

*Linear IC*

# 6-Channel 8-BIT A/D Converter

## MB4053

### ■ DESCRIPTION

The Fujitsu MB4053 is 6-channel, 8-bit, single-slope A/D converter subsystem designed to be used in a microprocessor based data control system.

The MB4053 is single monolithic bipolar IC providing a 1 of 8 address decoder, 8-channel analog multiplier, sample and hold, constant current generator, ramp integrator and comparator in a 16-pin package.

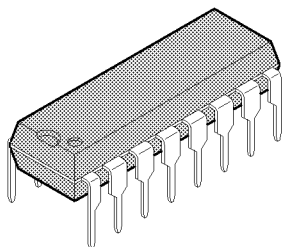
This A/D converter subsystems are suitable for a wide range of applications. The resolution required by an application can be obtained by arbitrarily selecting a suitable integration time. Also zero offset and full-scale error corrections can be made automatically (auto-zero and auto-calibration) to minimize conversion error.

### ■ FEATURES

- Microprocessor compatible
- Digital input/output: TTL compatible
- Zero offset and full-scale error correction capability
- Ratiometric conversion capability
- Available in 16-pin DIP and Flat Package
- Compatible with MC 14443 and  $\mu$ A9708 (DIP package)
- Single power supply: +4.75 V to +15 V
- Excellent linearity:  $\pm 0.2\%$  max. error
- Fast conversion time: 300  $\mu$ s/ch typ.
- Analog input voltage: 0 V to  $V_{CC} - 2$  V (5.25 V max.)
- Power Dissipation: 25 mW typ. at  $V_{CC} = 5$  V

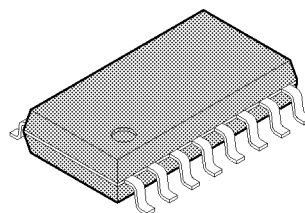
### ■ PACKAGES

16-pin Plastic DIP



(DIP-16P-M04)

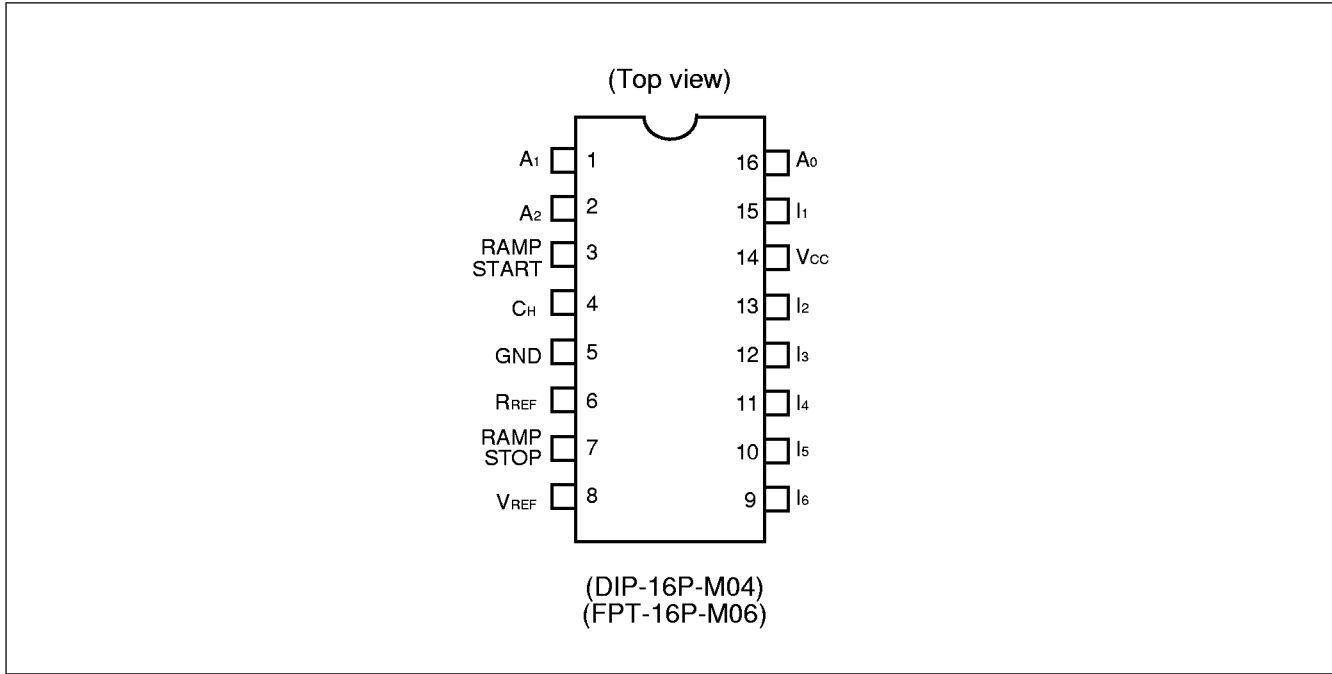
16-pin Plastic SOP



(FPT-16P-M06)

