FUJITSU SEMICONDUCTOR
DATA SHEET

DS04-13103-6E

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.

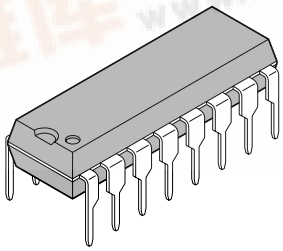
This A/D converter subsystems are suitable for a wide range of applications. The resolution required by an application can be obtained by arbitarily selecting a suitable integration time. Also zero offset and full-scale error corrections can be made automatically (auto-zero and auto-calibration) to minimize 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 µA9708 (DIP package)
- Single power supply: +4.75 V to +15 V
- Excellent linearity: ±0.2% max. error
- Fast conversion time: 300 µs/ch typ.
- Analog input volgage: 0 V to V_{CC} – 2 V (5.25 V max.)
- Power Dissipation: 25 mW typ. at V_{CC} = 5 V

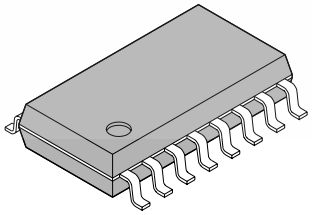
■ PACKAGES

16-pin Plastic DIP



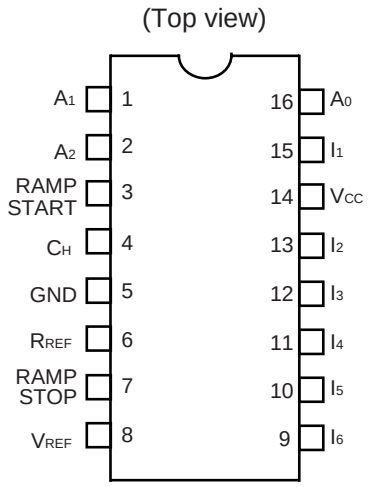
(DIP-16P-M04)

16-pin Plastic SOP



(FPT-16P-M06)

