DESCRIPTION

The MC1508/MC1408 series of 8-bit monolithic digital-to-analog converters provide high speed performance with low cost. They are designed for use where the output current is a linear product of an 8-bit digital word and an analog reference voltage.

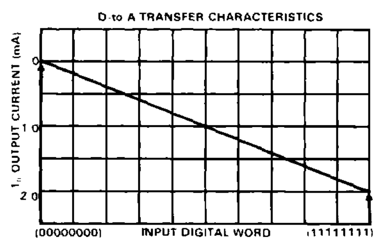
FEATURES

- **Fast settling time—300ns (typ)**
- **Relative accuracy ±0.19% (max error)**
- **Non-inverting digital inputs are TTL and CMOS compatible**
- **High speed multiplying rate 4.0mA/μs (input slew)**
- **Output voltage swing +.5V to -5.0V**
- **Standard supply voltages + 5.0V and -5.0V to -15V**
- **Military qualifications pending**

APPLICATIONS

- **Tracking A-to-D converters**
- **2½-digit panel meters and DVM's**
- **Waveform synthesis**
- **Sample and hold**
- **Peak detector**
- **Programmable gain and attenuation**
- **CRT character generation**
- **Audio digitizing and decoding**
- **Programmable power supplies**
- **Analog-digital multiplication**
- **Digital-digital multiplication**
- **Analog-digital division**
- **Digital addition and subtraction**
- **Speech compression and expansion**
- **Stepping motor drive**

TYPICAL PERFORMANCE CHARACTERISTICS



CIRCUIT DESCRIPTION

The MC1508/MC1408 consists of a reference current amplifier, and R-2R ladder, and 8 high speed current switches. For many applications, only a reference resistor and reference voltage need be added.

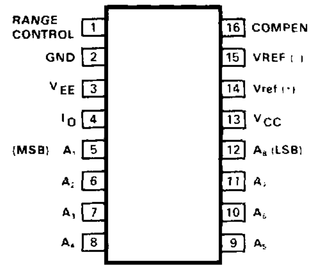
The switches are non-inverting in operation; therefore, a high state on the input turns on the specified output current component.

The switch uses current steering for high speed, and a termination amplifier consisting of an active load gain stage with unity gain feedback. The termination amplifier holds the parasitic capacitance of the ladder at a constant voltage during switching, and provides a low impedance termination of equal voltage for all legs of the ladder.

The R-2R ladder divides the reference amplifier current into binarily-related components, which are fed to the switches. Note that there is always a remainder current which is equal to the least significant bit. This current is shunted to ground, and the maximum output current is 255/256 of the reference amplifier current, or 1.992mA for a 2.0mA reference amplifier current if the NPN current source pair is perfectly matched.

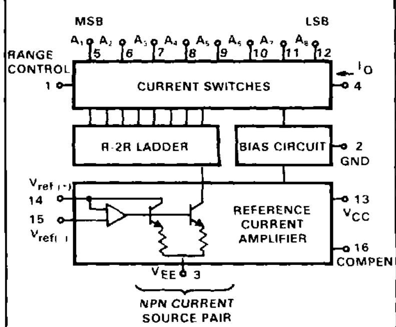
PIN CONFIGURATION

F,N PACKAGE*



*N = Plastic DIP
F = Cerdip

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATNGS T_A = +25°C unless otherwise specified

PARAMETER		RATING	UNIT
V_{CC}	Power supply voltage		V
V_{EE}	Positive	+5.5	
V_5-V_{12}	Negative	-16.5	
V_O	Digital input voltage	+5.5, 0	V
I_{14}	Applied output voltage	+0.5, -5.2	V
V_{14},V_{15}	Reference current	5.0	mA
	Reference amplifier inputs	V_{CC}, V_{EE}	V
P_D	Power dissipation (package limitation)		mW
	Ceramic package	1000	
	Plastic package	800	
T_A	Operating temperature range		°C
	MC1508	-55 to +125	
	MC1408	0 to +75	
T_{stg}	Storage temperature range	-65 to +70	°C