# MB4053

## ■ PIN ASSIGNMENT

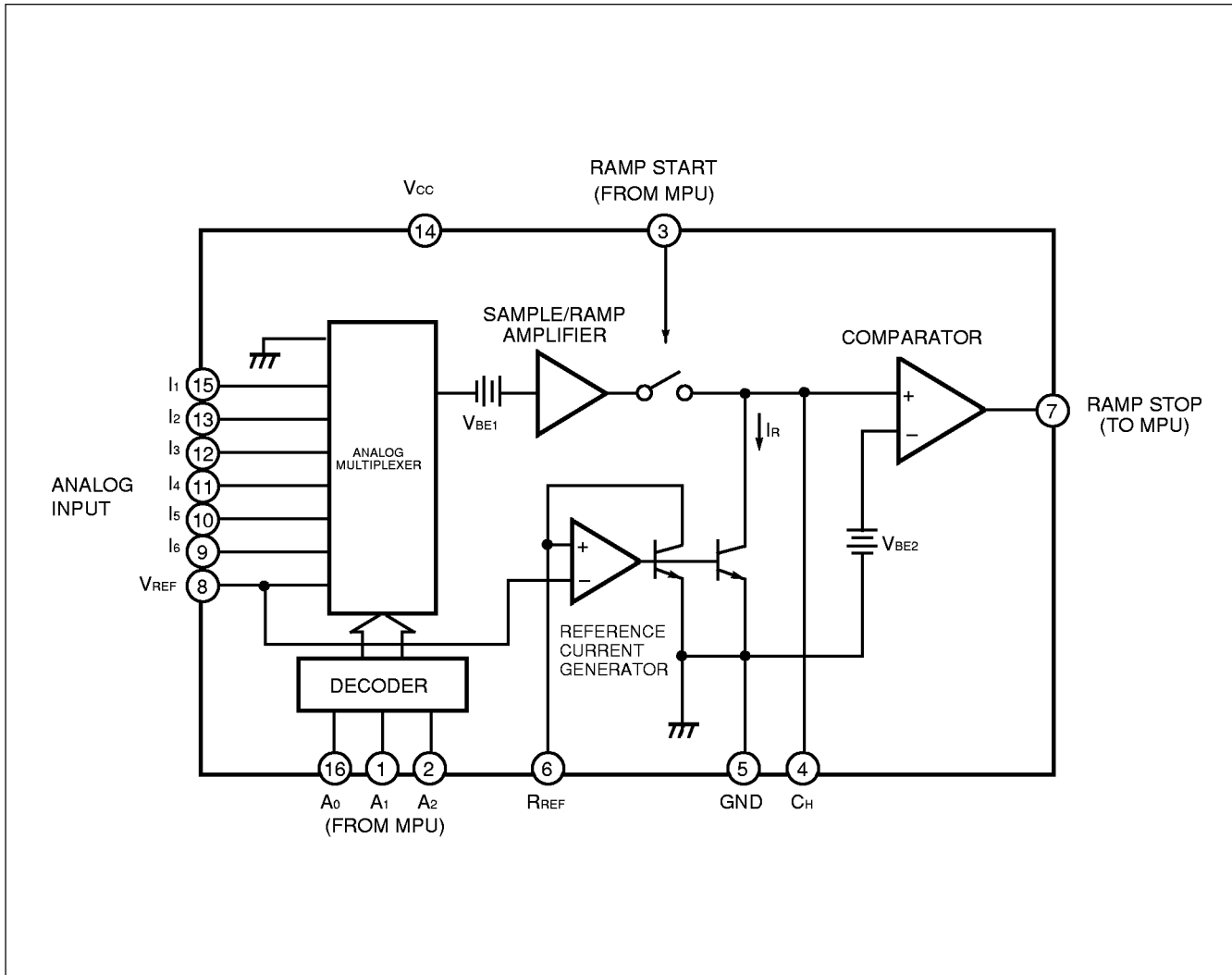


## ■ PIN DESCRIPTION

Pin no.	Pin name	Symbol	Function
9 to 13 15	Analog input	I <sub>1</sub> thru I <sub>6</sub>	Analog inputs for the six channels. One of the 6 is selected by a specific bit pattern on A <sub>0</sub> to A <sub>2</sub> .
16 1 2	Channel selection input	A <sub>0</sub> A <sub>1</sub> A <sub>2</sub>	Input for selecting an analog input channel. Either GND, one of channels I <sub>1</sub> to I <sub>6</sub> or V <sub>REF</sub> is selected by a specific bit pattern on the 3 inputs.
3	RAMP START signal input	RAMP START	A/D conversion start signal input. RAMP START (1 → 0) Ramp time start signal input. RAMP START (0 → 1)
7	RAMP STOP signal output	RAMP STOP	Indicates that C <sub>H</sub> is charged over comparator reference voltage V <sub>BE2</sub> . RAMP STOP (0 → 1) A/D conversion end signal (C <sub>H</sub> discharged to comparator reference voltage). RAMP STOP (0 → 1)
4	Ramp capacitor pin	C <sub>H</sub>	Pin for externally connecting the ramp capacitor. The value of C <sub>H</sub> in conjunction with V <sub>REF</sub> and R <sub>REF</sub> establishes the ramp time.
8	Reference voltage supply pin	V <sub>REF</sub>	Reference voltage supply pin. This is the reference voltage source for determining the discharge current and the analog reference voltage for full-scale factor correction. When the channel selection input is set 111, this pin is selected for channel conversion. The full-scale factor is corrected using the conversion results. The voltage at this pin must be set to (GND + 2 V) to (V <sub>CC</sub> – 2 V) and 5.25 V or less.
6	Reference resistance pin	R <sub>REF</sub>	Pin for external reference resistance for setting the discharge current. The external resistance is connected between the power source pin (V <sub>CC</sub> ) and the reference resistance pin (R <sub>REF</sub> ). The discharge current is, then, $I_R = (V_{CC} - V_{REF})/R_{REF}$ .
14	Power supply	V <sub>CC</sub>	Power supply pin
5	Ground	GND	Ground pin This pin is grounded. When the channel selection input is set to 000, this terminal is selected for channel conversion. The zero offset is corrected using the conversion results.