■ PIN ASSIGNMENT

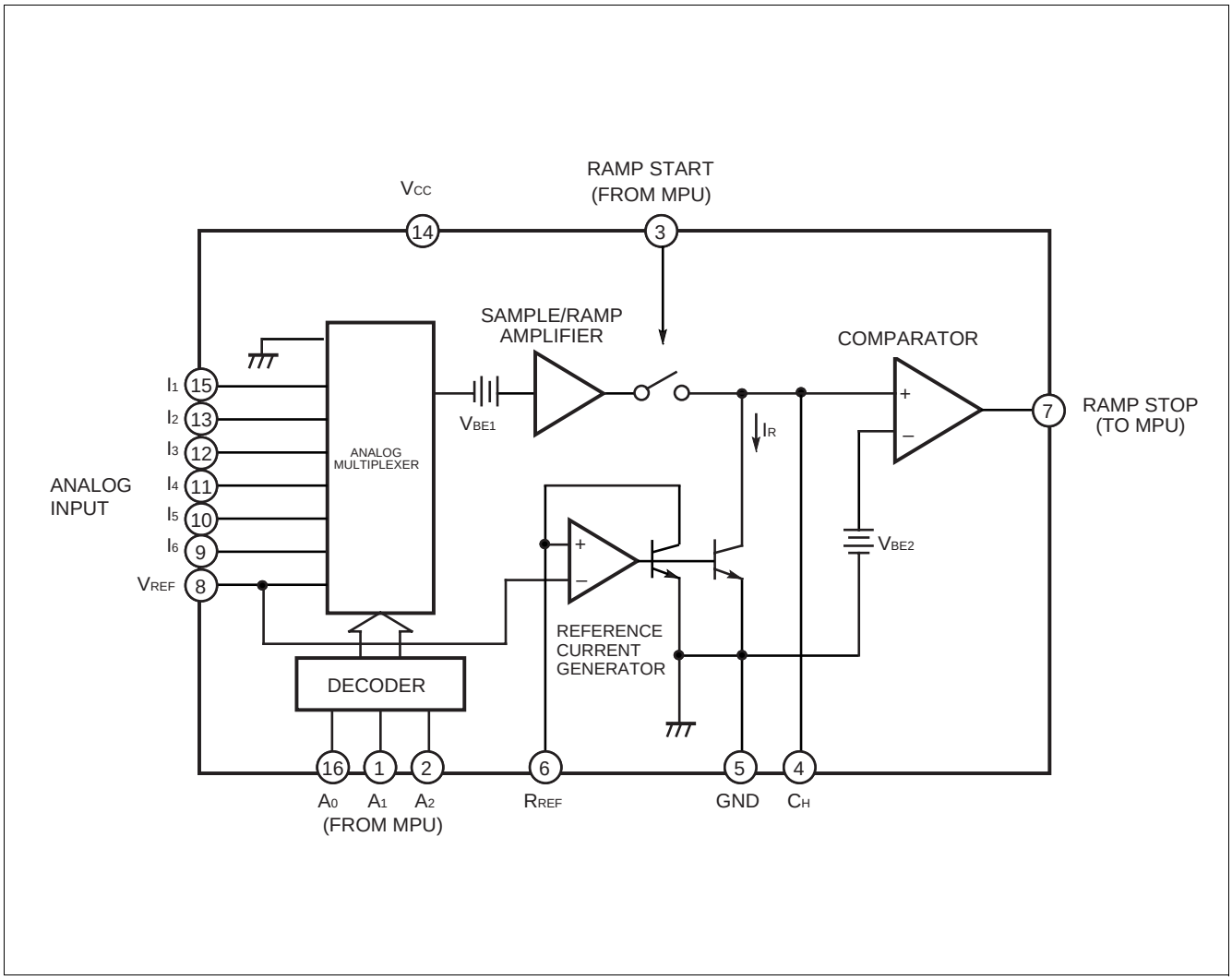


(DIP-16P-M04)
(FPT-16P-M06)

■ PIN DESCRIPTION

Pin no.	Pin name	Symbol	Function
9 to 13 15	Analog input	I_1 thru I_6	Analog inputs for the six channels. One of the 6 is selected by a specific bit pattern on A_0 to A_2.
16 1 2	Channel selection input	A_0 A_1 A_2	Input for selecting an analog input channel. Either GND, one of channels I_1 to I_6 or V_{REF} 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_H is charged over comparator reference voltage V_{BE2}. RAMP STOP (0 → 1) A/D conversion end signal (C_H discharged to comparator reference voltage). RAMP STOP (0 → 1)
4	Ramp capacitor pin	C_H	Pin for externally connecting the ramp capacitor. The value of C_H in conjunction with V_{REF} and R_{REF} establishes the ramp time.
8	Reference voltage supply pin	V_{REF}	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_{CC} – 2 V) and 5.25 V or less.
6	Reference resistance pin	R_{REF}	Pin for external reference resistance for setting the discharge current.
			The external resistance is connected between the power source pin (V_{CC}) and the reference resistance pin (R_{REF}). The discharge current is, then, $I_R = (V_{CC} - V_{REF})/R_{REF}$.
14	Power supply	V_{CC}	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.

■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATINGS

Parameter		Symbol	Rating		Unit
			Min.	Max.	
Power supply voltage		V_{CC}	—	18	V
Digital input voltage		V_{IND}	–0.5	+30	V
Digital output voltage when off		V_{OH}	–0.5	+18	V
Analog input voltage		V_{INA}	–0.5	+30	V
Output current		I_O	—	10	mA
Storage temperature	Ceramic	Tstg	–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_{CC}	4.75	5.0	15	V
Reference voltage*	V_{REF}	2.0	—	5.25	V
Ramp capacity	C_H	300	—	—	pF
Reference current	I_R	12	—	50	µA
Analog input voltage	V_{IA}	0	—	V_{REF}	V
Output current	I_O	—	—	1.6	mA
Operating temperature	Ta	–40	—	+85	°C

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

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.

■ ELECTRICAL CHARACTERISTIC

(V_{CC} = 4.75 V to 15 V, Ta = –40°C to +85°C)

