



# PM-562

## 12-BIT MULTIPLYING CURRENT-OUTPUT D/A CONVERTER

Precision Monolithics Inc.

### FEATURES

- Nonlinearity .....  $\pm 1/2$  LSB Max
- Settling Time ..... 1.5 $\mu$ s Typ
- No Laser Trimming Used in Fabrication
- Internal Range and Offset Scaling Resistors
- Guaranteed Monotonicity Over Temperature
- TTL or CMOS Logic Input Compatibility, Pin Selectable
- Low Power Consumption ..... 130mW Typ
- Directly Pin Compatible with AD562
- Available in Die Form

### ORDERING INFORMATION <sup>†</sup>

NONLINEARITY @25°C (LSB)	PACKAGE	TEMPERATURE RANGE
$\pm 1/2$	PM562HV	0°C to +70°C

\* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

<sup>†</sup> Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages. For ordering information, see 1990/91 Data Book, Section 2.

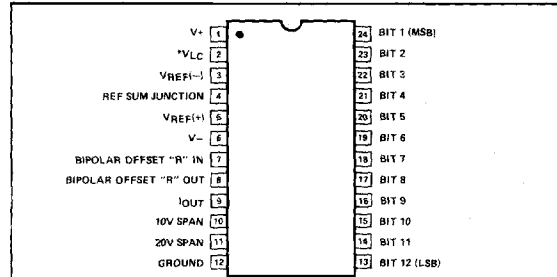
### GENERAL DESCRIPTION

The PM-562 is a 12-bit monolithic multiplying digital-to-analog converter consisting of a reference current amplifier, an R-2R ladder network, range and offset scaling resistors, and 12 high-speed current switches. Improvements provided by the PM-562 include greater negative power supply range

and increased output resistance. The PM-562 is pin compatible with the AD562.

A highly stable trim method; selective shorting of zener diodes, provides 13-bit accuracy without the need for laser trimming. Reliability of this trimming method has been proven in several other PMI products with many years of reliability history. Internal scaling resistors plus an external op amp simplifies construction in voltage output applications, while maintaining accuracy over wide operating temperature ranges. The PM-562 is recommended for 12-bit accuracy D/A applications where single-chip reliability, small size and low cost are primary considerations.