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## ■ BLOCK DIAGRAM



## ■ ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Rating		Unit	
		Min.	Max.		
Power supply voltage	V <sub>CC</sub>	—	18	V	
Digital input voltage	V <sub>IND</sub>	-0.5	+30	V	
Digital output voltage when off	V <sub>OH</sub>	-0.5	+18	V	
Analog input voltage	V <sub>IA</sub>	-0.5	+30	V	
Output current	I <sub>o</sub>	—	10	mA	
Storage temperature	Ceramic	T <sub>stg</sub>	-55	+150	°C
	Plastic		-55	+125	°C

WARNING: Semiconductor devices can be permanently damaged by application of stress (voltage, current, temperature, etc.) in excess of absolute maximum ratings. Do not exceed these ratings.

## ■ RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Value			Unit
		Min.	Typ.	Max.	
Power supply voltage	V <sub>CC</sub>	4.75	5.0	15	V
Reference voltage*	V <sub>REF</sub>	2.0	—	5.25	V
Ramp capacity	C <sub>H</sub>	300	—	—	pF
Reference current	I <sub>R</sub>	12	—	50	μA
Analog input voltage	V <sub>IA</sub>	0	—	V <sub>REF</sub>	V
Output current	I <sub>o</sub>	—	—	1.6	mA
Operating temperature	T <sub>a</sub>	-40	—	+85	°C

\* :  $2\text{ V} \leq V_{\text{REF}} \leq V_{\text{CC}} - 2\text{ V}$

WARNING: Recommended operating conditions are normal operating ranges for the semiconductor device. All the device's electrical characteristics are warranted when operated within these ranges.

Always use semiconductor devices within the recommended operating conditions. Operation outside these ranges may adversely affect reliability and could result in device failure.

No warranty is made with respect to uses, operating conditions, or combinations not represented on the data sheet. Users considering application outside the listed conditions are advised to contact their FUJITSU representative beforehand.

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## ■ ELECTRICAL CHARACTERISTIC

(V<sub>CC</sub> = 4.75 V to 15 V, T<sub>a</sub> = -40°C to +85°C)

Parameter	Symbol	Value			Unit	Remarks
		Min.	Typ.	Max.		
Conversion error	E <sub>A</sub>	—	±0.2	±0.3	%	*1
Linearity error	E <sub>R</sub>	—	±0.08	±0.2	%	*2
Analog input current	I <sub>B</sub>	—	-50	-250	nA	
Crosstalk between any two channels	V <sub>CR</sub>	60	—	—	dB	*3
Multiplexer input offset voltage	V <sub>OSM</sub>	—	2.0	4.0	mV	
Conversion time	t <sub>c</sub>	—	296	350	μs/ch	See "■MEASUREMENT CIRCUIT" Analog input: 0 thru V <sub>REF</sub> C <sub>H</sub> = 3300 pF, I <sub>R</sub> = 50 μA
Acquisition time	t <sub>A</sub>	—	20	40	μs	See "■MEASUREMENT CIRCUIT" C <sub>H</sub> = 1000 pF*4
Acquisition current	I <sub>A</sub>	150	—	—	μA	
Ramp start delay time	t <sub>o</sub>	—	100	—	ns	
Multiplexer address time	t <sub>M</sub>	—	1	—	μs	
Digital high level input voltage	V <sub>IH</sub>	2.0	—	—	V	
Digital low level input voltage	V <sub>IL</sub>	—	—	0.8	V	
Digital low level input current	I <sub>IL</sub>	—	-5	-15	μA	V <sub>IL</sub> = 0.4 V
Digital high level input current	I <sub>IH</sub>	—	—	1	μA	V <sub>IH</sub> = 5.5 V
High level output current	I <sub>OH</sub>	—	—	10	μA	V <sub>OH</sub> = 15 V
Low level output voltage	V <sub>OL</sub>	—	—	0.4	V	I <sub>OL</sub> = 1.6 mA
Power supply current	I <sub>CC</sub>	—	5	10	mA	

A minus sign (-) prefixing a current value indicates that the current flows from the IC to the external circuit.