Parameter	Symbol	Value			Unit	Remarks
		Min.	Typ.	Max.		
Conversion error	E_A	—	±0.2	±0.3	%	*1
Linearity error	E_R	—	±0.08	±0.2	%	*2
Analog input current	I_B	—	–50	–250	nA	
Crosstalk between any two channels	V_{CR}	60	—	—	dB	*3
Multiplexer input offset voltage	V_{OSM}	—	2.0	4.0	mV	
Conversion time	t_C	—	296	350	µs/ch	See "■MEASURMENT CIRCUIT" Analog input: 0 thru V_{REF} C_H = 3300 pF, I_R = 50 µA
Acquisition time	t_A	—	20	40	µs	See "■MEASURMENT CIRCUIT" C_H = 1000 pF*4
Acquisition current	I_A	150	—	—	µA	
Ramp start delay time	t_D	—	100	—	ns	
Multiplexer address time	t_M	—	1	—	µs	
Digital high level input voltage	V_{IH}	2.0	—	—	V	
Digital low level input voltage	V_{IL}	—	—	0.8	V	
Digital low level input current	I_{IL}	—	–5	–15	µA	V_{IL} = 0.4 V
Digital high level input current	I_{IH}	—	—	1	µA	V_{IH} = 5.5 V
High level output current	I_{OH}	—	—	10	µA	V_{OH} = 15 V
Low level output voltage	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
Power supply current	I_{CC}	—	5	10	mA	

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

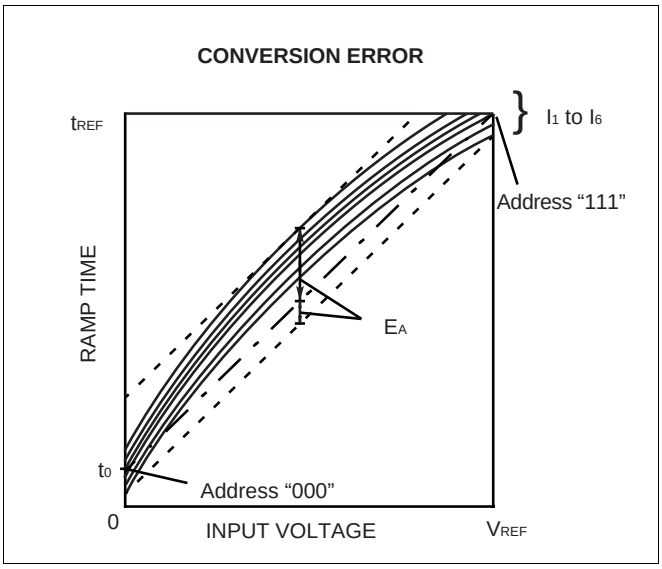
*1: Conversion error: For all channels, deviation from a straight line between two points obtained by channel addresses 000 (0 scale) and 111 (full scale).

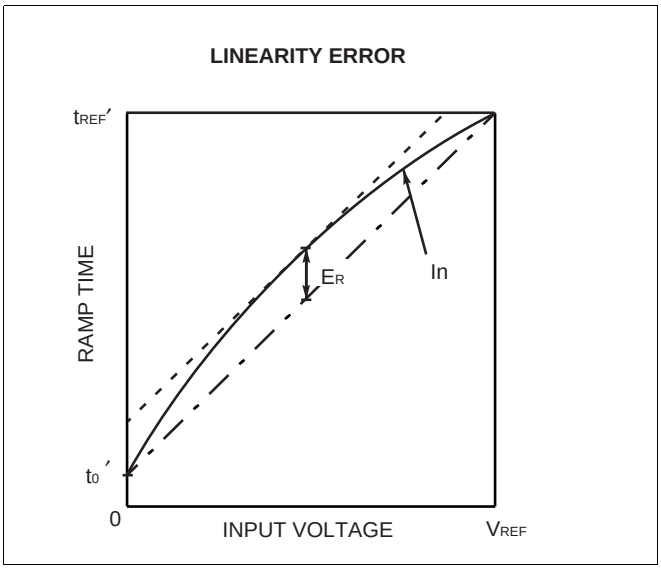
*2: Linearity error; Deviation from a straight line between the 0 and full scale points for each channel.

*3: Crosstalk between channels: Voltage change V_{CH} of C_H terminal occurring when an input voltage of a channel is changed by ΔV_1 while another channel is already charged (RAMP START = 0).

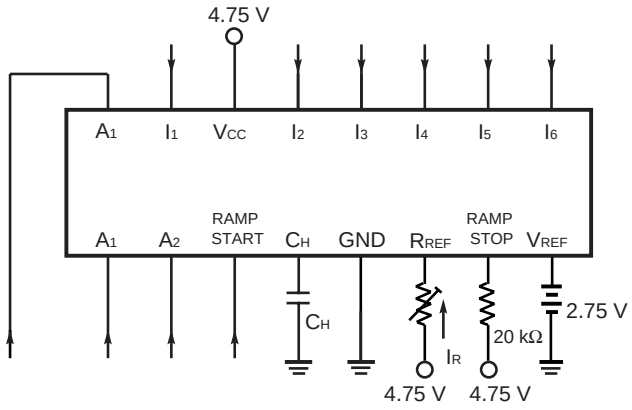
This calculated by $20\log \frac{\Delta V_{CH}}{\Delta V_1}$

*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.


