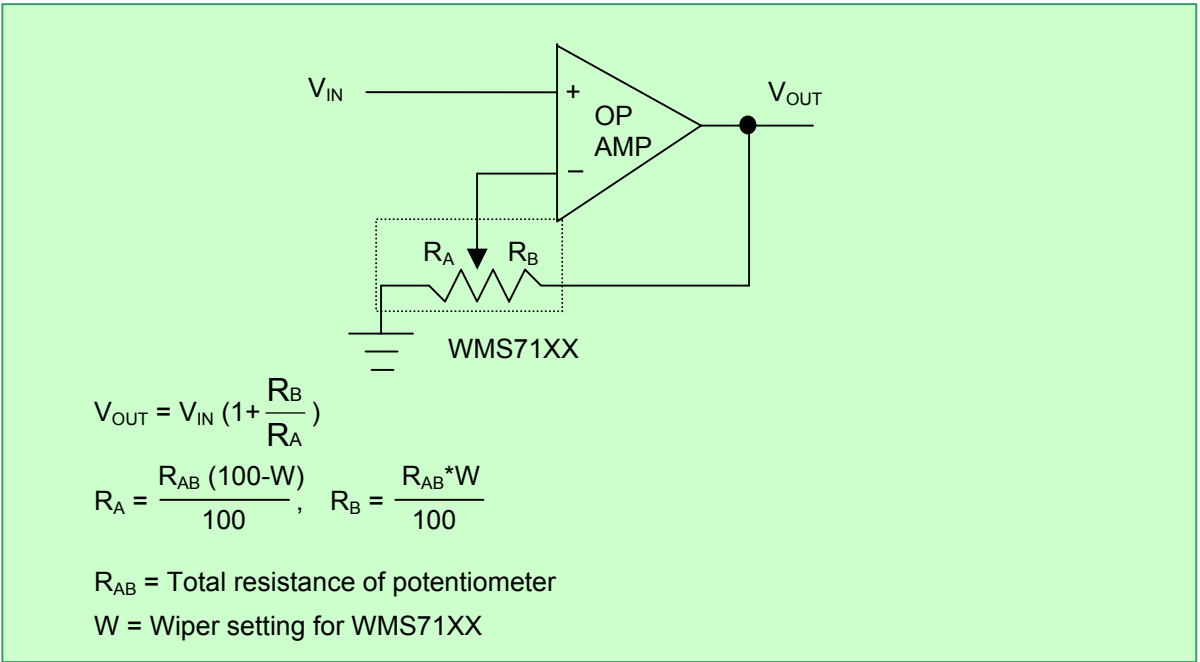


FIGURE 6 – PROGRAMMABLE NON-INVERTING GAIN AMPLIFIER USING THE WMS7170/7171



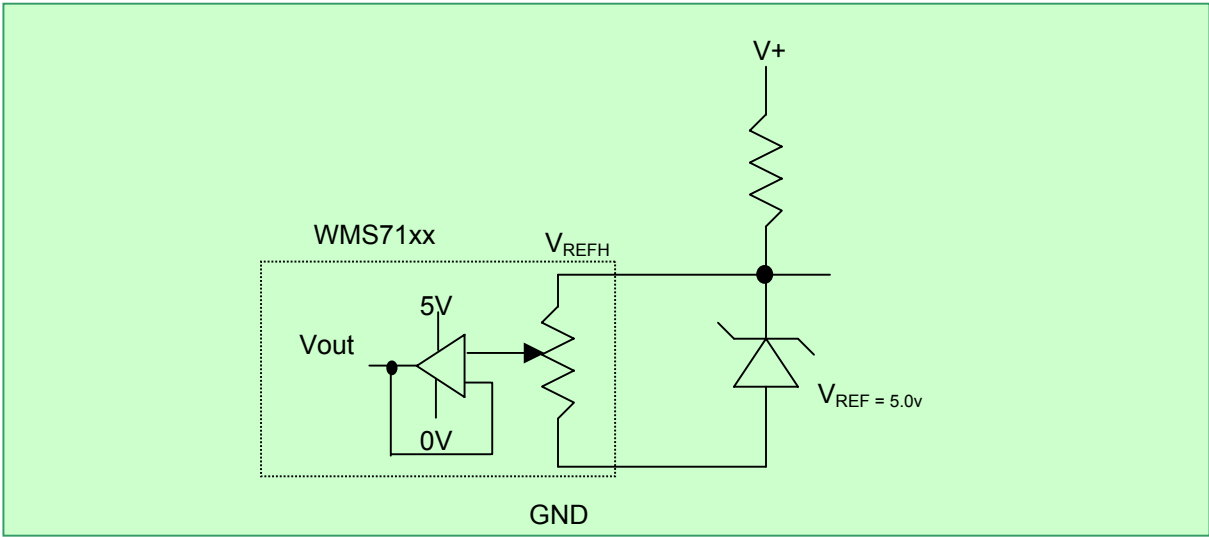


FIGURE 7 – WMS7171 TRIMMING VOLTAGE REFERENCE



FIGURE 8 – WMS7171 RF AMP CONTROL



11.1. LAYOUT CONSIDERATIONS

Use a 0.1μF bypass capacitor as close as possible to the V<sub>DD</sub> 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<sub>DD</sub> and V<sub>SS</sub> 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 – WMS7170/7171 LAYOUT



