A/D Converter Subsystem

MB4053

6 Channel / 8 Bit

DATASHEET

OEM – Fujitsu

Source: Fujitsu Databook 1983

FUJITSU MICROELECTRONICS

MB4053

6-CHANNEL 8-BIT A/D CONVERTER SUBSYSTEM

DESCRIPTION

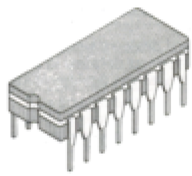
The Fujitsu MB4053 is a 6-channel 8-bit single-slope A/D converter subsystem for use with a microprocessor in data control systems.

The MB4053 is a single monolithic chip device manufactured using bipolar technology and is provided with a 1 of 8 address decoder, 8-channel analog multiplexer, sample and hold, constant current generator, ramp integrator, and comparator.

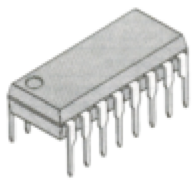
Necessary addressing, counting and timing functions for this unit are provided by a microprocessor such as the MB8840/50, MBL8048, and MBL6800 Series.

An arbitrary integration time can be set for this unit by changing an external constant. Therefore, since the required resolution can be obtained, this unit is suitable for a wide range of applications.

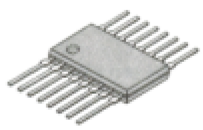
Packages are classified into two types: Standard 16-pin DIP and flat package.



CERAMIC PACKAGE
DIP-16C-C02



PLASTIC PACKAGE
DIP-16P-M01

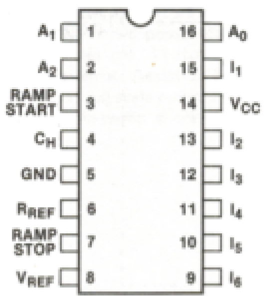


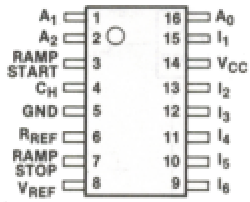
PLASTIC PACKAGE
FPT-16P-M01

FEATURES

- **Single Power Supply +4.75V to +15V**
- **Microprocessor compatible**
- **Linearity error— ±0.2% (max.)**
- **Conversion time— 300 µs/ch (Typ.)**
- **Analog input voltage 0 to (V_{CC} −2V) (5.25V max.)**
- **Ratio metric conversion**
- **Digital input/output — TTL compatible**
- **Pulse width data output (open collector)**
- **Standard 16-pin dual in-line package (DIP) and dual flat package**
- **DIP type is compatible with the MC14443 and µA9708**
- **Power comsumption 25 mW (Typ.) at V_{CC} = 5V**

PIN ASSIGNMENT





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ABSOLUTE MAXIMUM RATINGS* (See NOTE)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	18	V
Digital Input Voltage	V_{ID}	-0.5 ~ +30	V
Digital Output Voltage when Off	V_{OH}	-0.5 ~ +18	V
Analog Input Voltage	V_{IA}	-0.5 ~ +30	V
Output Current	I_O	10	mA
Operating Temperature	T_A	-45 ~ +90	°C
Storage Temperature	T_{stg}	-55 ~ +150	°C