MC1508-8/MC1408-8/MC1408-7 -F,N

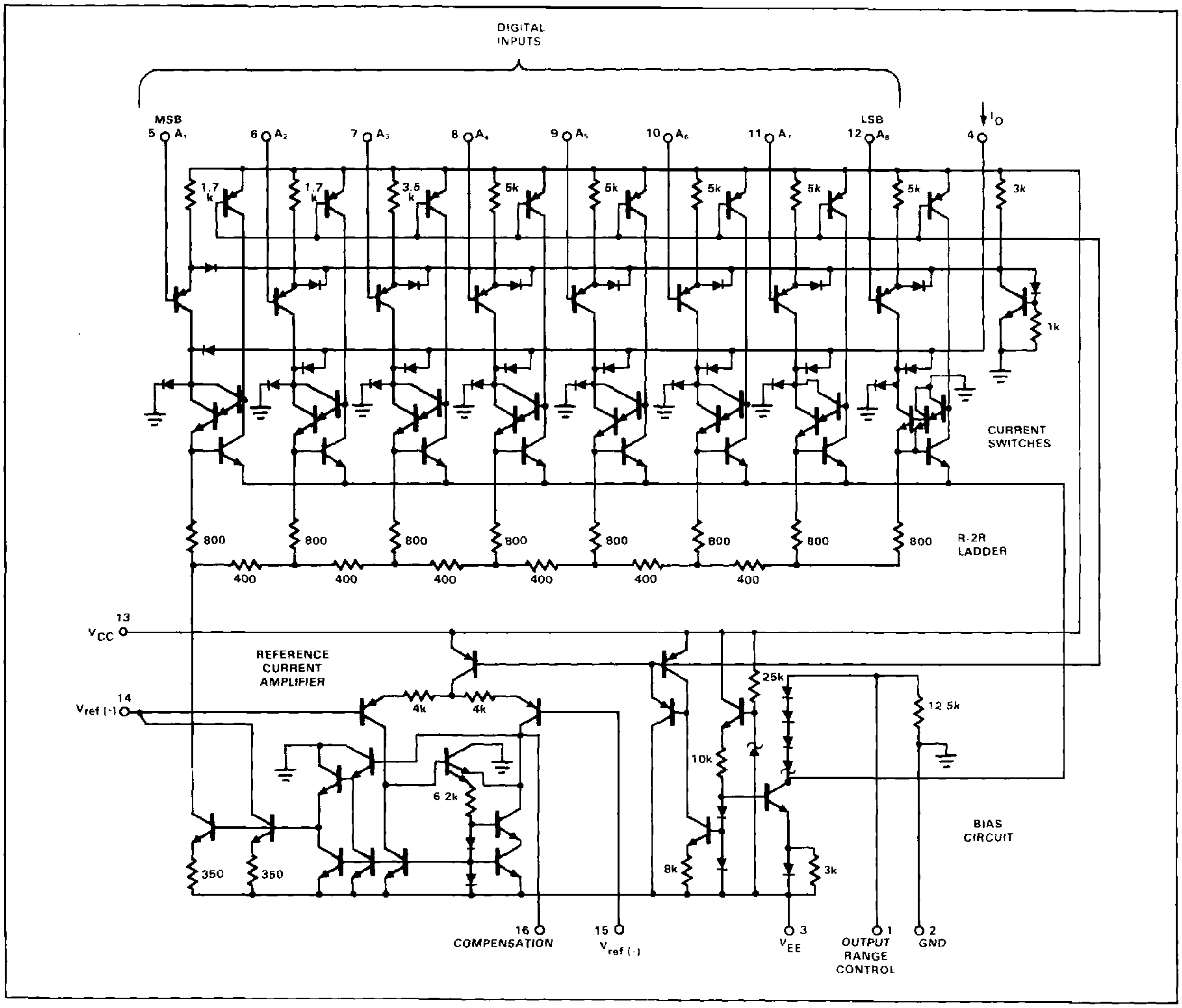
DC ELECTRICAL CHARACTERISTICS[1]