### PIN CONNECTIONS

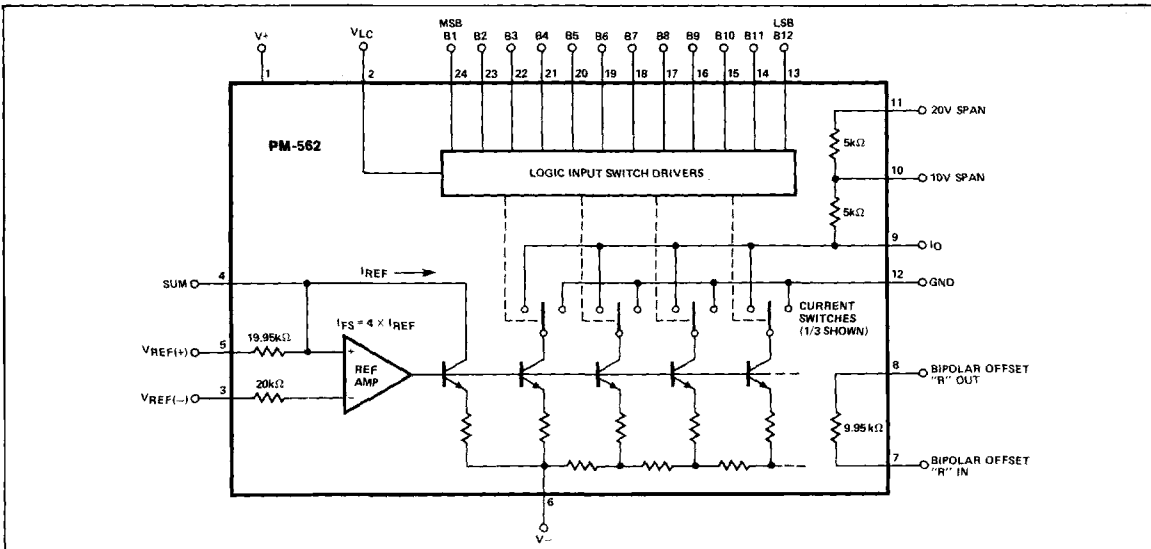


#### TOP VIEW

#### 24-PIN HERMETIC DIP

\* Connect  $V_{LC}$  to  $V+$  for CMOS logic inputs. Leave  $V_{LC}$  open circuit or grounded for TTL inputs.

### EQUIVALENT CIRCUIT



**ABSOLUTE MAXIMUM RATINGS**

Operating Temperature	0°C to +70°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C
Supply Voltage (V <sub>+</sub> )	+18V
Supply Voltage (V <sub>-</sub> )	-18V
V <sub>+</sub> to V <sub>-</sub>	36V
Logic Inputs	V <sub>-</sub> to (V <sub>-</sub> plus 36V)
Summing Junction (Pin 4)	V <sub>-</sub> to V <sub>+</sub>

CMOS/TTL Threshold (Pin 2)	V <sub>-</sub> to V <sub>+</sub>
I <sub>OUT</sub> (Pin 9)	-5V to +18V
Span Resistors	36V

PACKAGE TYPE	$\theta_{JA}$ (Note 1)	$\theta_{JC}$	UNITS
24-Pin Hermetic DIP (V)	57	10	°C/W

**NOTE:**

1.  $\theta_{JA}$  is specified for worst case mounting conditions, i.e.,  $\theta_{JA}$  is specified for device in socket for CerDIP package.

**ELECTRICAL CHARACTERISTICS** at V<sub>+</sub> = 5V, V<sub>-</sub> = -15V, V<sub>REF</sub> (+) = +10.0000V, V<sub>REF</sub> (-) = 0V, T<sub>A</sub> = +25° C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	PM-562H			UNITS
			MIN	TYP	MAX	
Resolution	N	T <sub>A</sub> = Full Range	12	—	—	Bits
Monotonicity		T <sub>A</sub> = Full Range	12	—	—	Bits
Nonlinearity	NL		—	—	±1/2	LSB
Differential Nonlinearity	DNL		—	—	±1/2	LSB
Settling Time	t <sub>S</sub>	To ±1/2 LSB, all bits ON or OFF	—	1.5	—	μs
Output Voltage Compliance	V <sub>OC</sub>		—	+10/-1.5	—	V
Full-Scale Output Current Range	I <sub>FR</sub>	V <sub>REF</sub> (+) = +10.0000V Unipolar R <sub>2</sub> = 50Ω Bipolar	-1.6 ±0.8	-2.0 ±1.0	-2.4 ±1.2	mA
Zero-Scale Current	I <sub>ZS</sub>	All bits OFF	—	.005	0.05	%FS
Output Resistance	R <sub>O</sub>		—	2	—	MΩ
Output Capacitance	C <sub>O</sub>		—	30	—	pF
Reference Input Impedance	Z <sub>IN</sub>	Pin 5	—	20	—	kΩ
Gain Error	I <sub>FSE</sub>	R <sub>2</sub> = 50Ω, (Note 1)	—	±0.2	—	%FS
Bipolar Zero-Scale Error	I <sub>BZSE</sub>	R <sub>1</sub> = 50Ω, (Note 1)	—	±0.1	—	%FS
Full-Scale Gain Adjustment Range	ΔI <sub>FSR</sub>	R <sub>2</sub> = 100Ω Trimpot, (Note 1)	—	±0.25	—	%FS
Bipolar Zero-Scale Adjustment Range	ΔI <sub>BZSR</sub>	R <sub>1</sub> = 100Ω Trimpot, (Note 1)	—	±0.25	—	%FS
Power Supply Gain Sensitivity	+P <sub>SS</sub> -P <sub>SS</sub>	V <sub>+</sub> = 5V or V <sub>+</sub> = 15V V <sub>-</sub> = -15V	—	—	2 6	ppmFS/%
Supply Current	I <sub>+</sub> I <sub>-</sub>	V <sub>+</sub> = 4.75V to 15.8V V <sub>-</sub> = -15V ± 10%	— —	5 -7	18 -25	mA
TTL Logic Input Voltage	V <sub>IH</sub> V <sub>IL</sub>	Pin 2 Open Circuit	I <sub>IH</sub> = 100nA I <sub>IL</sub> = -100μA	2.0 —	— 0.8	V
CMOS Voltage Logic Input	V <sub>IH</sub> V <sub>IL</sub>	Pin 2 tied to Pin 1	I <sub>IH</sub> = 100nA I <sub>IL</sub> = -100μA	70 —	— 30	%V <sub>+</sub>

