FUJITSU SEMICONDUCTOR
DATA SHEET

DS04-13211-3E

General Purpose Linear IC's General Purpose Converters

CMOS

D/A Converter for Digital Tuning
(With Built-in OP Amp and I/O Expander)

MB88141

■ DESCRIPTION

The FUJITSU MB88141 is a D/A converter with 12 built-in channels.

The 12 analog output channels have built-in OP Amps, providing large current drive capability.

Data input is compatible with I²C specifications, and is controlled by two control lines.

The built-in I/O expander function allows the MB88141 to be controlled by devices incompatible with I²C bus specifications (provides conversion between I²C serial and 8- or 4-bit parallel I/O).

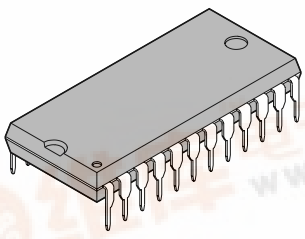
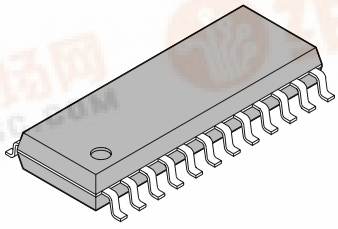
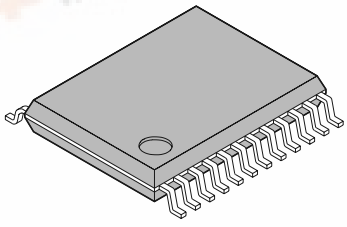
Can be adapted for tuning by electronically variable or pre-fixed resistance, etc.

■ FEATURES

- Ultra-low power consumption (0.9 mW/channel Typ.)
- Ultra-compact package
- Built-in 12-channel R-2R type 8-bit D/A converter
- Built-in analog output amplifier (maximum sink current 1.0 mA, maximum source current 1.0 mA)
- Analog output range 0 V to V_{CC}

(Continued)

■ PACKAGES

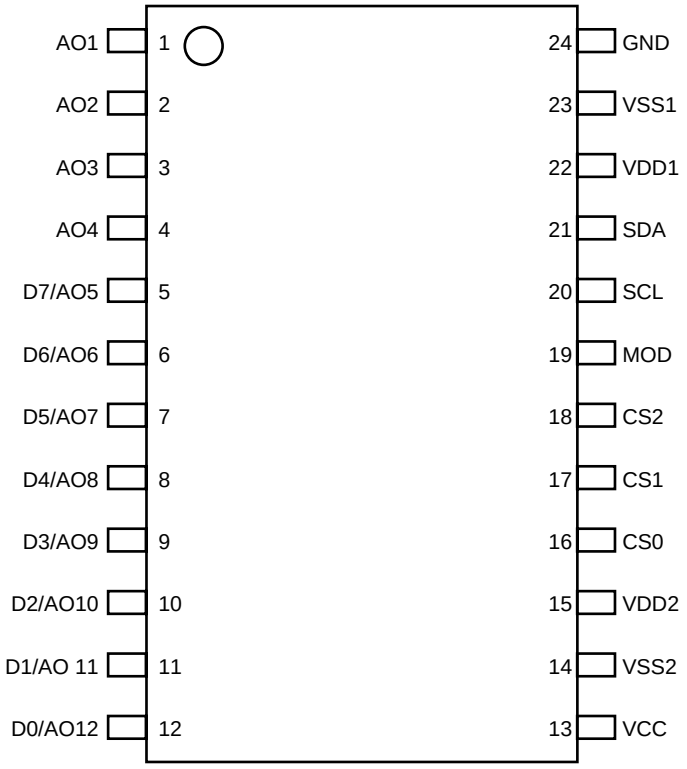
24-pin plastic DIP	24-pin plastic SOP	24-pin plastic SSOP
		
(DIP-24P-M02)	(FPT-24P-M01)	(FPT-24P-M03)

(Continued)

- 5 V single power supply
- Power supply/GND for MCU interface and OP Amp is separate from power supply/GND for D/A converter
- Power supply for D/A converter is divided into two systems for V_{DD1}/V_{SS1} (AO_1 to AO_4) and V_{DD2}/V_{SS2} (AO_5 to AO_{12}), allowing separate level settings for each system
- Compatible with serial data input, I^2C specifications
- Built-in I/O expander function (converts between I^2C serial and 8- or 4-bit parallel)
- CMOS process
- Packages: DIP 24-pin, SOP 24-pin, SSOP 24-pin