V_{CC} = +5.0Vdc, V_{EE} = −15Vdc, $\frac{V_{ref}}{R_{14}}$ = 2.0mA unless otherwise specified.
MC1508: T_A = −55°C to 125°C. MC1408: T_A = 0°C to 70°C

PARAMETER		TEST CONDITIONS	MC1508-8			MC1408-8			MC1408-7			UNIT
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
E_r	Relative accuracy	Error relative to full scale I_O, Figure 3			±0.19			±0.19			±0.39	%
t_s	Setting time[1]	To within 1/2 LSB, includes t'PLH, T'A = +25°C, Figure 4		300			300			300		ns
	Propagation delay time											ns
t_{PLH}	Low-to-high	T_A = +25°C,		30	100		30	100		30	100	
t_{PHL}	High-to-low	Figure 4										
TCI_O	Output full scale current drift			-20			-20			-20		PPM/°C
	Digital input logic level (MSB)											Vdc
V_{IH}	High	Figure 5	2.0			2.0			2.0			
V_{IL}	Low				0.8			0.8			0.8	
	Digital input current (MSB)	Figure 5										mA
I_{IH}	High	V_{IH} = 5.0V		0	0.04		0	0.04		0	0.04	
I_{IL}	Low	V_{IL} = 0.8V		-0.4	-0.8		-0.4	-0.8		-0.4	-0.8	
I_{15}	Reference input bias current	Pin 15, Figure 5		-1.0	-3.0		-1.0	-3.0		-1.0	-3.0	μA
I_{OR}	Output current range	Figure 5										mA
		V_{EE} = -5.0V	0	2.0	2.1	0	2.0	2.1	0	2.0	2.1	
		V_{EE} = -6.0V to -15V	0	2.0	4.2	0	2.0	4.2	0	2.0	4.2	
I_O	Output current	Figure 5 V_{ref} = 2.000V, R14 = 1000Ω	1.9	1.99	2.1	1.9	1.99	2.1	1.9	1.99	2.1	mA
$I_{O(min)}$	Off-state	All bits low		0	4.0		0	4.0		0	4.0	μA
V_O	Output voltage compliance	E_r≤0.19% at T_A = +25°C, Figure 5										Vdc
		V_{EE} = -5V			-0.6, +0.5			-0.6, +0.5			-0.6, +0.5	
		V_{EE} below -10V			-5.0, +0.5			-5.0, +0.5			-5.0, +0.5	
SRI_{ref}	Reference current slew rate	Figure 6		4.0			4.0			4.0		mA/μs
$PSRR_{(-)}$	Output current power supply sensitivity	I_{ref} = 1mA		0.5	2.7		0.5	2.7		0.5	2.7	μA/V
	Power supply current											mA
I_{CC}	Positive	All bits low,		+13.5	+22		+13.5	+22		+13.5	+22	
I_{EE}	Negative	Figure 5		-7.5	-13		-7.5	-13		-7.5	-13	
	Power supply voltage range											Vdc
V_{CCR}	Positive	T_A = +25°C,	+4.5	+5.0	+5.5	+4.5	+5.0	+5.5	+4.5	+5.0	+5.5	
V_{EER}	Negative	Figure 5	-4.5	-15	-16.5	-4.5	-15	-16.5	-4.5	-15	-16.5	
P_D	Power dissipation	All bits low, Figure 5										mW
		V_{EE} = -5.0Vdc		105	170		105	170		105	170	
		V_{EE} = -15Vdc		190	305		190	305		190	305	
		All bits high, Figure 5										
		V_{EE} = -5.0Vdc		90			90			90		
		V_{EE} = -15Vdc		160			160			160		

NOTES
1 All bits switched

EQUIVALENT CIRCUIT SCHEMATIC



FUNCTIONAL DESCRIPTION

Reference Amplifier Drive and Compensation

The reference amplifier provides a voltage at pin 14 for converting the reference voltage to a current, and a turn-around circuit or current mirror for feeding the ladder. The reference amplifier input current (I_{14}) must always flow into pin 14 regardless of the setup method or reference voltage polarity.