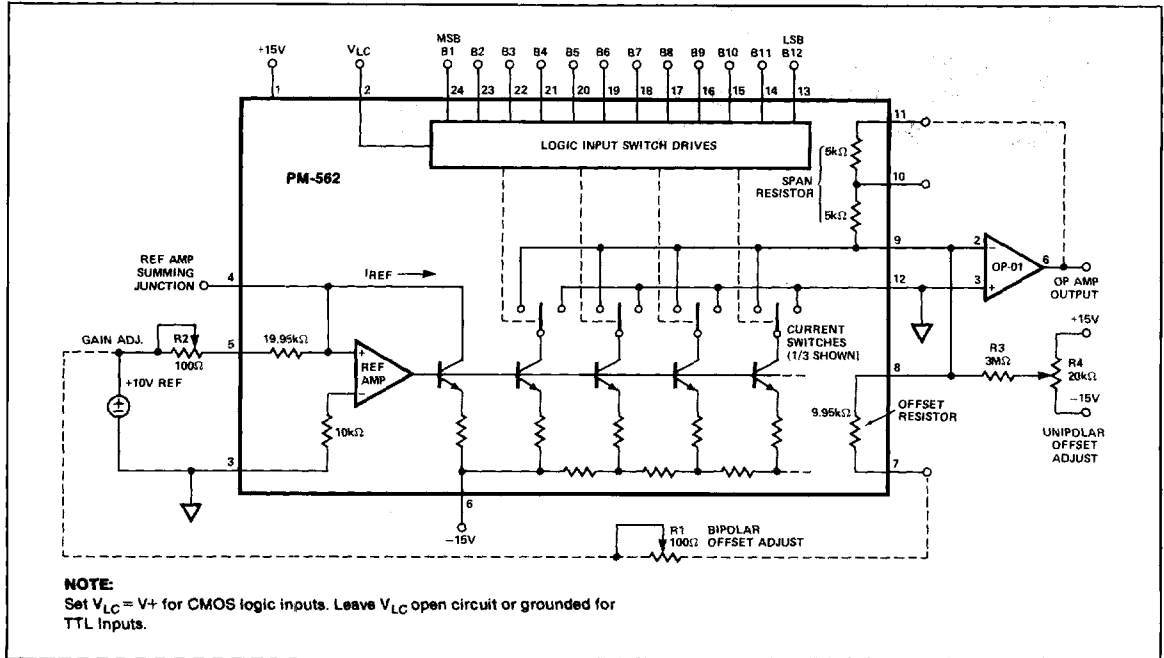
**ELECTRICAL CHARACTERISTICS** at  $V_+ = 5V$ ,  $V_- = -15V$ ,  $V_{REF(+)} = +10.0000V$ ,  $V_{REF(-)} = 0V$ ,  $0^\circ C \leq T_A \leq +70^\circ C$  for PM-562H, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	PM-562H			UNITS
			MIN	TYP	MAX	
Zero-Scale Temperature Coefficient	$TC_{I_{ZS}}$	Unipolar Leakage Current Change (Note 2)	—	—	2	ppmFS/°C
Bipolar Zero-Scale Temperature Coefficient	$TC_{I_{BZS}}$	Bipolar (Note 2)	—	—	4	ppmFS/°C
Full-Scale Gain Temperature Coefficient	$TC_{I_{FS}}$	Excludes $V_{REF}$ (Note 2)	—	—	5	ppmFS/°C
Differential Nonlinearity Temperature Coefficient	$TC_{DNL}$	(Note 2)	—	2	—	ppmFS/°C