■ PIN ASSIGNMENT

(TOP VIEW)



(DIP-24P-M02)
(FPT-24P-M01)
(FPT-24P-M03)

■ PIN DESCRIPTIONS

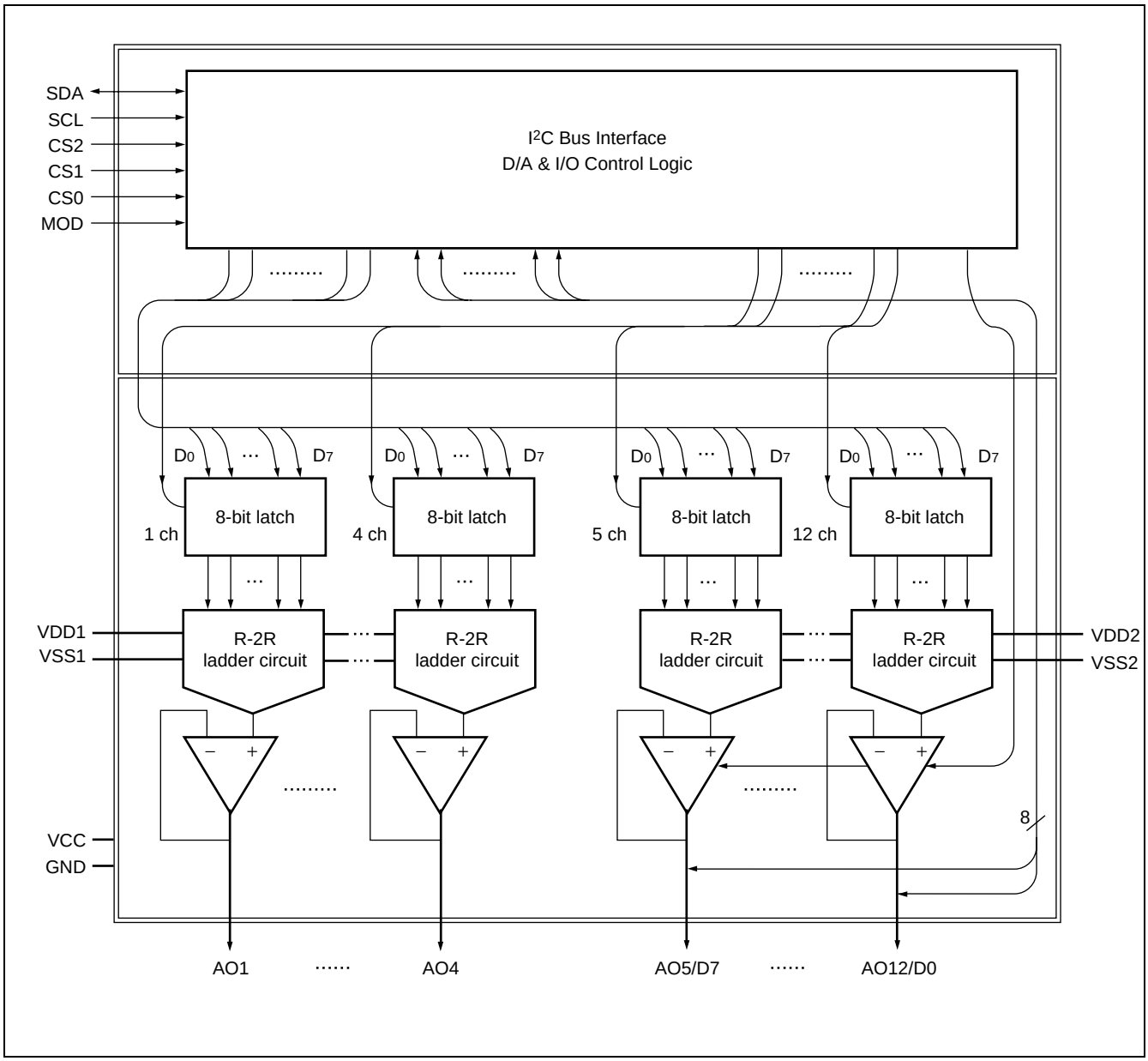
Pin no.	Symbol	I/O	Description
21	SDA	BUS	I^2C bus data input/output pin (hysteresis input). *2 Outputs the acknowledge signal.
20	SCL	I	I^2C bus shift clock input pin (hysteresis input). *2
19	MOD	I	D/A converter and I/O expander mode switching pin. *1, *3 Input “L” to operate as a D/A converter, “H” to operate as I/O expander and D/A converter.
16 17 18	CS0 CS1 CS2	I	Lower 3 bits of the slave address setting pins. *1 This allows up to eight MB88141 chips to be used on the same bus line.
1 2 3 4	AO1 AO2 AO3 AO4	O	8-bit D/A output with OP Amp. *3
5 6 7 8 9 10 11 12	D7/AO5 D6/AO6 D5/AO7 D4/AO8 D3/AO9 D2/AO10 D1/AO11 D0/AO12	I/O	8-bit D/A output with OP Amp. *3 In I/O expander operation, these pins function as parallel data input/output pins.
13	VCC	—	Power supply pin for digital circuits and OP Amp.
24	GND	—	GND pin for digital circuits and OP Amp.
22	VDD1	—	Reference power supply pin for D/A converter (H). AO1 to AO4.
23	VSS1	—	Reference power supply pin for D/A converter (L). AO1 to AO4.
15	VDD2	—	Reference power supply pin for D/A converter (H). AO5 to AO12.
14	VSS2	—	Reference power supply pin for D/A converter (L). AO5 to AO12.