Connections for a positive reference voltage are shown in Figure 1. The reference voltage source supplies the full current I_{14}. For bipolar reference signals, as in the multiplying mode, R_{15} can be tied to a negative voltage corresponding to the minimum input level. It is possible to eliminate R_{15} with only a small sacrifice in accuracy and temperature drift.

The compensation capacitor value must be increased with increases in R_{14} to maintain proper phase margin; for R_{14} values of 1.0, 2.5 and 5.0kΩ, minimum capacitor values are 15, 37, and 75pF. The capacitor may be tied to either V_{EE} or ground, but using V_{EE} increases negative supply rejection.

A negative reference voltage may be used if R_{14} is grounded and the reference voltage is applied to R_{15} as shown in Figure 2. A high input impedance is the main advantage of this method. Compensation involves a capacitor to V_{EE} on pin 16, using the values of the previous paragraph. The negative reference voltage must be at least 3.0V above the V_{EE} supply. Bipolar input signals may be handled by connecting R_{14} to a positive reference voltage equal to the peak positive input level at pin 15.

When a dc reference voltage is used, capacitive bypass to ground is recommended. The 5.0V logic supply is not recommended as a reference voltage. If a well regulated 5.0V supply which drives logic is to be used as the reference, R_{14} should be decoupled by connecting it to +5.0V through another resistor and bypassing the junction of the 2 resistors with 0.1µF to ground. For reference voltages greater than 5.0V, a clamp diode is recommended between pin 14 and ground.

If pin 14 is driven by a high inpedance such as a transistor current source, none of the above compensation methods apply and the amplifier must be heavily compensated, decreasing the overall bandwidth.

Output Voltage Range

The voltage on pin 4 is restricted to a range of -0.6 to +0.5V at -24°C, due to the current switching methods employed in the MC1508/MC1408. When a current switch is turned off, the positive voltage on the output terminal can turn on the output diode and increase the output current level. When a current switch is turned on, the negative output voltage range is restricted. The base of the termination circuit Darlington transistor is 1 diode voltage below ground when pin 1 is grounded, so a negative voltage below ground when pin 1 is grounded, so a negative voltage below the specified safe level will drive the low current device of the Darlington into saturation, decreasing the output current level.

The negative output voltage compliance of the MC1508/MC1408 may be extended to -5.0V by opening the circuit at pin 1. The negative supply voltage must be more negative than -10V. Using a full scale current of 1.992mA and load resistor of 2.5kΩ between pin 4 and ground will yield a voltage output of 256 levels between 0 and -4.980V. Floating pin 1 does not affect the converter speed or power dissipation. However, the value of the load resistor determines the switching time due to increased voltage swing. Values of R_L up to 500Ω do not significantly affect performance, but 2.5kΩ load increases worst case settling time to 1.2μs (when all bits are switched on). Refer to the subsequent text section on settling time for more details on output loading.

If a power supply value between -5.0V and -10V is desired, a voltage of between 0 and -5.0V may be applied to pin 1. The value of this voltage will be the maximum allowable negative output swing.

Output Current Range

The output current maximum rating of 4.2mA may be used only for negative supply voltages more negative than -7.0V, due to the increased voltage drop across the 350Ω resistors in the reference current amplifier.

Accuracy

Absolute accuracy is the measure of each output current level with respect to its intended value, and is dependent upon relative accuracy and full scale current drift. Relative accuracy is the measure of each output current level as a fraction of the full scale current. The relative accuracy of the MC1508/MC1408 is essentially constant with temperature due to the excellent temperature tracking of the monolithic resistor ladder. The reference current may drift with temperature, causing a change in the absolute accuracy of output current. However, the MC1508/MC1408 has a very low full scale current drift with temperature.

The MC1508/±MC1408 series is guaranteed accurate to within ±1/2 LSB at +25°C at a full scale output current of 1.992mA. This corresponds to a reference amplifier output current drive to the ladder network of 2.0mA, with the loss of 1 LSB = 8.0μA which is the ladder remainder shunted to ground. The input current to pin 14 has a guaranteed value of between 1.9 and 2.1mA, allowing some mismatch in the NPN current source pair. The accuracy test circuit is shown in Figure 3. The 12-bit converter is calibrated for a full scale output current of 1.992mA. This is an optional step since the MC1508/MC1408 accuracy is essentially the same between 1.5 and 2.5mA. Then the MC1508/MC1408 circuits' full scale current is trimmed to the same value with R14 so that a zero value appears at the error amplifier output. The counter is activated and the error band may be displayed on an oscilloscope, detected by comparators, or stored in a peak detector.