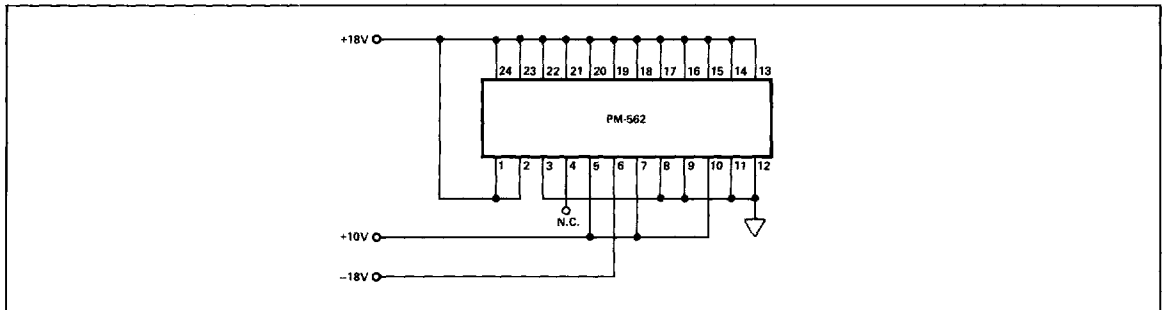
**NOTES:**

1. See connection diagram.
2. Guaranteed by design.

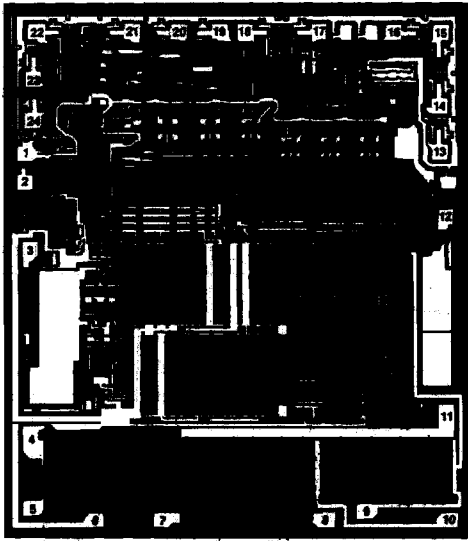
**CONNECTION DIAGRAM**



**BURN-IN CONFIGURATION**



DICE CHARACTERISTICS



DIE SIZE 0.163 × 0.142 inch, 23,146 sq. mils  
(4.140 × 3.607 mm, 14.933 sq. mm)

- |                           |                  |
|---------------------------|------------------|
| 1. V+                     | 13. BIT 12 (LSB) |
| 2. V <sub>LC</sub>        | 14. BIT 11       |
| 3. V <sub>REF</sub> (-)   | 15. BIT 10       |
| 4. REF SUM JUNCTION       | 16. BIT 9        |
| 5. V <sub>REF</sub> (+)   | 17. BIT 8        |
| 6. V-                     | 18. BIT 7        |
| 7. BIPOLAR OFFSET "R" IN  | 19. BIT 6        |
| 8. BIPOLAR OFFSET "R" OUT | 20. BIT 5        |
| 9. I <sub>OUT</sub>       | 21. BIT 4        |
| 10. 10V SPAN              | 22. BIT 3        |
| 11. 20V SPAN              | 23. BIT 2        |
| 12. GROUND                | 24. BIT 1 (MSB)  |

For additional DICE ordering information, refer to 1990/91 Data Book, Section 2.