12. PACKAGE DRAWINGS AND DIMENSIONS

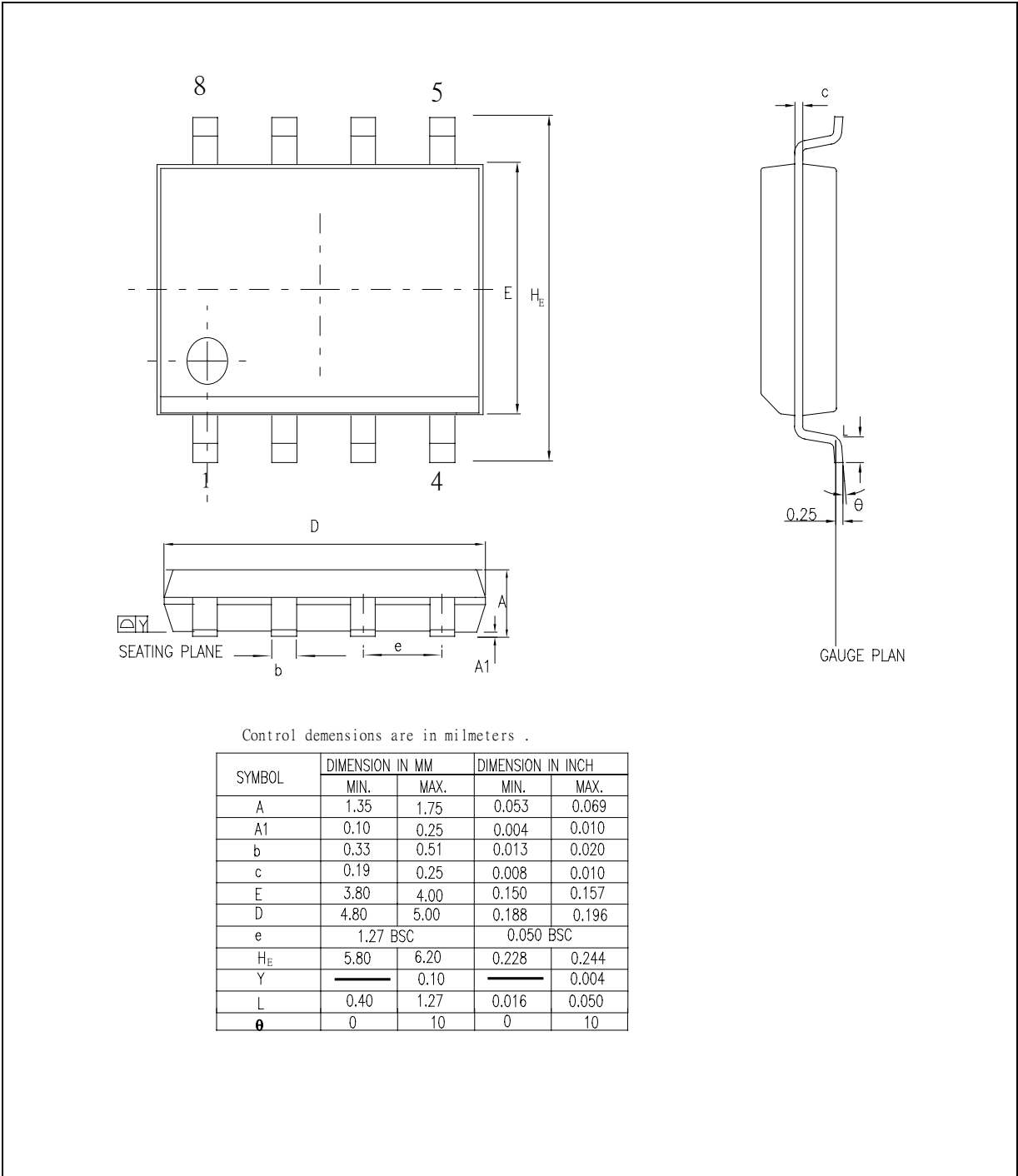