*1: The MOD and CS0-CS2 pins should be used with fixed level input.

*2: Use particular caution in handling the SDA and SCL pins. These pins have no transistor protection against V_{CC} voltage and therefore have weaker anti-static characteristics than other pins.

*3: When using the I/O expander function together with the D/A converter function, take care that D/A converter output precision is within a range that will not affect overall system operation.

■ BLOCK DIAGRAM

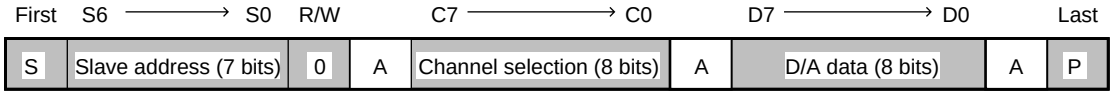


■ DATA CONFIGURATION

The MB88141 data configuration differs in each of the two operating modes (D/A converter (12-channel) and I/O expander plus D/A converter), selected by the MOD pin signal.

1. For D/A Converter (12-channel) Operation (MOD = "L")

(1) I²C Bus Format



: Sent from master device : Sent from MB88141 (slave device)

S: "Start" condition P: "Stop" condition A: "Acknowledge" output

(2) Slave Address Comparison (7 bits)

Slave address input (7 bits)								Internally fixed				Externally set		
S6	**S5**	**S4**	**S3**	**S2**	**S1**	**S0**		**CS6**	**CS5**	**CS4**	**CS3**	**CS2**	**CS1**	**CS0**
1	0	0	1	0	0	0	=	1	0	0	1	0	0	0
1	0	0	1	0	0	1	=	1	0	0	1	0	0	1
1	0	0	1	0	1	0	=	1	0	0	1	0	1	0
1	0	0	1	0	1	1	=	1	0	0	1	0	1	1
1	0	0	1	1	0	0	=	1	0	0	1	1	0	0
1	0	0	1	1	0	1	=	1	0	0	1	1	0	1
1	0	0	1	1	1	0	=	1	0	0	1	1	1	0
1	0	0	1	1	1	1	=	1	0	0	1	1	1	1

Address comparison: Operates only for devices whose own slave address (internally fixed CS6 to CS3 and externally set CS2 to CS0) matches the slave address input value.

(3) R/W Selection (1 bit)

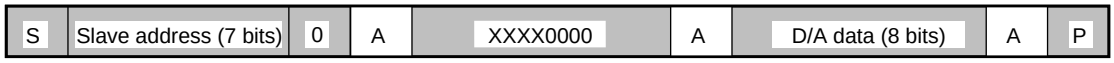
Fixed at "0" (the D/A converter performs write operations only).