WAFER TEST LIMITS at V+ = 5V, V- = -15V, V<sub>REF</sub> = 10.0000V, T<sub>A</sub> = 25° C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	PM-562G LIMITS	UNITS
Nonlinearity	NL		±1/2	LSB
Differential Nonlinearity	DNL		±1/2	LSB
Zero-Scale Current	I <sub>ZS</sub>	All Bits OFF	0.05	%FS
Full-Scale Output Current Range	I <sub>FR</sub>	I <sub>REF</sub> = 0.5mA Unipolar	-1.6/-2.4	mA
Logic Input High	V <sub>IH</sub>	I <sub>IH</sub> = 100nA	2	V
Logic Input Low	V <sub>IL</sub>	I <sub>IL</sub> = -100µA	0.8	V
Positive Supply Current	I+	V+ = 4.75 to 15.8V	18	mA
Negative Supply Current	I-	V- = -13.5 to -16.5V	-25	mA

NOTE:

Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications bases on dice lot qualification through sample lot assembly and testing.

TYPICAL ELECTRICAL CHARACTERISTICS at V+ = 5V, V- = -15V, V<sub>REF</sub> = 10.0000V, T<sub>A</sub> = 25° C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	PM-562G TYPICAL	UNITS
Settling Time	t <sub>S</sub>	to ±1/2 LSB, V <sub>O</sub> = 0V	1.5	µs
Full-Scale Gain Temperature Coefficient	TCl <sub>FS</sub>	Excludes V <sub>REF</sub>	5	ppmFS/°C
Output Voltage Compliance	V <sub>OC</sub>		-1.5/+10	V
Output Resistance	R <sub>O</sub>		2	MΩ
Output Capacitance	C <sub>O</sub>		30	pF
Power Supply Gain Sensitivity	+P <sub>SS</sub>	V+ = +5V or +15V	2	ppmFS/%
Power Supply Gain Sensitivity	-P <sub>SS</sub>	V- = -15V	6	ppmFS/%

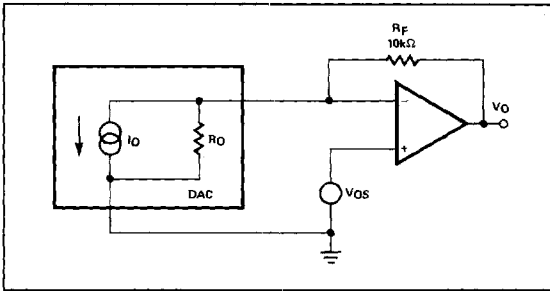
## APPLICATIONS INFORMATION

### $R_O$ EFFECT ON ACCURACY

The D/A converter equivalent circuit and output voltage equations show that a low output resistance ( $R_O$ ) can provide a significant error term due to  $V_{OS}$  drift of the output amplifier. Note that the higher  $R_O$  ( $2M\Omega$ ) offered by the PM-562 gives an apparent  $V_{OS}$  drift that is one-half as large as that resulting from the  $6.6k\Omega$   $R_O$  of the standard AD562 when using a  $10k\Omega$  span resistor ( $R_F$ ).

$$\Delta V_O = \Delta I_O R_F + \Delta V_{OS}$$

Since:  $\Delta I_O = \Delta V_{OS}/R_O$   
Then:  $\Delta V_O = \Delta V_{OS} (R_F/R_O + 1)$



### LAYOUT SUGGESTIONS

Good layout practice appropriate for a 12-bit resolution analog system provides the overriding guideline. Power supplies should have small high frequency noise content. The  $V^-$  ( $-15V$ ) supply should be the cleanest since it has the most direct effect on  $I_{OUT}$ . The PM-562 should have bypass capacitors on both  $V^+$  and  $V^-$  supplies. A tantalum or electrolytic 1 to 10 micro Farad in parallel with a ceramic 0.01 micro Farad bypass capacitor adequately attenuate high frequency supply noise.