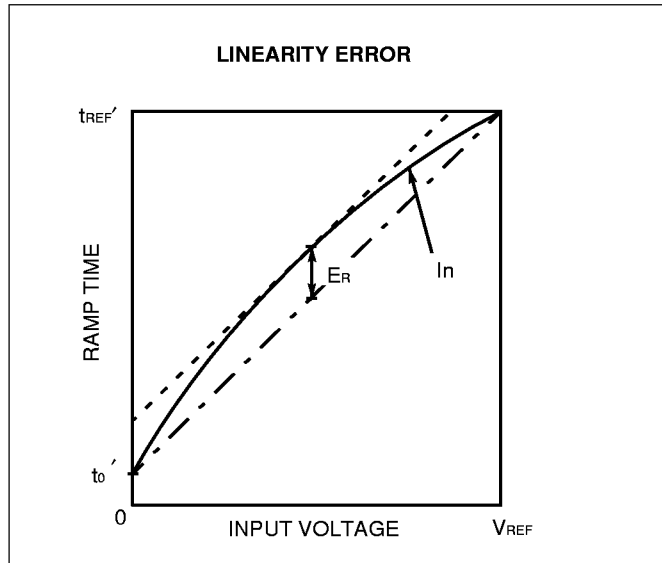
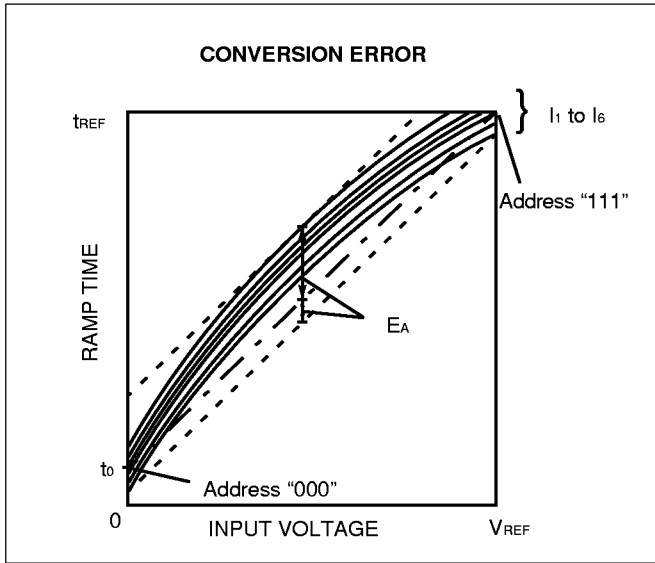
\*1: Conversion error: For all channels, deviation from a straight line between two points obtained by channel addresses 000 (0 scale) and 111 (full scale).

\*2: Linearity error; Deviation from a straight line between the 0 and full scale points for each channel.

\*3: Crosstalk between channels: Voltage change V<sub>CH</sub> of C<sub>H</sub> terminal occurring when an input voltage of a channel is changed by ΔV<sub>1</sub> while another channel is already charged (RAMP START = 0).

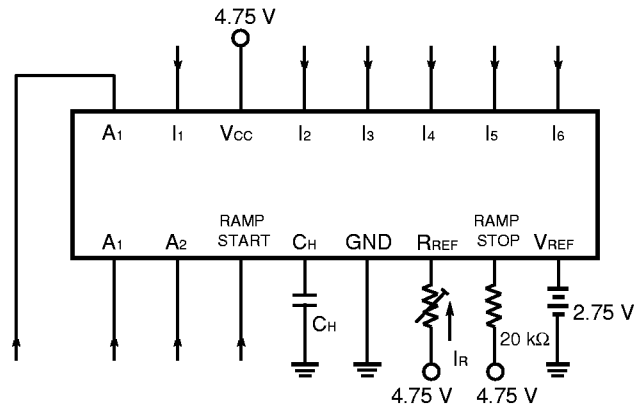
This calculated by  $20 \log \frac{\Delta V_{CH}}{\Delta V_1}$

\*4: Acquisition time: Sum of multiplexer delay time, RAMP START delay time, and time required to charge the selected input voltage to the ramp capacitor.



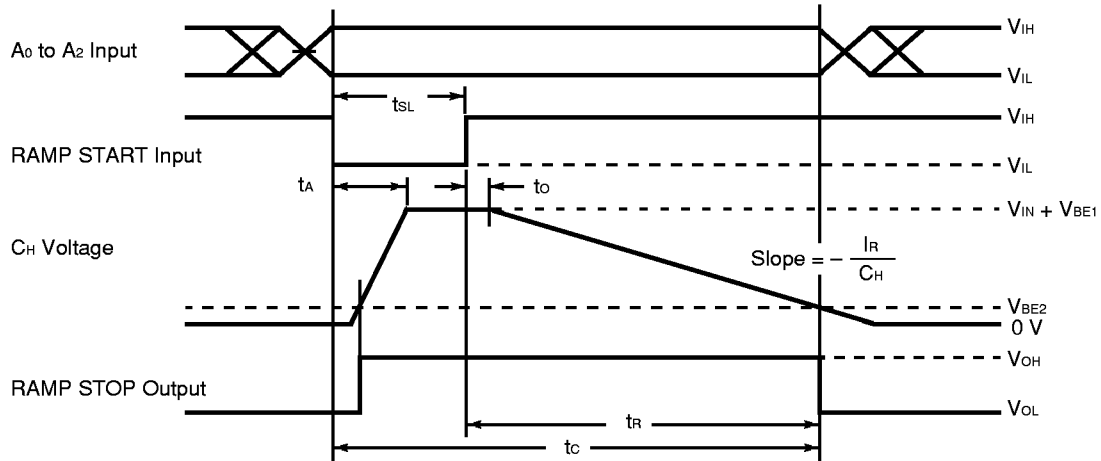
# MB4053

## MEASUREMENT CIRCUIT



Note: Adjust  $R_{REF}$  in the range 40 to 200  $k\Omega$  so that  $I_R$  is 12 to 50  $\mu A$ .