(4) Channel Selection (8 bit)

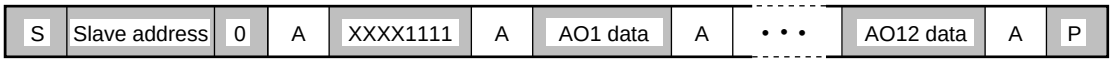
C7	C6	C5	C4	C3	C2	C1	C0	Channel select
×	×	×	×	0	0	0	0	All channels selected *1
×	×	×	×	0	0	0	1	AO1 selected
↓	↓	↓	↓	↓	↓	↓	↓	↓
×	×	×	×	1	1	0	0	AO12 selected
×	×	×	×	1	1	0	1	Don't care
×	×	×	×	1	1	1	0	Don't care
×	×	×	×	1	1	1	1	All channels selected *2

×: Don't care

*1: The 1 byte of data following the channel selection is set on all channels (all channels set to the same data value).



*2: The 12 bytes of data following the channel selection are set on all channels (all channels set to separate data values).



: Sent from master device : Sent from MB88141 (slave device)

S: "Start" condition P: "Stop" condition A: "Acknowledge" output

Note: Setting will repeat, continuing in order from ch1, until the start and stop conditions are acknowledged.

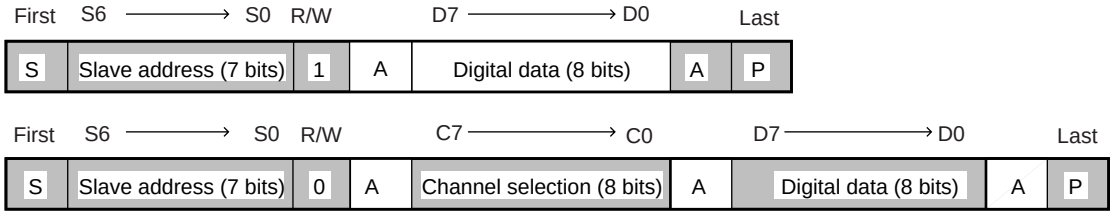
(5) D/A Data (8 bits)

D7	D6	D5	D4	D3	D2	D1	D0	Channel select
0	0	0	0	0	0	0	0	$\cong V_{SS}$
0	0	0	0	0	0	0	1	$\cong (V_{REF} / 256) \times 1 + V_{SS}$
0	0	0	0	0	0	1	0	$\cong (V_{REF} / 256) \times 2 + V_{SS}$
↓	↓	↓	↓	↓	↓	↓	↓	↓
1	1	1	1	1	1	1	0	$\cong (V_{REF} / 256) \times 254 + V_{SS}$
1	1	1	1	1	1	1	1	$\cong (V_{REF} / 256) \times 255 + V_{SS}$

Note: $V_{REF} = V_{DD} - V_{SS}$

2. For D/A Converter + I/O Expander Operation (MOD = "H")

(1) I²C Bus Format



: Sent from master device : Sent from MB88141 (slave device)

S: "Start" condition P: "Stop" condition A: "Acknowledge" output

(2) Slave Address Comparison (7 bits)

Slave address comparison is the same as for D/A converter (12-channel) operation (see "1. (2) "Slave Address Comparison"), with the exception that the CS2 setting determines the number of D/A converter channels and the number of I/O expander bits.

CS2	D/A converter	I/O expander
0	4 channels (AO1 to AO4)	8 bits (D7 to D0)
1	8 channels (AO1 to AO8)	4 bits (D3 to D0)

When CS2 = "1" is selected, the upper 4 bits (D_7 to D_4) of write operations (I²C bus to parallel interface) are ignored, and the upper 4 bits or read operations (parallel interface to I²C bus) are output at "0" (low).

(3) R/W Selection (1 bit)

R/W	I/O expander operation	D/A converter operation
0	I²C bus input → parallel data output	I²C bus input → analog output
1	Parallel data input → I²C bus output	—

(4) Channel Selection (8 bits)

C7	C6	C5	C4	C3	C2	C1	C0	Channel select
×	×	×	×	0	0	0	0	I/O expander operation
×	×	×	×	0	0	0	1	AO1 selected
≀	≀	≀	≀	≀	≀	≀	≀	≀
×	×	×	×	0	1	0	0	AO4 selected
×	×	×	×	0	1	0	1	Don't care (AO5 selected)
≀	≀	≀	≀	≀	≀	≀	≀	≀
×	×	×	×	1	0	0	0	Don't care (AO8 selected)
×	×	×	×	1	0	0	1	Don't care
≀	≀	≀	≀	≀	≀	≀	≀	≀
×	×	×	×	1	1	1	0	Don't care
×	×	×	×	1	1	1	1	I/O expander continuous operation

( ): When using D/A converter 8 channel, I/O expander 4 bit operation.
×: Don't care

(5) D/A Data (8 bits)

Same as "1. (5) D/A Data (8 bits)."