The ground line between Pin-3 and Pin-12 should not conduct any other current paths. Placing the common ground point at Pin-12 provides good results. Pin-9 is the most sensitive node to high frequency noise pickup. Keep the signal path between Pin-9 and the current-to-voltage converter (op amp or resistor) as short as possible.

### LOGIC INTERFACING (TTL OR CMOS)

The PM-562 digital inputs (BIT 1 through BIT 12) can be programmed by the  $V_{LC}$  (Pin-2) for TTL or CMOS logic input compatibility.

For TTL input compatibility leave Pin-2 open circuit or ground it to Pin-12. The logic threshold trip point stays at 1.4V for  $V^+$  set anywhere from 4.75 to 15.8V.

For CMOS input compatibility tie  $V_{LC}$  (Pin-2) to  $V^+$ . This establishes the CMOS Logic threshold trip point at 1/2 of  $V^+$ . Therefore  $V^+$  should be set to the same  $V_{DD}$  voltage used by the CMOS driving logic.

### MULTIPLYING MODE

The output current of the PM-562 is the product of the reference voltage input and the number represented by the digital input code divided by 4096. The reference voltage  $V_{REF (+)}$  must be positive with respect to  $V_{REF (-)}$ . The PM-562 typically maintains 12-bit linearity with reference voltages as small as one volt. Reference signal feedthrough is typically 60dB down at 10kHz with a digital input of zero. The DAC output typically takes 20 microseconds to settle to within 1/2 LSB for a 5 volt step on the reference input. The small signal bandwidth for a 100mVpp reference input signal is typically 65kHz, and the typical large signal bandwidth for a 5Vpp reference input signal is 20kHz.

### UNIPOLAR OPERATION (0 to +10V OUTPUT)

Figure 1 shows the simplest unipolar setup for 0 to +10V operation. The output should be buffered since the output resistance is  $5k\Omega$ . The digital input code is complemented in this configuration. That is, binary "0" in produces +10V full-scale out. And all binary one's in produces 0V out.

Figure 2 shows the best configuration to achieve a 0V to 10V output digital-to-analog converter. In this configuration digital "0" in produces 0V out. All one's in produces 10V out.

Calibration of Figure 2 is accomplished by placing digital "0" on all input bits and adjusting  $R_1$  until 0V appears at  $V_{OUT}$ . Next the span (or full-scale) is adjusted by  $R_2$  for an output voltage of 9.9976V.

### BIPOLAR OPERATION ( $\pm 10V$ OUTPUT)

The bipolar configuration of Figure 3 provides positive and negative output voltage under control of one's complement digital input coding. Calibration is accomplished by turning all bits OFF (digital zero input code) and adjusting trimmer  $R_1$  for  $-10.000V$  output. Next turn ON the MSB (digital 1000 0000 input code) and adjust  $R_2$  for 0.0000V.

This circuit can easily be converted to  $\pm 5V$  output by connecting Pin-10 to the OP-01 output, making the span resistor  $5k\Omega$ .