## DIAGRAM



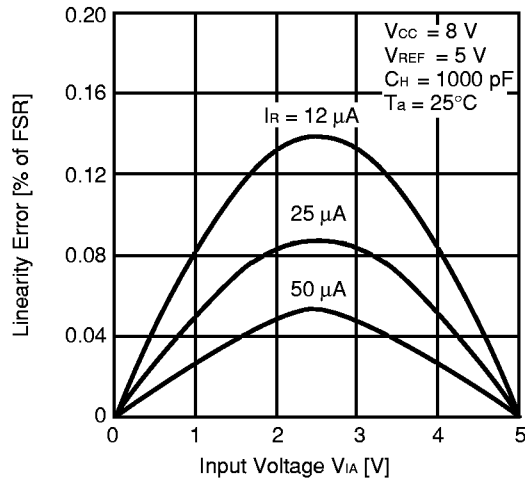
## CHANNEL SELECTION

Input address line			Selected analog input
A <sub>2</sub>	A <sub>1</sub>	A <sub>0</sub>	
0	0	0	GND
0	0	1	I <sub>1</sub>
0	1	0	I <sub>2</sub>
0	1	1	I <sub>3</sub>
1	0	0	I <sub>4</sub>
1	0	1	I <sub>5</sub>
1	1	0	I <sub>6</sub>
1	1	1	V <sub>REF</sub>

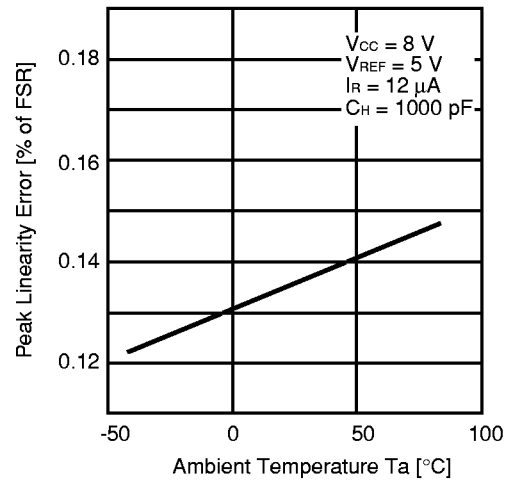


## TYPICAL CHARACTERISTICS

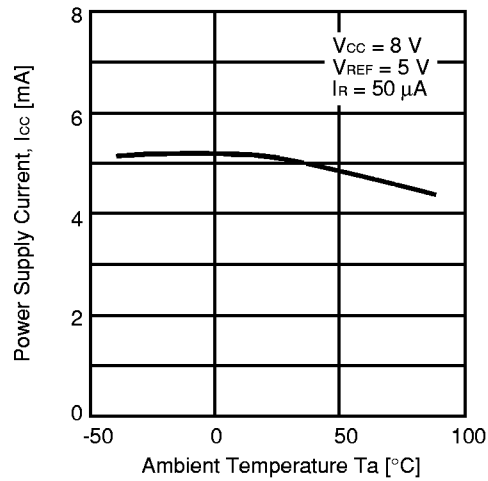
### LINEARITY ERROR vs INPUT VOLTAGE



### PEAK LINEARITY ERROR vs AMBIENT TEMPERATURE $T_a$



### SUPPLY CURRENT vs AMBIENT TEMPERATURE



# MB4053

## ■ OPERATION DESCRIPTION

Refer to BLOCK DIAGRAM, and DIAGRAM. Address inputs  $A_0$  to  $A_2$  are used to select the analog input to be converted, (one of the six analog inputs  $I_1$  to  $I_6$ ). The RAMP START input is switched from a logic 1 to a logic zero. This causes the external ramp capacitor  $C_H$  to charge at a fixed rate. (Note 1) until it reaches the sum of the selected analog input voltage and a constant offset voltage  $V_{BE1}$ . The RAMP STOP output (open-collector switches from a logic 0 to logic 1 when the voltage on  $C_H$  reaches the comparator reference voltage  $V_{BE2}$ . The RAMP START input is switched back to a logic 1 after  $C_H$  is completely charged. This disconnects the analog input from  $C_H$  and allows it to be gin discharging at a fixed rate (Note 2). When the voltage on  $C_H$  reaches the comparator reference voltage  $V_{BE2}$  the RAMP STOP output switches back to a logic 0. This completes a conversion cycle for 1 channel.

The time between the RAMP START input switching (0→1) and RAMP STOP output switching (1→0) is the RAMP TIME  $t_R$ . This would be directly proportional to the analog input voltage for the ideal situation where there was no comparator switching level error, leakage, switching delay times or effect of the impedance of the internal reference current source.  $t_R$  can be calculated for the ideal case as follows:

$$t_R = V_{IN} \times \frac{C_H}{I_R}$$

Where:  $V_{IN}$  = Analog input voltage to be measured

$C_H$  = External ramp capacitor

$$I_R = \frac{V_{CC} - V_{REF}}{R_{REF}}$$

This ramp time is converted to a digital representation by counting  $t_R$  with the microprocessor. If a small error can be tolerated, the A/D conversion software can be reduced and the conversion time minimized by omitting corrections.

Notes:

$$*1 \text{ Charge slope} = \frac{I_A - I_R}{C_H} \geq \frac{150 \mu A - I_R}{C_H}$$

Where:  $I_A$  is the acquisition current whose value is determined from the circuit constant in the IC.