CONVERSION ERROR
tREF
RAMP TIME
I1 to I6
Address “111”
EA
t0
Address “000”
0
INPUT VOLTAGE
VREF

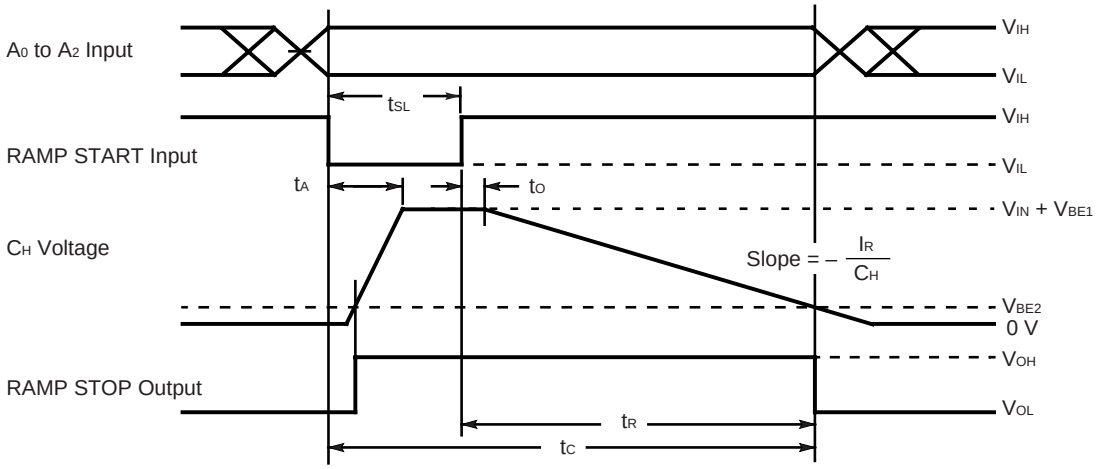

LINEARITY ERROR
tREF′
RAMP TIME
ER
In
t0 ′
0
INPUT VOLTAGE
VREF

■ MEASURMENT CIRCUIT



Note: Adjust R_{REF} in the range 40 to 200 kΩ so that I_R is 12 to 50 μA.

■ DIAGRAM

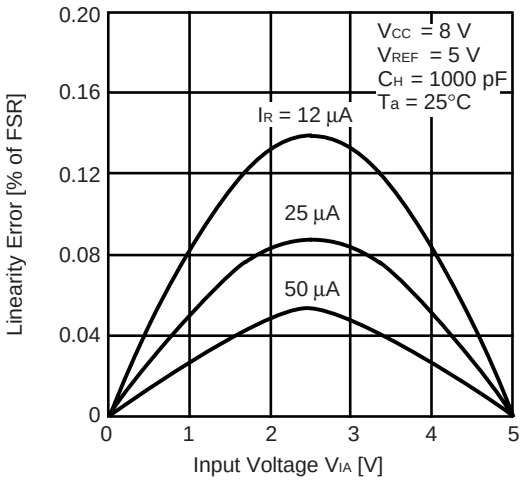


■ CHANNEL SELECTION

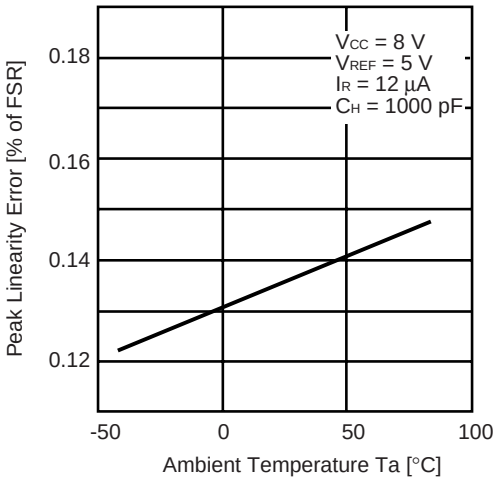
Input address line			Selected analog input
A_2	A_1	A_0	
0	0	0	GND
0	0	1	I_1
0	1	0	I_2
0	1	1	I_3
1	0	0	I_4
1	0	1	I_5
1	1	0	I_6
1	1	1	V_{REF}