FIGURE 10: 8L 150MIL SOIC

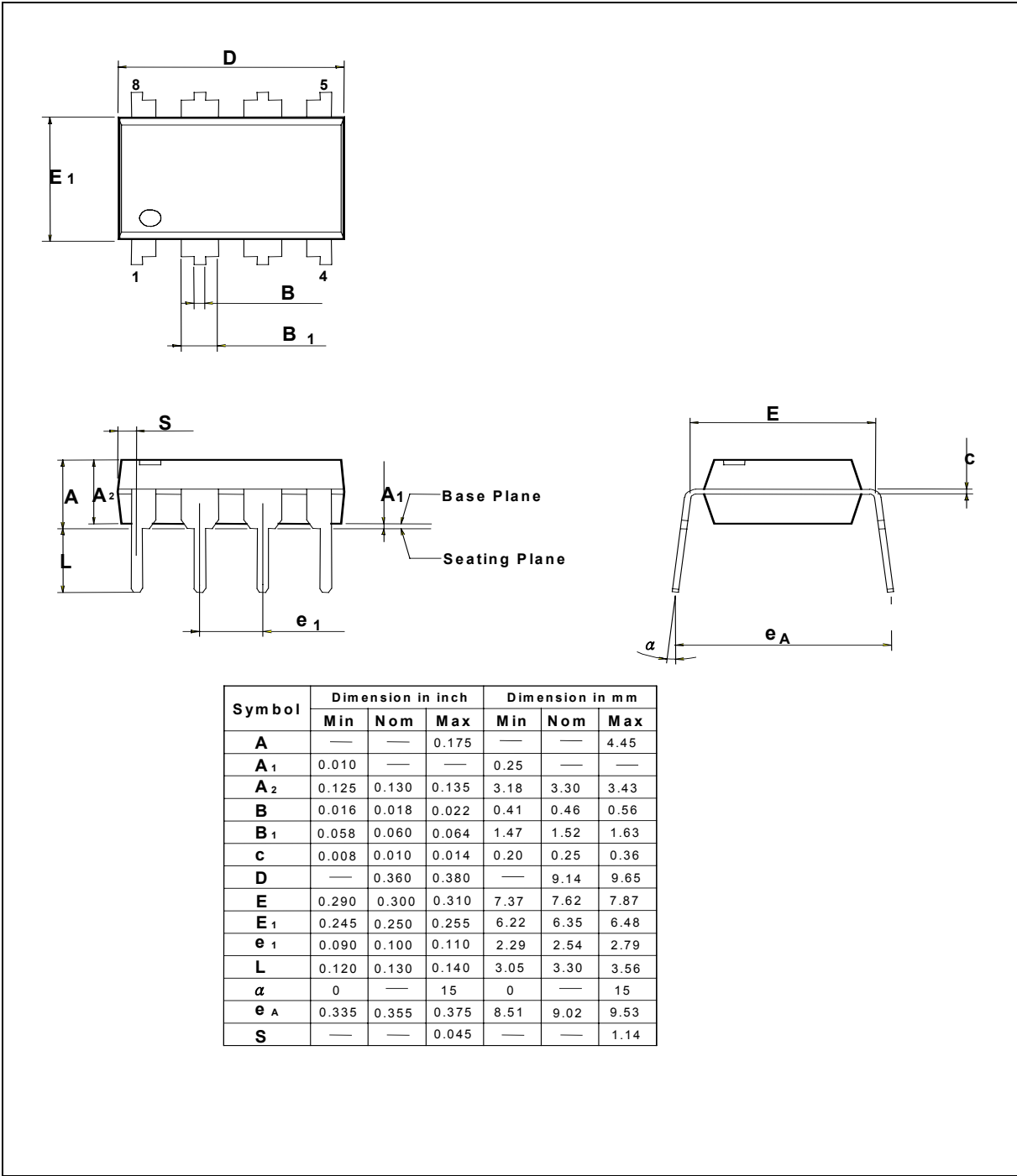
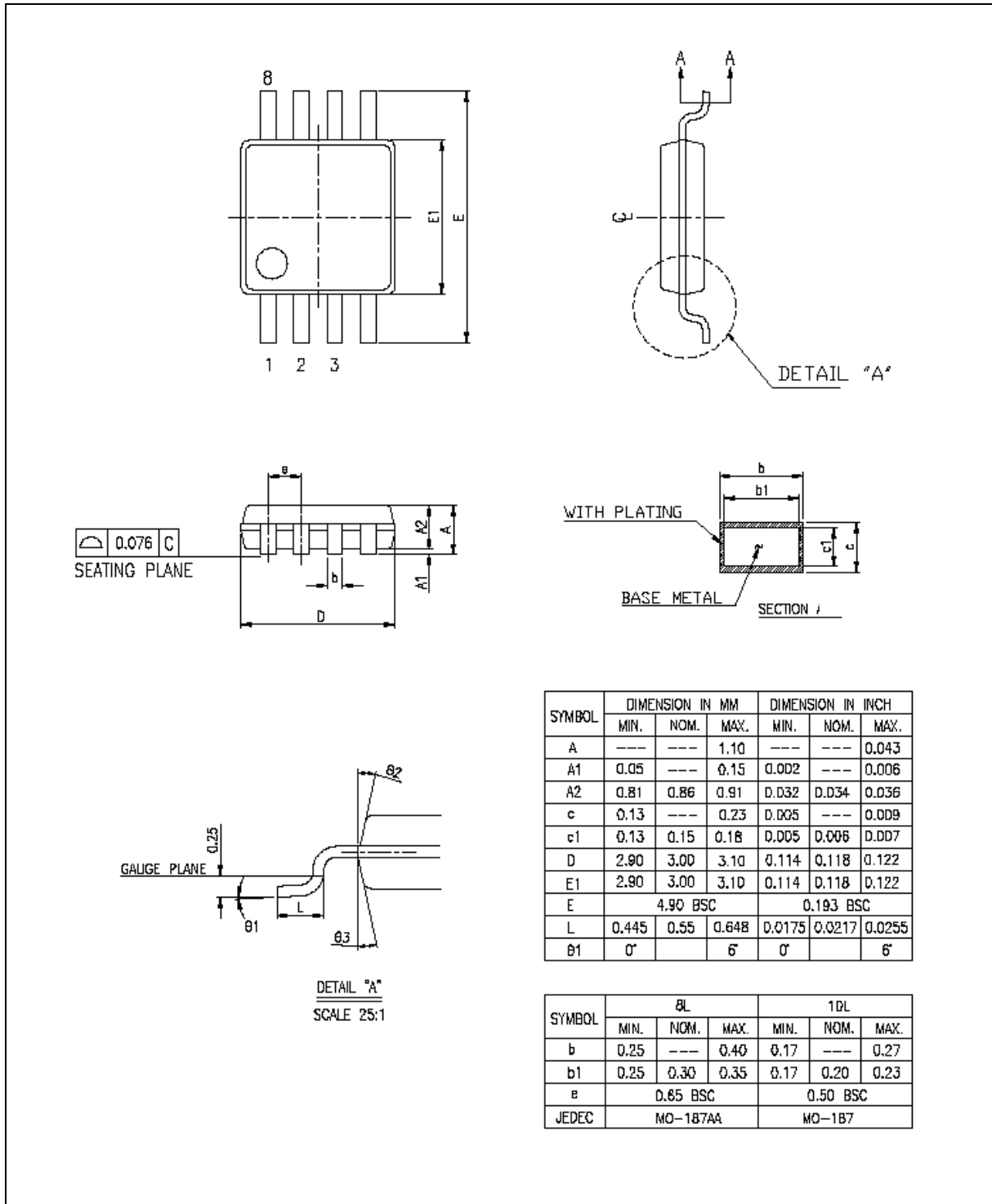