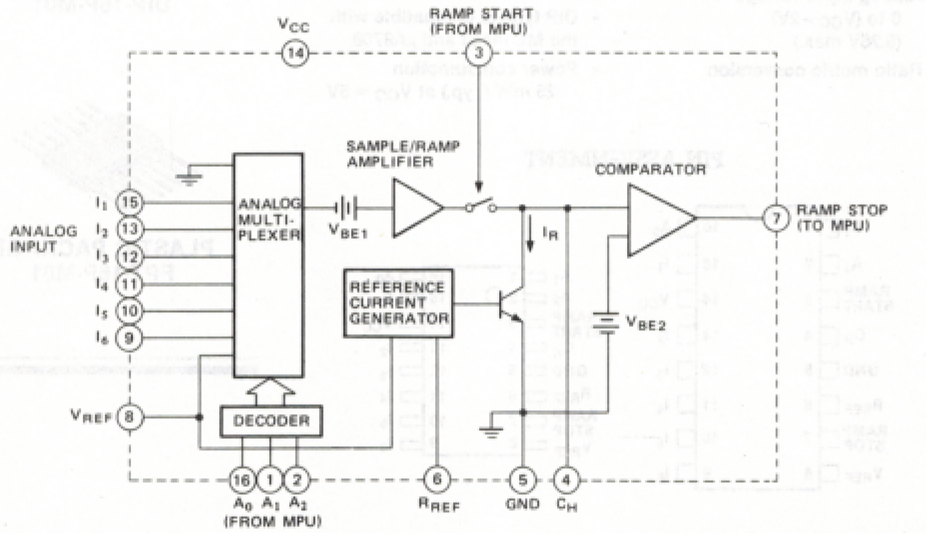
*Permanent device damage may occur if ABSOLUTE MAXIMUM RATINGS are exceeded. Functional operation should be restriced to the conditions as detailed in the operational sections of this data sheet. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Condition			Unit
		Min.	Typ.	Max.	
Supply Voltage	V_{CC}	4.75	5.0	1.5	V
Reference Voltage*	V_{REF}	2.0		5.25	V
Ramp Capacity	C_H	300			pF
Reference Voltage	I_R	12		50	μA
Analog Input Voltage	V_{IA}	0		V_{REF}	V
Output Current	I_O			1.6	mA
Operating Temperature	T_A	-40		+85	°C

Note: $^*2V \leqq V_{REF} \leqq V_{CC} - 2V$

MB4053 BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

(V_{CC} = 4.75V ~ 15V, T_A = −40°C ~ 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 test circuit Analog input: 0 ~ V_{REF} C_H = 3300 pF, I_R = 50µA
Acquisition Time	t_A		20	40	µs	See test circuit C_H = 1000 pF †4
Acquisition Current	I_A	150			µA	
Ramp Start Delay Time	t_O		100		ns	
Multiplexer Address Time	t_M		1		µs	
Digital H Level Input Voltage	V_{IH}	2.0			V	
Digital L Level Input Voltage	V_{IL}			0.8	V	
Digital L Level Input Current	I_{IL}		-5	-15	µA	V_{IL} = 0.4V
Digital H Level Input Current	I_{IH}			1	µA	V_{IH} = 5.5V
H Level Output Current	I_{OH}			10	µA	V_{OH} = 15V
L Level Output Voltage	V_{OL}			0.4	V	I_{OL} = 1.6 mA
Supply Current	I_{CC}		5	10	mA	

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

†1 Conversion error: Errors for all channels 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 quantity V_{CH} of the C_H terminal occurring when an input voltage of a channel is changed by ΔV_I while another channel is already charged (RAMP START = 0). This is calculated by $20 \log \frac{\Delta V_{CH}}{\Delta V_I}$.

†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.

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Fig. 2 – CONVERSION ERROR

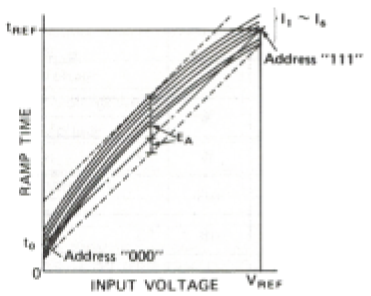


Fig. 3 – LINEARITY ERROR

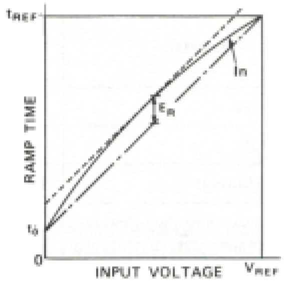
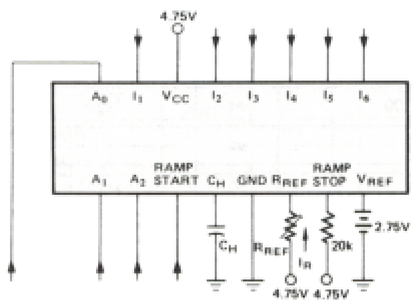