Two 8-bit D-to-A converters may not be used to construct a 16-bit accurate D-to-A converter. Sixteen-bit accuracy implies a total error ±1/2 of 1 part in 65,536, or ±0.00076%, which is much more accurate than the ±0.19% specification provided by the MC1508/MC1408.

Multiplying Accuracy

The MC1508/MC1408 may be used in the multiplying mode with 8-bit accuracy when the reference current is varied over a range of 256:1. The major source of error is the bias current of the termination amplifier. Under worst case conditions, these 8 amplifiers can contribute a total of 1.6μA extra current at the output terminal. If the reference current in the multiplying mode ranges from 16μA to 4.0mA, the 1.6μA contributes an error of 0.1 LSB. This is well within 8-bit accuracy.

A monotonic converter is one which supplies an increase in current for each increment in the binary word. Typically, the MC1508/MC1408 in monotonic for all values of reference current above 0.5mA. The recommended range for operation with a dc reference current is 0.5 to 4.0mA.

Settling Time

The worst case switching condition occurs when all bits are switched on, which corresponds to a low-to-high transition for all bits. This time is typically 300ns for settling to within ±1/2 LSB for 8-bit accuracy and 200ns to 1/2 LSB for 7-bit accuracy. The turnoff is typically under 100ns. These times apply when $R_L \leq 500\Omega$ and C_O 25pF.

The slowest single switch is the least significant bit, which turns on and settles in 250ns and truns off in 80ns. In applications where the D-to-A converter functions in a positive going ramp mode, the worst case switching condition does not occur, and a settling time of less than 300ns may be realized. Bit A7 turns on in 200ns and off in 80ns, while bit A6 turns on in 150ns and off in 80ns.

The test circuit of Figure 4 requires a smaller voltage swing for the current switches due to internal voltage clamping in MC1508/MC1408. A 1.0kΩ load resistor from pin 4 to ground gives a typical settling time of 400ns. Thus, it is voltage swing and not the output R_C time constant that determines settling time for most applications.

Extra care must be taken in board layout since this is usually the dominant factor in satisfactory test results when measuring settling time. Short leads, 100μF supply bypassing for low frequencies, and minimum scope lead length are all mandatory.