■ TYPICAL CHARACTERISTICS

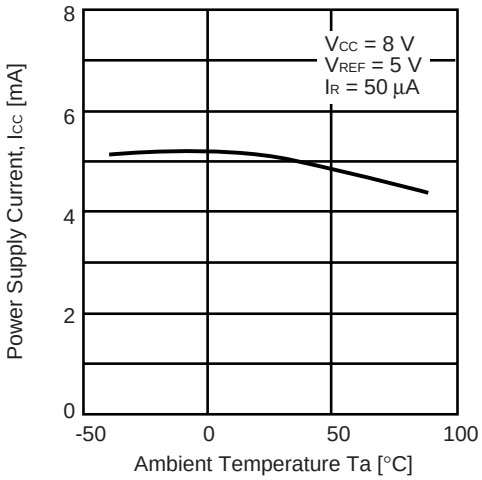
LINEARITY ERROR vs INPUT VOLTAGE



PEAK LINEARITY ERROR vs AMBIENT TEMPERATURE Ta



SUPPLY CURRENT vs AMBIENT TEMPERATURE



■ 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 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 Discharge slope = $-\frac{I_R}{C_H}$

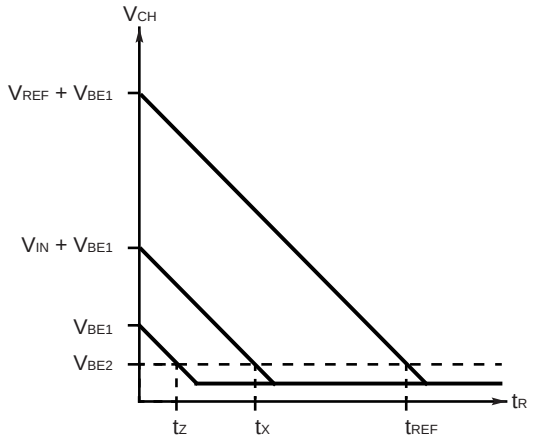
■ ZERO OFFSET AND FULL-SCALE FACTOR CORRECTIONS

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.

$$(V_{BE1})_C = t_Z$$
$$(V_{REF} + V_{BE1})_C = t_{REF}$$
$$(V_{IN} + V_{BE1})_C = t_X$$
$$(V_{REF})_C = t_{REF} - t_Z$$
$$(V_{IN})_C = t_X - t_Z$$

$$\frac{(V_{IN})_C}{(V_{REF})_C} = \frac{t_X - t_Z}{t_{REF} - t_Z}$$



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

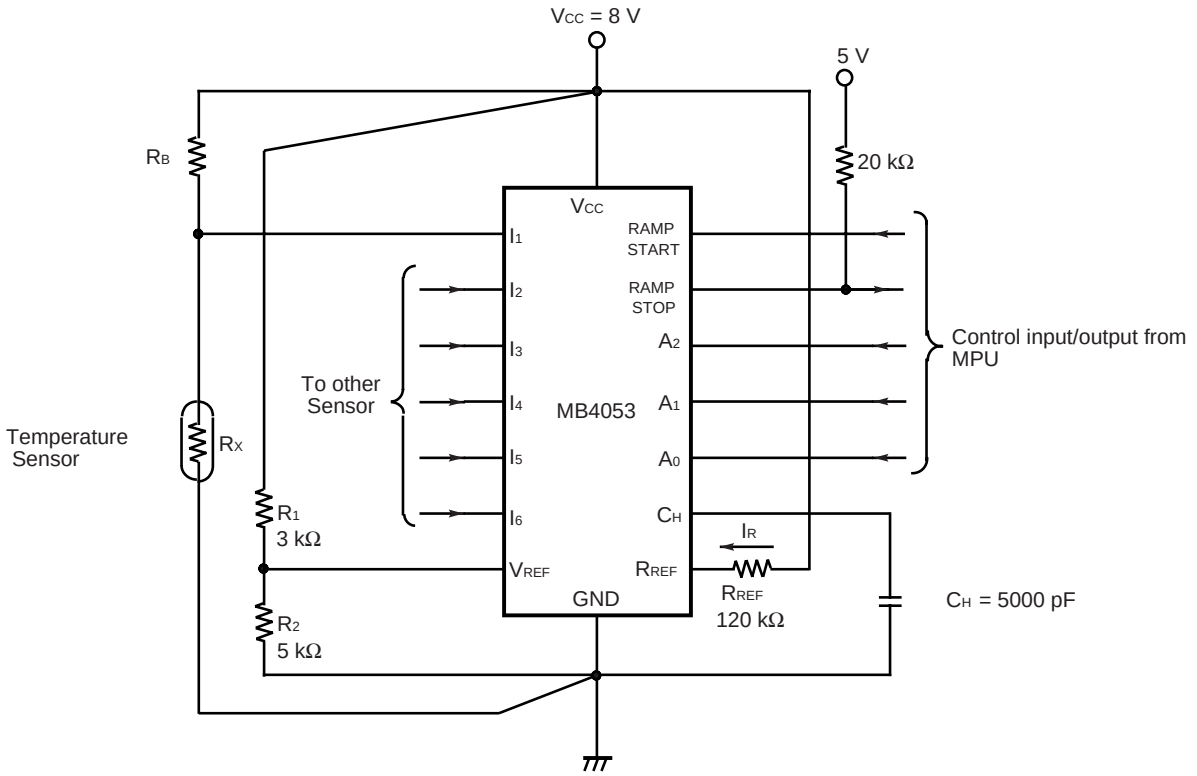
$$(V_{IN})_C = (V_{REF})_C \times \frac{t_X - t_Z}{t_{REF} - t_Z}$$