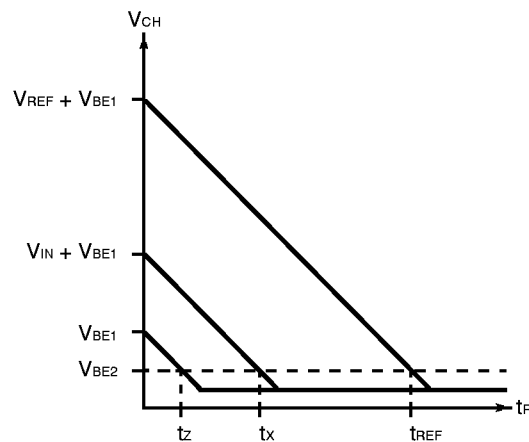
$$*2 \text{ Discharge slope} = - \frac{I_R}{C_H}$$

## ■ ZERO OFFSET AND FULL-SCALE FACTOR CORRECTIONS

High precision conversions can be achieved by correcting for zero offset and full scale factor as follows:

The channel select address ( $A_0$  to  $A_2$ ) is set to 000. Ground (GND) is selected (internally) as the analog input and converted. This results in ramp time  $t_R$ . Next the address is set to 111.  $V_{REF}$  is selected (internally) and converted. This results in ramp time,  $t_{REF}$ . Finally the desired analog input (one of  $I_1$  to  $I_6$ ) is selected and converted. This results in ramp time  $t_x$ . This conversion sequence is arbitrary and the GND and  $V_{REF}$  conversions are not needed each time a channel is converted but only as required for calibration. The relationships between the inputs and ramp times are shown below.

$$\begin{aligned} (V_{BE1})_C &= t_z \\ (V_{REF} + V_{BE1})_C &= t_{REF} \\ (V_{IN} + V_{BE1})_C &= t_x \\ (V_{REF})_C &= t_{REF} - t_z \\ (V_{IN})_C &= t_x - t_z \\ \frac{(V_{IN})_C}{(V_{REF})_C} &= \frac{t_x - t_z}{t_{REF} - t_z} \end{aligned}$$



The conversion error can then be minimized by using the above results in the expression below to calculate the corrected analog input voltage.

$$(V_{IN})_C = (V_{REF})_C \times \frac{t_x - t_z}{t_{REF} - t_z}$$

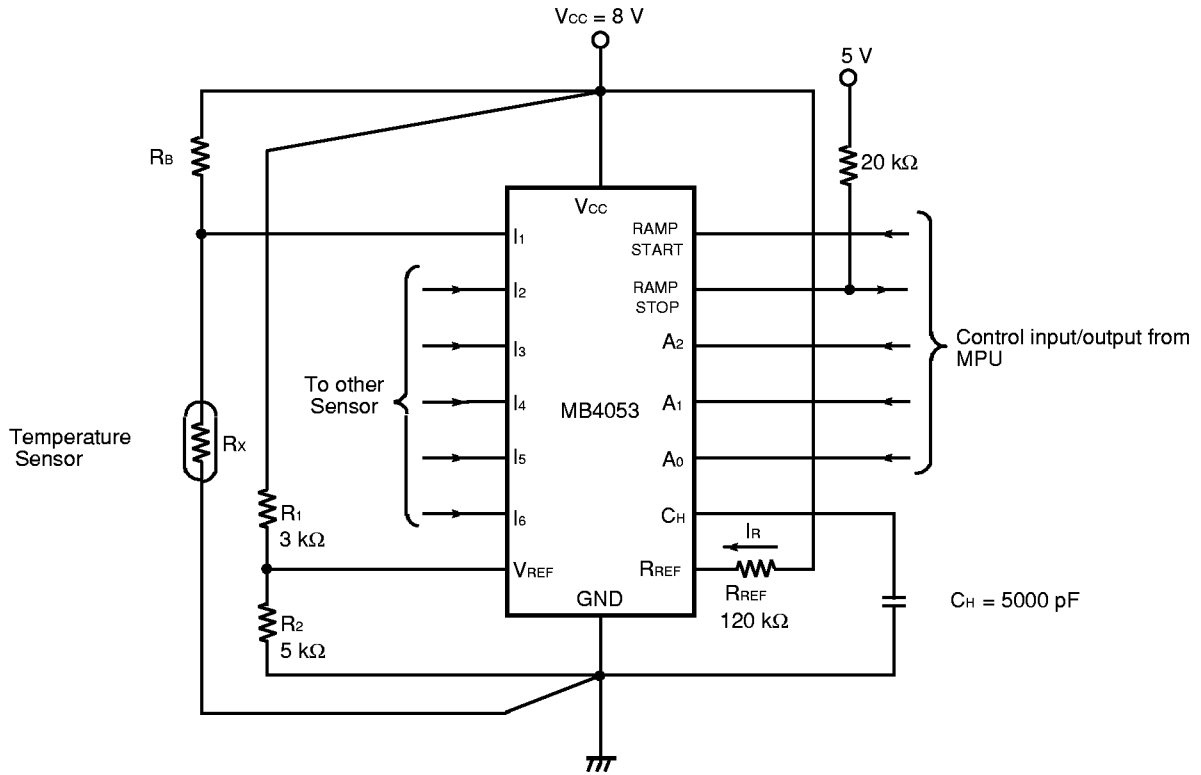
Where:  $V_{IN}$  = Analog input voltage to be measured  
 $V_{REF}$  = Reference voltage  
 $V_{BE1}$  = Shift voltage in sample/ramp amplifier  
 $V_{BE2}$  = Threshold voltage of comparator  
 $V_{CH}$  =  $C_H$  voltage

The GND and  $V_{REF}$  conversion sequence is arbitrary, the GND and  $V_{REF}$  conversions not being needed each time a channel ( $I_1$  to  $I_6$ ) is converted.