TEST CIRCUITS

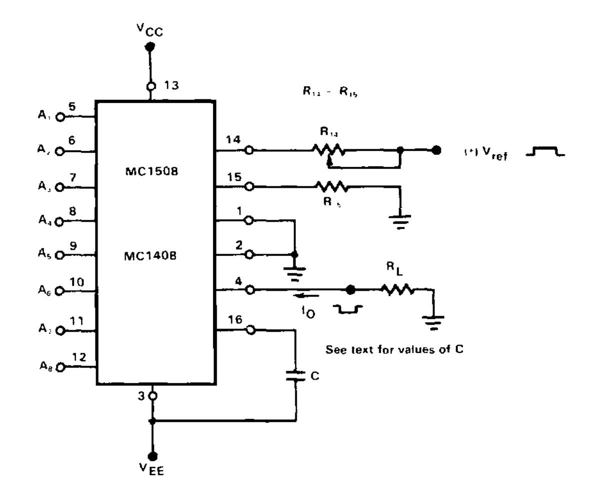


Figure 1

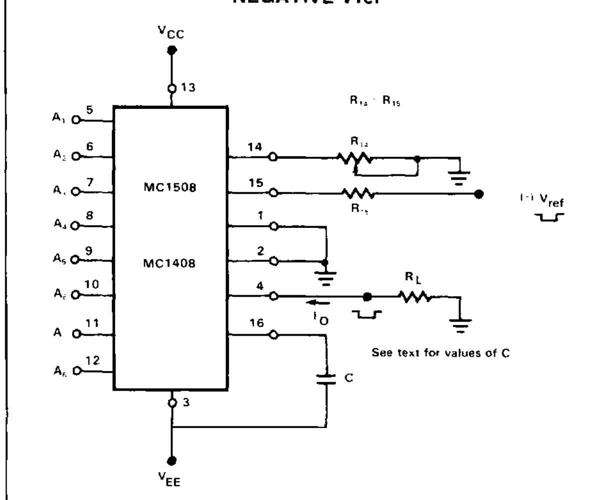


Figure 2

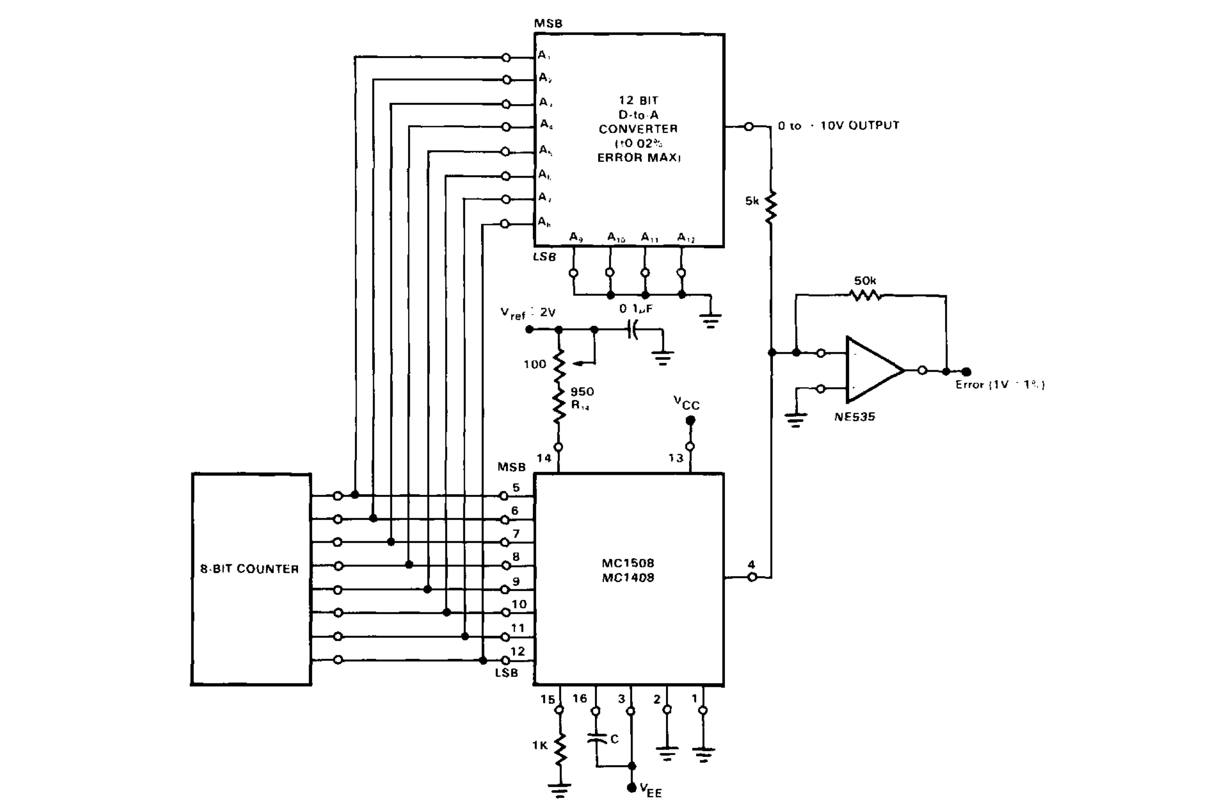


Figure 3

TEST CIRCUITS (Cont'd)