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

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

■ 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 Ta” and “SUPPLY CURRENT vs AMBIENT TEMPERATURE”.



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

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

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

Ramp Time: $t_R \fallingdotseq V_{IN} \cdot \frac{C_H}{I_R}$

$= \frac{R_X}{R_X + R_B} \cdot (1 + \frac{R_2}{R_1}) \cdot C_H \cdot R_{REF}$ 7-4

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

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

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

$t_{Rmax} \fallingdotseq \frac{C_H \times V_{REF}}{I_R} = \frac{5000\ pF \times 5\ V}{25\ \mu A} = 1000\ \mu s$

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

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

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

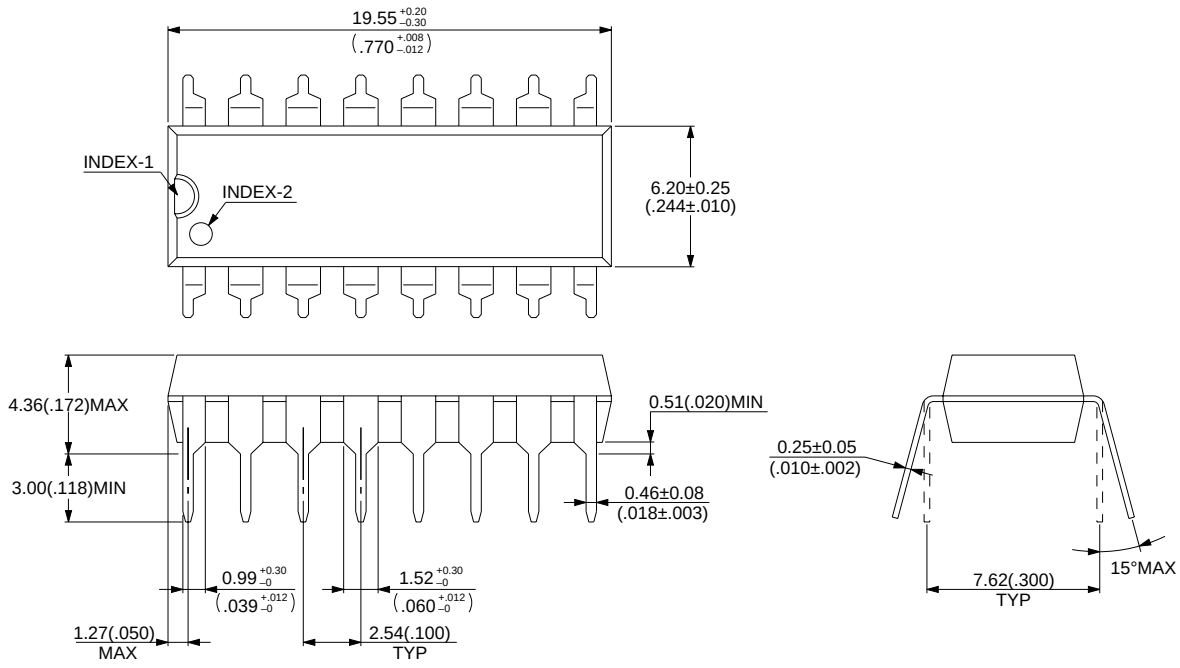
1. Shince the impedance of the ramp capacitor pin is approximately 30 MΩ (high), a resistance must not be connected in paralleled with this input. A ramp capacitor with no leakage must be used.
2. At V_{IN} = 0 V, t_R has a finite value.
3. Since RAMP STOP is an open collector output, an external pull-up resistor is required. (For example, when a 20 kΩ external pull-up resistor is used.)
4. All digital inputs/output are TTL compatible.
5. The time from RAMP START input switching (0 →1) to RAMP STOP output switching (1 → 0) is ramp time t_R.
6. $t_{SL} \geq t_A$ (max) = $\dfrac{C_H}{150\ \mu A - 1_R} \times (V_{REF} + 0.7\ V)$
7. $t_R \fallingdotseq \dfrac{C_H}{I_R} \times V_{IN}$, t_R (max) $\fallingdotseq \dfrac{C_H}{1_R} \times V_{REF}$
8. $I_R = \dfrac{V_{CC} - V_{REF}}{R_{REF}}$
9. 2 V ≤ V_{REF} ≤ (V_{CC} – 2 V) and V_{REF} ≤ 5.25 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 ±0.2 [% of FSR] or less in I_R (min) = 12 μA.