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## APPLICATION EXAMPLES

Examples of analog voltage (0 to 5 V) A/D conversion with 10-bit resolution are shown in “PEAK LINEARITY ERROR vs AMBIENT TEMPERATURE  $T_a$ ” and “SUPPLY CURRENT vs AMBIENT TEMPERATURE”.



$$\text{Reference Voltage: } V_{REF} = \frac{R_2}{R_1 + R_2} \cdot V_{CC} \dots\dots\dots 7-1$$

$$\text{Ramp Current: } I_R = \frac{R_1}{R_1 + R_2} \cdot \frac{1}{R_{REF}} \cdot V_{CC} \dots\dots\dots 7-2$$

$$\text{Input Voltage: } V_{IN} = \frac{R_X}{R_X + R_B} \cdot V_{CC} \dots\dots\dots 7-3$$

$$\begin{aligned} \text{Ramp Time: } t_R &\cong V_{IN} \cdot \frac{C_H}{I_R} \\ &= \frac{R_X}{R_X + R_B} \cdot \left(1 + \frac{R_2}{R_1}\right) \cdot C_H \cdot R_{REF} \dots\dots\dots 7-4 \end{aligned}$$

$$V_{REF} = \frac{5 \text{ k}\Omega}{3 \text{ k}\Omega + 5 \text{ k}\Omega} \times 8 \text{ V} = 5 \text{ V}$$

$$I_R = \frac{V_{CC} - V_{REF}}{R_{REF}} = \frac{8 \text{ V} - 5 \text{ V}}{120 \text{ k}\Omega} = 25 \mu\text{A}$$

$$t_{SL} \geq \frac{C_H \times V_{REF}}{I_{A(\min)} - I_R} = \frac{5000 \text{ pF} \times (5 \text{ V} + 0.7 \text{ V})}{150 \mu\text{A} - 25 \mu\text{A}} = 228 \mu\text{s}$$

$$t_{R_{\max}} \cong \frac{C_H \times V_{REF}}{I_R} = \frac{5000 \text{ pF} \times 5 \text{ V}}{25 \mu\text{A}} = 1000 \mu\text{s}$$

If the ramp time is counted with a 1 MHz clock, the following resolution is obtained.

$$\frac{1000 \mu\text{s}}{1 \mu\text{s}} = 1000 \cong 2^{10}$$

As shown in this example, the voltage output of the sensor is proportional to  $V_{CC}$  (Eq. 7-3) and  $V_{REF}$  is also proportional to  $V_{CC}$  (Eq. 7-1), the sensor output conversion results (Eq. 7-4) are not influenced by power supply voltage fluctuation. Such a conversion is called ratio metric conversion and is effective for minimizing the effects of conversion error. Supply voltage fluctuations during discharge do result in error, however.

## ■ USAGE PRECAUTIONS

1. Since the impedance of the ramp capacitor pin is approximately 30 M $\Omega$  (high), a resistance must not be connected in parallel with this input. A ramp capacitor with no leakage must be used.
2. At  $V_{IN} = 0$  V,  $t_R$  has a finite value.
3. Since RAMP STOP is an open collector output, an external pull-up resistor is required. (For example, when a 20 k $\Omega$  external pull-up resistor is used.)
4. All digital inputs/output are TTL compatible.
5. The time from RAMP START input switching (0  $\rightarrow$  1) to RAMP STOP output switching (1  $\rightarrow$  0) is ramp time  $t_R$ .
6.  $t_{SL} \geq t_A (\text{max}) = \frac{C_H}{150 \mu\text{A} - I_R} \times (V_{REF} + 0.7 \text{ V})$
7.  $t_R \cong \frac{C_H}{I_R} \times V_{IN}$ ,  $t_R (\text{max}) \cong \frac{C_H}{I_R} \times V_{REF}$
8.  $I_R = \frac{V_{CC} - V_{REF}}{R_{REF}}$
9.  $2 \text{ V} \leq V_{REF} \leq (V_{CC} - 2 \text{ V})$  and  $V_{REF} \leq 5.25 \text{ V}$
10. While and analog input voltage is being sampled, channel selection signals  $A_0$ ,  $A_1$ , and  $A_2$  must not be changed for ( $t_{SL}$ ).
11. When  $I_R$  is little, Linearity Error extends. However, Linearity Error is  $\pm 0.2$  [% of FSR] or less in  $I_R (\text{min}) = 12 \mu\text{A}$ .