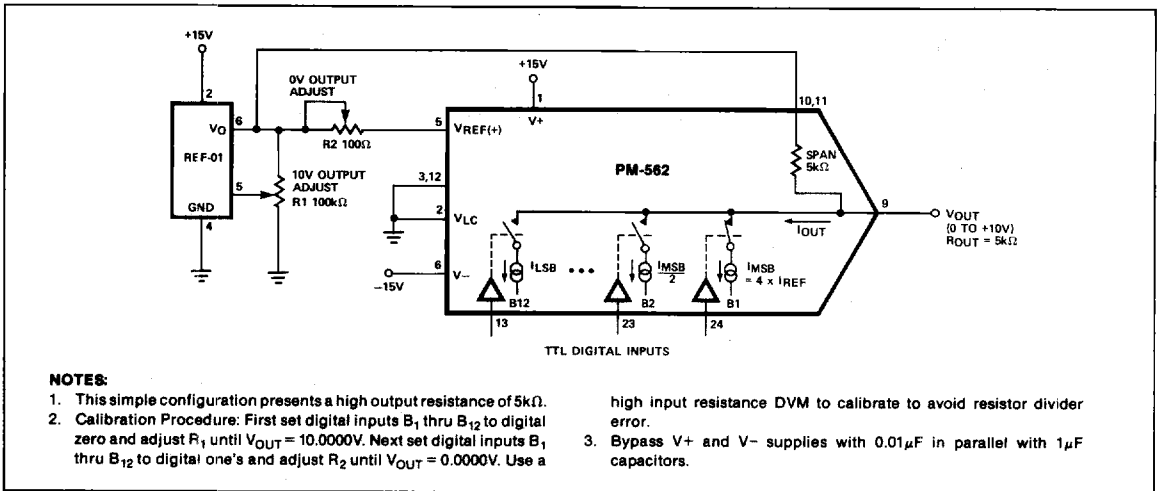


FIGURE 1: Unbuffered Unipolar 0 to +10V Output

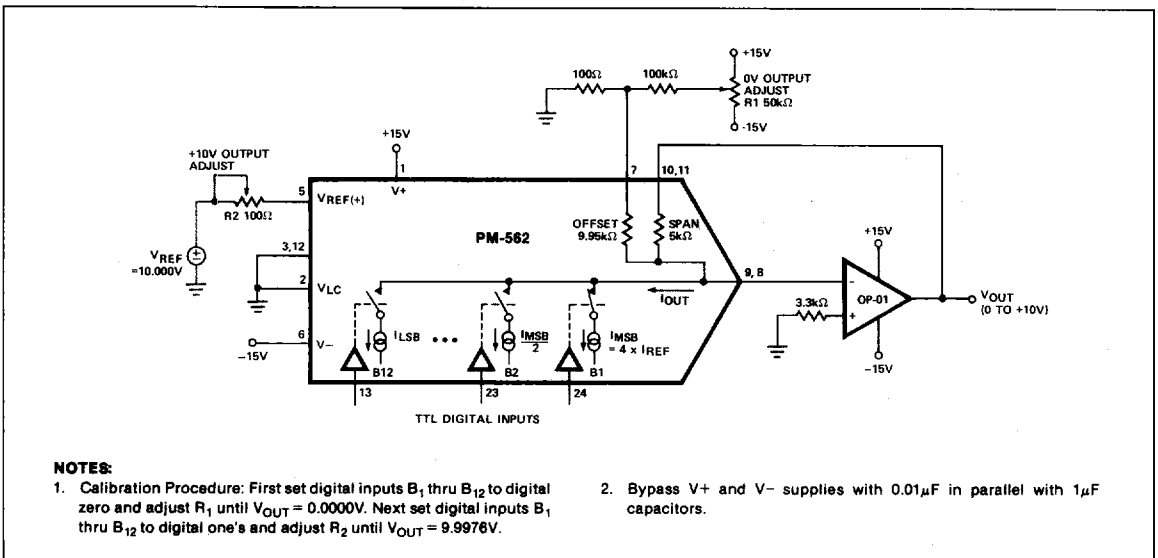


FIGURE 2: +10V Unipolar Voltage Output

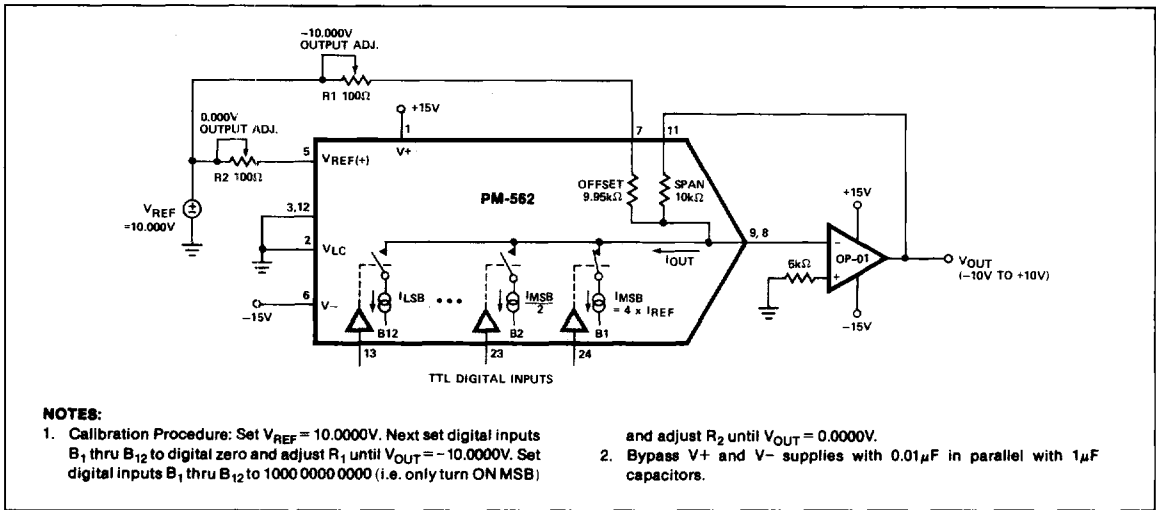