■ 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)



Dimensions in mm (inches)

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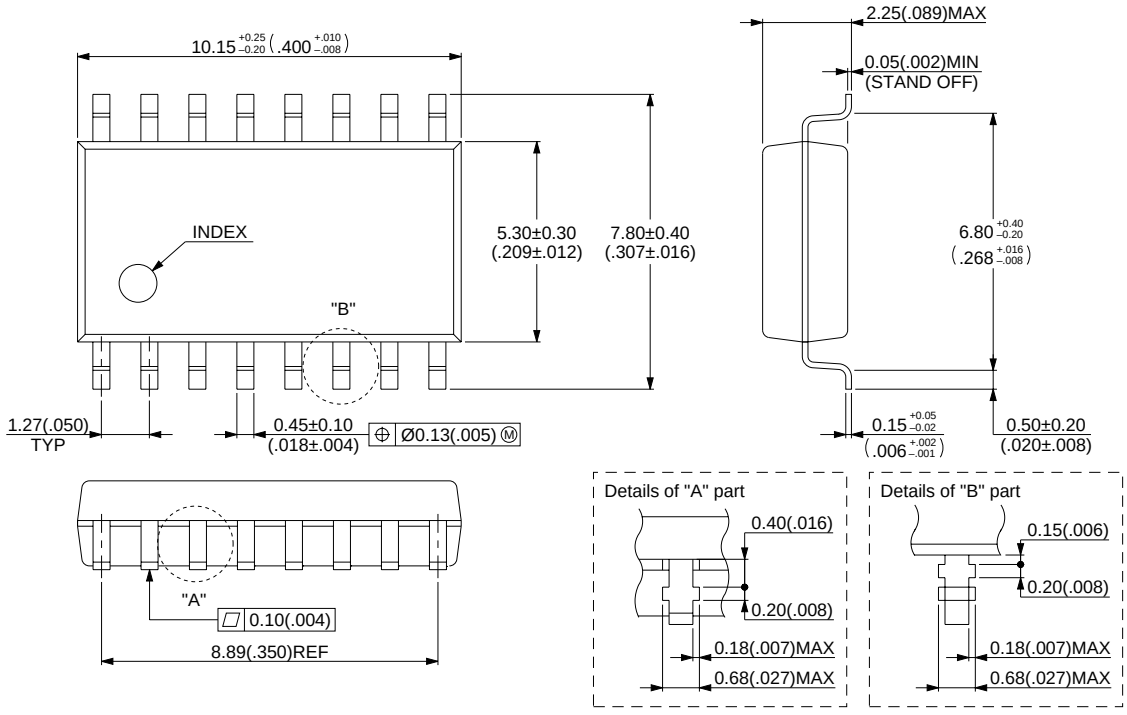
16-pin Plastic SOP
(FPT-16P-M06)



Dimensions in mm (inches)

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