(6) I/O Expander Continuous Operation

I^2C bus input → parallel data output

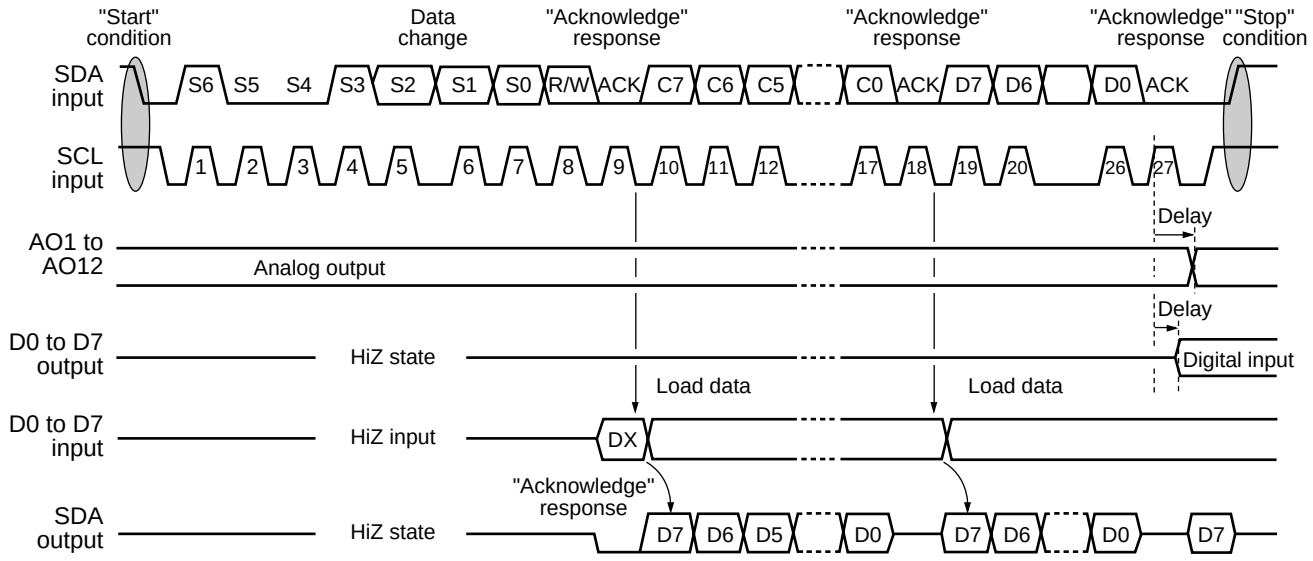
Note: In continuous operation, operation continues until start and stop conditions are acknowledged.

Parallel data input → I^2C bus output

: Sent from master device : Sent from MB88141 (slave device)

S: "Start" condition P: "Stop" condition A: "Acknowledge" output

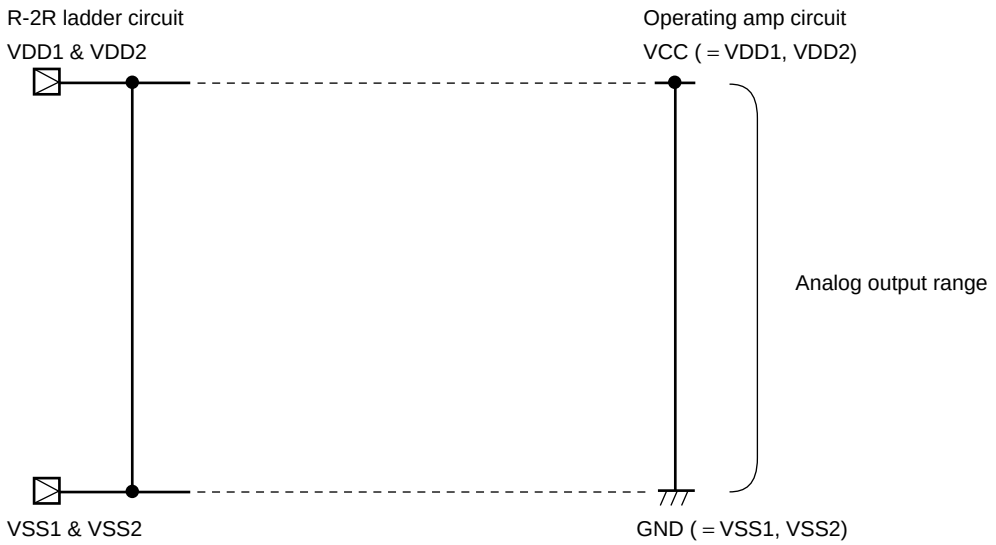
■ TIMING CHART (I²C BUS SPECIFICATIONS)