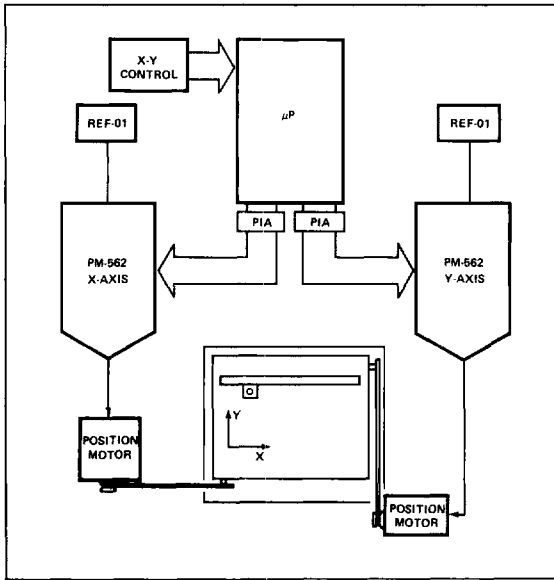
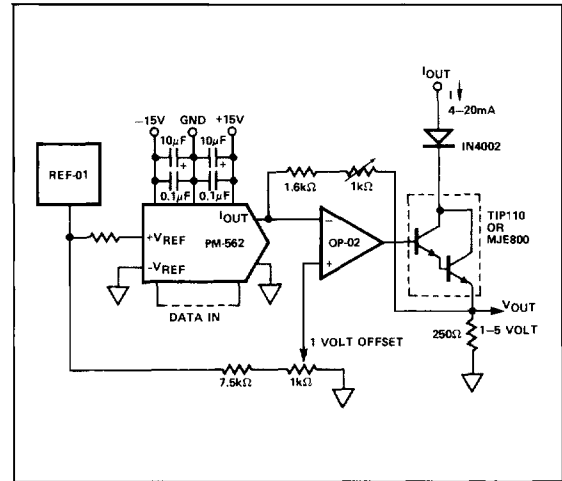


FIGURE 3:  $\pm 10V$  Bipolar Voltage Output

**PRECISION X-Y POSITIONING SYSTEM**



**4-20mA TRANSMITTER**



**DIGITALLY CONTROLLED R.F. OSCILLATOR**