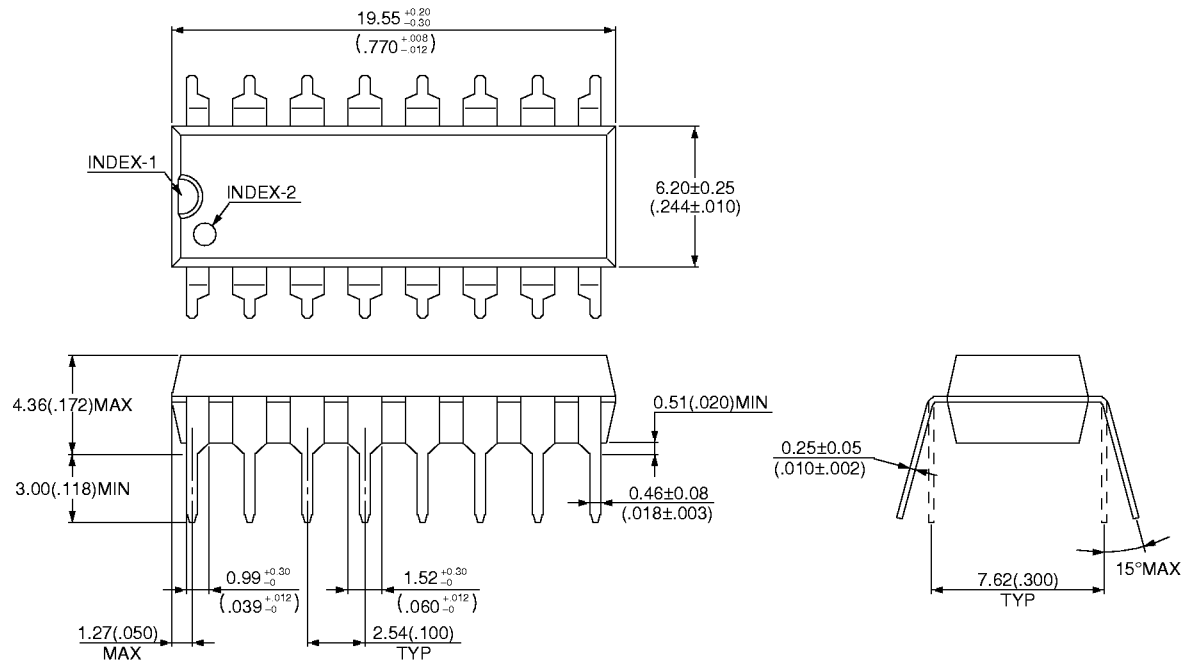
# MB4053

## ■ ORDERING INFORMATION

Part number	Package	Remarks
MB4053M	16-pin Plastic DIP (DIP-16P-M04)	
MB4053PF	16-pin Plastic SOP (FPT-16P-M06)	

## ■ PACKAGE DIMENSIONS

16-pin Plastic DIP  
(DIP-16P-M04)



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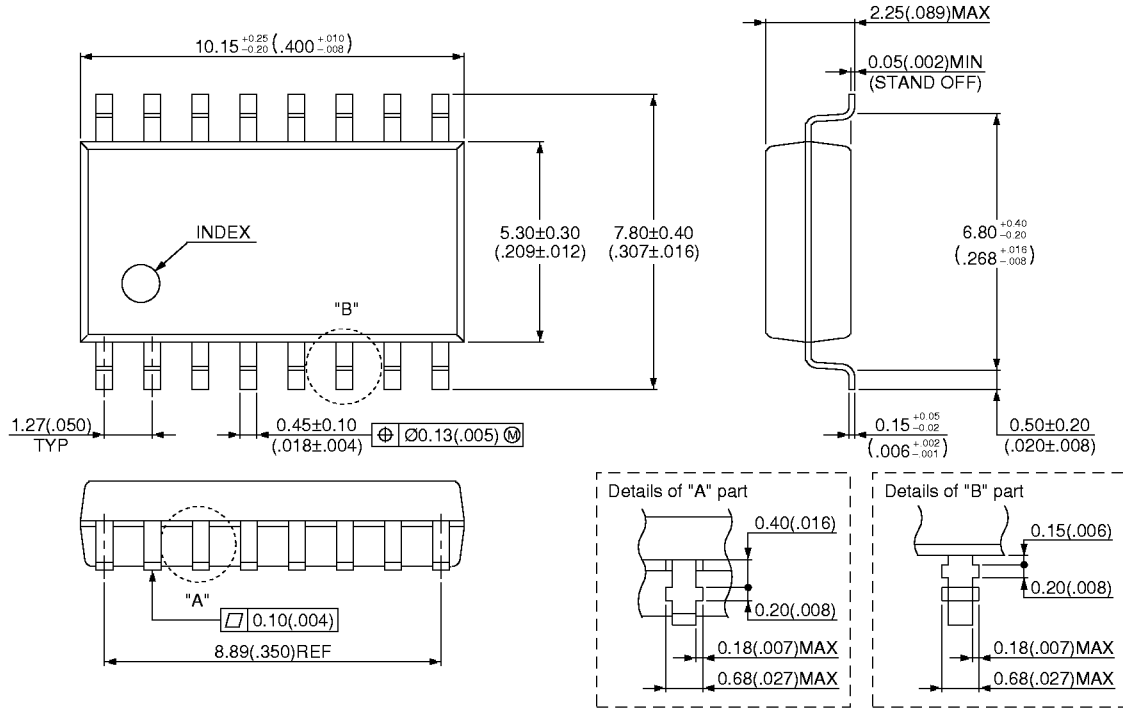
Dimensions in mm (inches)

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# MB4053

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16-pin Plastic SOP  
(FPT-16P-M06)



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Dimensions in mm (inches)



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