Fig. 4 – ACQUISITION/CONVERSION TIME TEST CIRCUIT

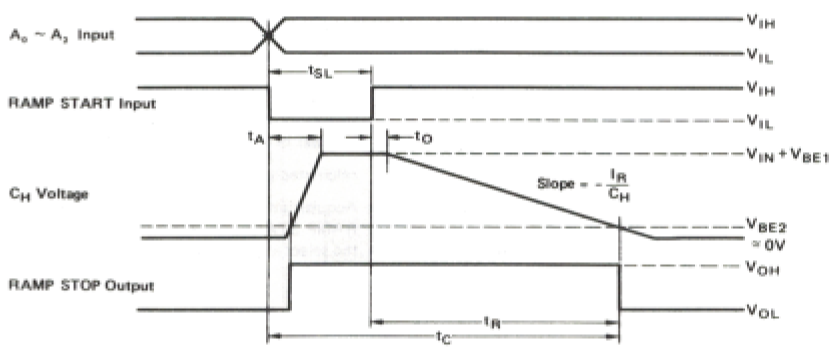


Adjust R_{REF} in the range 40 to 200 kΩ so that I_R is 12 to 50 μA.

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}

Fig. 5 – TIMING CHART



OPERATION DESCRIPTION

The address of the channel to be converted (from among the eight analog input channels of the MB 4053; I_1 to I_6, GND, and V_{REF}) is set on address lines A_0 to A_2 and the RAMP START input is set from 1 to 0. Then, an external ramp capacitor connected to the C_H pin is charged at a fixed rate *1 and the voltage at C_H increases until it matches the sum of the input voltage of the selected channel and a constant shift voltage (V_{BE1}).
If the voltage at C_H exceeds the threshold voltage (V_{BE2}) of the comparator during C_H charging, the RAMP STOP output is set from 0 to 1.
After charging is completed, the RAMP START input is set from 0 to 1. Then, the analog input is disconnected from the external capacitor and the external ramp capacitor is discharged at a fixed speed *2.
When the voltage at C_H is less than the threshold voltage (V_{BE2}) of the comparator, the RAMP STOP output is set to 0, completing a conversion cycle for one channel.
The time, RAMP time t_R, from RAMP START input switching ($0 \rightarrow 1$) to RAMP STOP output ($1 \rightarrow 0$) is almost directly proportional to the analog input voltage. If there is no error caused by impedance of the internal reference current source, comparator switching level error, leakage path, or delay time, ramp time t_R is calculated 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 capacity
$I_R = \frac{V_{CC} - V_{REF}}{R_{REF}}$

This ramp time is converted to a digital representation by counting t_R with the microprocessor.
In practice, the result is not completely accurate, but the error can be minimized by performing correction processing with the microprocessor using the GND and V_{REF} voltage conversion results. When a small error is allowable the A/D coversion software functions can be reduced and conversion time minimized by omitting the GND and V_{REF} conversion.

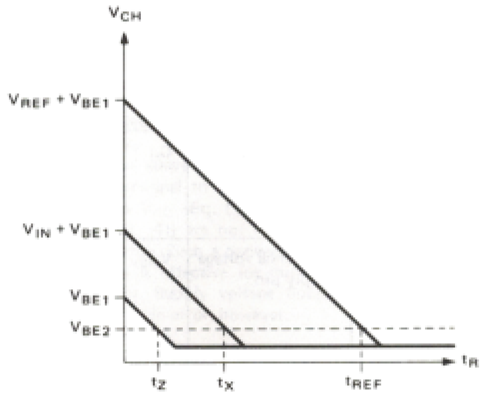
*1 Charge slope $= \frac{I_A - I_R}{C_H} \geq \frac{150\mu A - I_R}{C_H}$

Where: I_A = 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

When high-precision conversion is required, the zero offset and full-scale factor can be corrected as follows:
The channel select address is set to 000 and GND is converted; the ramp time is assumed to be t_Z. Next, the address is set to 111 and V_{REF} is converted; the ramp time is assumed to be t_{REF}. Finally, the address of the analog input to be measured is specified and converted; the ramp time is assumed to be t_X. The correspondence between each analog input voltage and ramp time is as follows:



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

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

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

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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PIN DESCRIPTION

Pin number	Name	Symbol	Function
9 ~ 13 15	Analog input	$I_1 \sim I_6$	Analog inputs for the six channels. A channel is selected with channel specification input A_0 to A_2.
16 1 2	Channel selection input	A_0 A_1 A_2	Inputs for selecting an analog input channel. One of channels GND, I_1 to I_6, and V_{REF} is selected with the three inputs, A_0 to A_2.
3	RAMP START signal input	RAMP START	A/D conversion start signal input. At RAMP START = 0, an analog voltage of the input channel selected with A_0 to A_2 charged to the ramp capacity is discharged.
7	RAMP STOP signal output	RAMP STOP	A/D conversion end signal output. When the voltage of the ramp capacitor exceeds the threshold voltage (V_{BE2}) of the comparator, the RAMP STOP output is set to 1; otherwise, it is set to 0.
4	Ramp capacitor pin	C_H	Pin for externally connecting the ramp capacitor. A ramp time is generated by discharging the analog input voltage charged to this capacitor level according to the reference current.
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 to 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 externally connecting the reference resistance for setting the discharge current. The external resistance is connected between the power source pin (V_{CC}) and 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.

NOTES ON USE

1. Since 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 esternal pull-up resistor is required. (For example, when a 40 kΩ external pull-up resistor is used, the RAMP STOP output switching (1 → 0) is ramp time t_R.
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. $t_{SL} \geqq \frac{C_H}{150\mu A - I_R} \times V_{REF}$
7. $t_R \fallingdotseq \frac{C_H}{I_R} \times V_{IN}$, t_R (max) $\fallingdotseq \frac{C_H}{I_R} \times V_{REF}$
8. $I_R = \frac{V_{CC} - V_{REF}}{R_{REF}}$
9. $2\text{ V} \leqq V_{REF} \leqq (V_{CC} - 2\text{ V})$ and $V_{REF} \leqq 5.25$ V
10. While an analog input voltage is being sampled, channel selection signals A_0, A_1, and A_2 must not be changed for (t_{SL}).

APPLICATION EXAMPLE

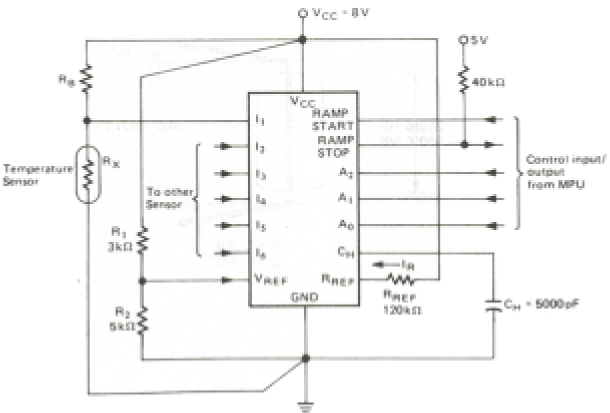
Example of circuit for analog voltage (0–5V) A/D conversion with 10-bit resolution

1. Temperature sensor
2. To other sensor
3. Control input/output from MPU
4. Reference voltage:
5. Ramp current:
6. Input voltage:
7. Ramp time

Example of analog voltage (0–5V) A/D conversion with 10-bit resolution is shown in Fig. 7.
If the ramp time is counted with a 1 MHz clock, the following resolution is obtained.

The resolution can be increased by increasing the value of the capacitor, reducing discharge current I_R, or raising the clock frequency.
As shown in the above example, the voltage output of the sensor is proportional to V_{CC} (Eq. (3)) and V_{REF} is also proportional to V_{CC} (Eq. (1)), the sensor output conversion results (Eq. (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 discharging do result in error, however.