TRANSIENT RESPONSE AND SETTLING TIME

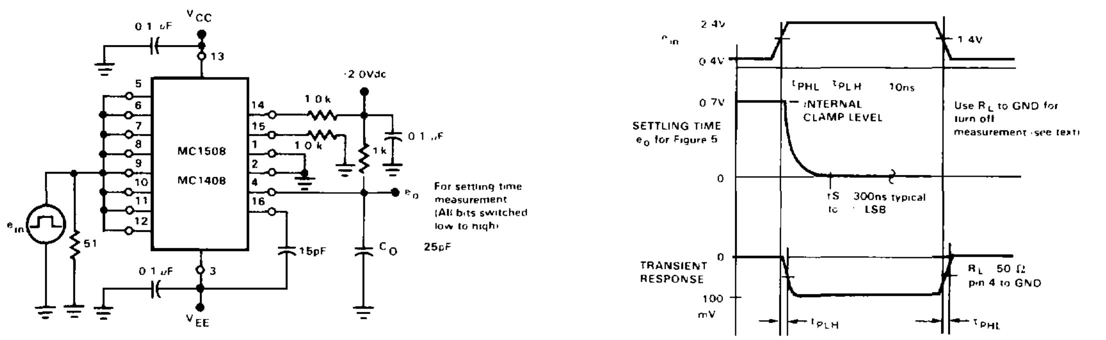
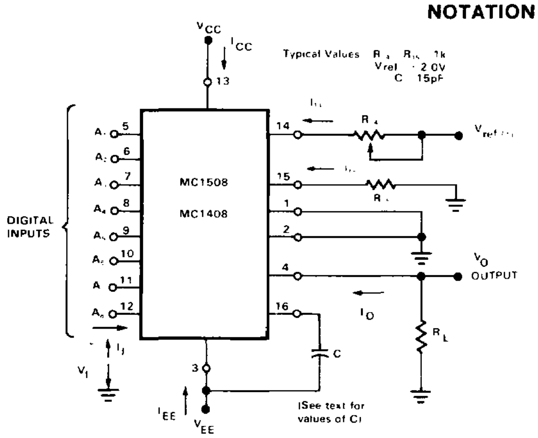


Figure 4

NOTATION DEFINITIONS



V_I and I_I apply to inputs A_1 thru A_8

The resistor tied to pin 15 is to temperature compensate the bias current and may not be necessary for all applications

$$I_O = K\left\{\frac{A_1}{2} + \frac{A_2}{4} + \frac{A_3}{8} + \frac{A_4}{16} + \frac{A_5}{32} + \frac{A_6}{64} + \frac{A_7}{128} + \frac{A_8}{256}\right\}$$

where $K = \frac{V_{ref}}{R_{14}}$

and A_N = "1" if A_N is at high level
A_N = "0" if A_N is at low level

Figure 5

REFERENCE CURRENT SLEW RATE MEASUREMENT

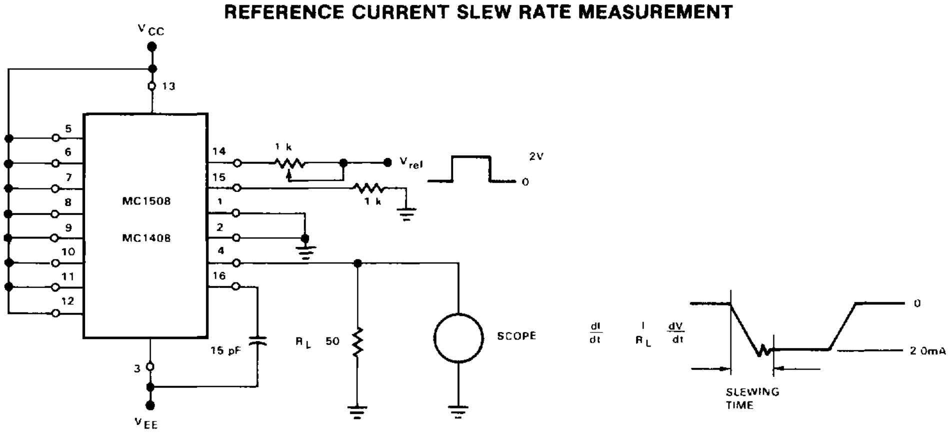


Figure 6