FIGURE 11: 8L 300MIL PDIP

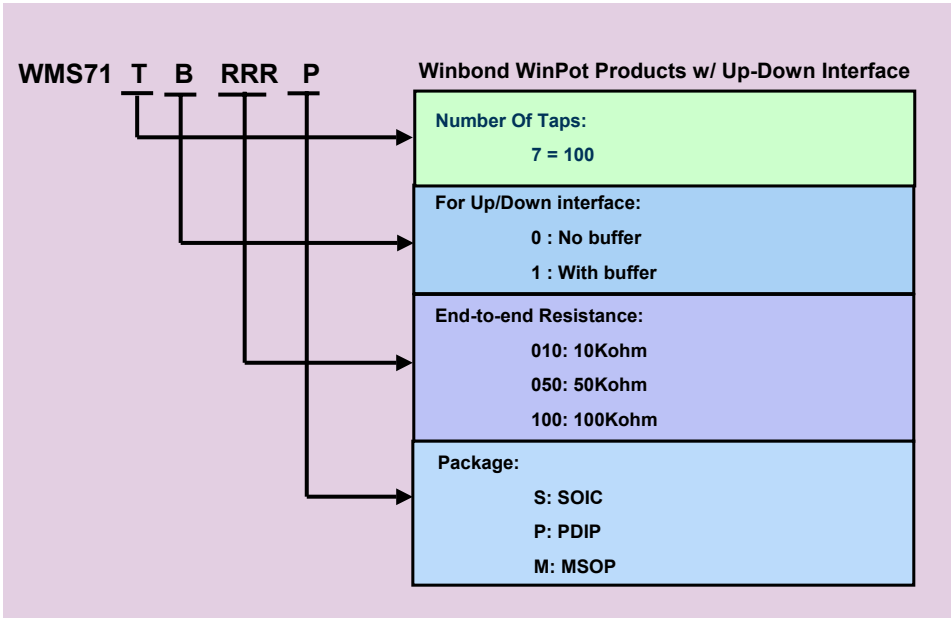


**FIGURE 12: 8L 3MM MSOP**



**13. ORDERING INFORMATION**

Winbond's WinPot Part Number Description:



Output Buffer	End-to-End Resistance	SOIC	PDIP	MSOP
NO	10K	WMS7170010S	WMS7170010P	WMS7170010M
	50K	WMS7170050S	WMS7170050P	WMS7170050M
	100K	WMS7170100S	WMS7170100P	WMS7170100M
YES	10K	WMS7171010S	WMS7171010P	WMS7171010M
	50K	WMS7171050S	WMS7171050P	WMS7171050M
	100K	WMS7171100S	WMS7171100P	WMS7171100M

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## 14. VERSION HISTORY

VERSION	DATE	DESCRIPTION
1.0	July 2003	Initial issue

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