Fig. 7 – APPLICATION EXAMPLE



Reference Voltage: $V_{REF} = \frac{R_2}{R_1 + R_2} V_{CC}$ – (1)

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

Input Voltage: $V_{IN} = \frac{R_X}{R_X + R_B} \cdot V_{CC}$ – (3)

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

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

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

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

$t_{SL} \geqq \frac{C_H \times V_{REF}}{I_{A(min)} - I_R} = \frac{5000pF \times 5V}{150\mu A - 25\mu A} = 200\mu s$

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

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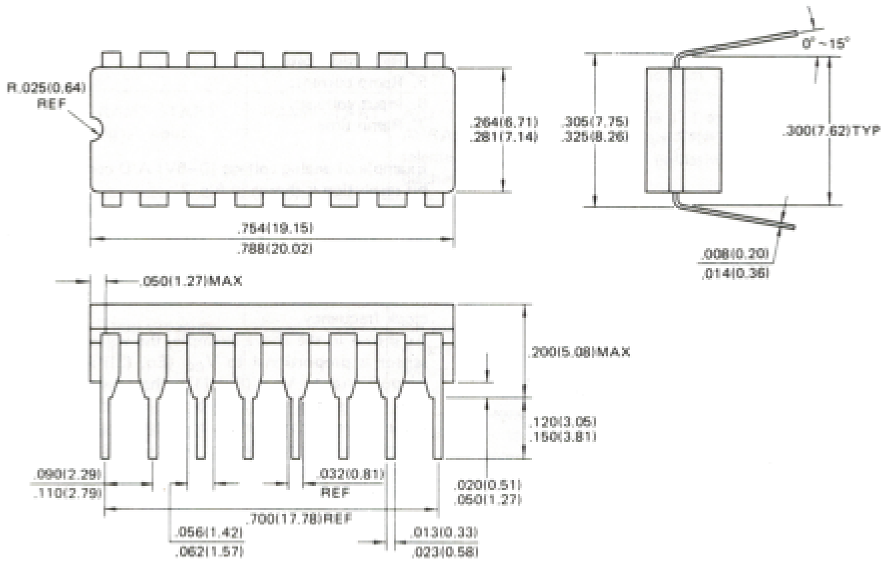
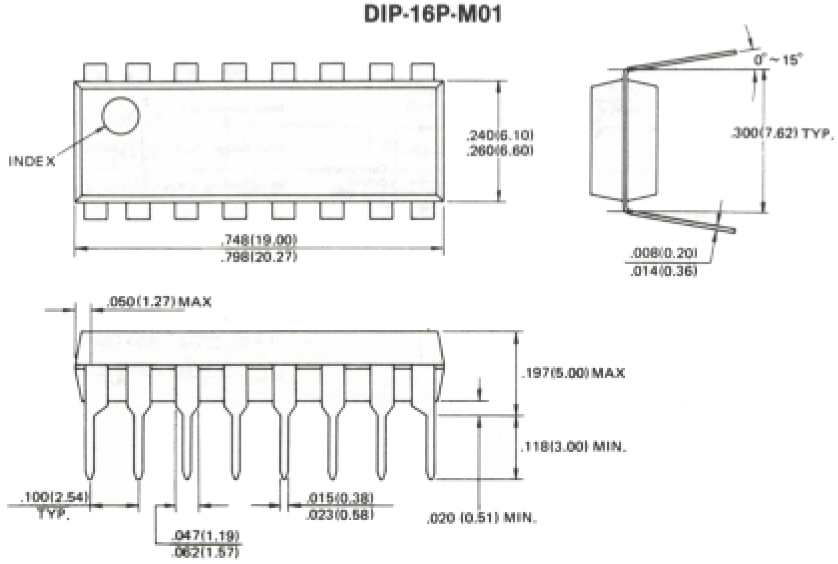
PACKAGE DIMENSIONS Dimensions in inches (millimeters)

16-LEAD CERAMIC (CERDIP) DUAL IN-LINE PACKAGE
DIP-16C-C02



16-LEAD PLASTIC DUAL IN-LINE PACKAGE
DIP-16P-M01



PACKAGE DIMENSIONS Continued

16-LEAD PLASTIC FLAT PACKAGE FPT-16P-M01