Note:

- The SDA input acknowledge response (ACK) is an output signal from the MB88141.
- The D0-D7 input and output timing represent the timing of switching to write and read operations respectively. Also, D0-D7 input remains in HiZ state between the end of a read operation and the acknowledgment of the next I/O write signal.

■ ANALOG OUTPUT VOLTAGE RANGE



■ ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Rating		Unit
			Min.	Max.	
Supply voltage	V_{CC}	With reference to GND, at Ta = +25 °C	–0.3	+7.0*	V
	V_{DD}		–0.3	+7.0*	V
	V_{SS}		–0.3	+7.0*	V
Input voltage	V_{IN}		–0.3	V_{CC} + 0.3	V
Output voltage	V_{OUT}		–0.3	V_{CC} + 0.3	V
Power consumption	P_D	—	—	250	mW
Operating temperature	Ta	—	–20	+85	°C
Storage temperature	Tstg	—	–55	+120	°C

*: $V_{CC} \geq V_{DD1} \geq V_{SS1}$, $V_{CC} \geq V_{DD2} \geq V_{SS2}$

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	Conditions	Value			Unit
			Min.	Typ.	Max.	
Supply voltage 1	V_{CC}	—	4.5	5.0	5.5	V
	GND	—	—	0	—	V
Supply voltage 2	V_{DD1}	$V_{CC} \geq V_{DD1} > V_{SS1}$ $V_{DD1} - V_{SS1} \geq 2.0$ V	2.0	—	V_{CC}	V
	V_{SS1}		0	—	3.5	V
Supply voltage 3	V_{DD2}	$V_{CC} \geq V_{DD2} > V_{SS2}$ $V_{DD2} - V_{SS2} \geq 2.0$ V	2.0	—	V_{CC}	V
	V_{SS2}		0	—	3.5	V
Analog output current	I_{AL}	Source current	0	—	1.0	mA
	I_{AH}	Sink current	0	—	1.0	mA
Oscillator limit output capacitance	C_{OL}	—	—	—	1.0	µF
Digital data setting range	—	—	#00	—	#FF	—
Operating temperature	Ta	—	–20	—	+85	°C

WARNING: The recommended operating conditions are required in order to ensure the normal operation of the semiconductor device. All of the device's electrical characteristics are warranted when the device is operated within these ranges.

Always use semiconductor devices within their recommended operating condition ranges. 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 representatives beforehand.

■ ELECTRICAL CHARACTERISTICS

1. DC Characteristics

(1) Digital Circuits

(VCC = 5 V ± 10%, GND = 0 V, Ta = –20 °C to +85 °C)

Parameter	Symbol	Pin name	Conditions	Value			Unit
				Min.	Typ.	Max.	
Supply voltage	V_{CC}	VCC	—	4.5	5.0	5.5	V
Supply current	I_{CC}		SCL = 400 kHz, no load	—	1.0	3.7	mA
Input leak current	I_{ILK}	SDA, SCL, CS0, CS1, CS2, MOD, D0 to D7	V_{IN} = 0 to V_{CC}	–10	—	+10	µA
"L" level input voltage	V_{IL}		—	0	—	0.3 V_{CC}	V
"H" level input voltage	V_{IH}		—	0.7 V_{CC}	—	V_{CC}	V
Input hysteresis width	V_{HYS}	SDA, SCL	—	0.05 V_{CC}	—	—	V
"H" level output voltage	V_{OH}	D0 to D7	I_{OH} = –400 µA	V_{CC} – 0.4	—	—	V
"L" level output voltage	V_{OL1}		I_{OL} = 2.5 mA	—	—	0.4	V
	V_{OL2}	SDA	I_{OL} = 3.0 mA	—	—	0.4	V
	V_{OL3}		I_{OL} = 6.0 mA	—	—	0.6	V

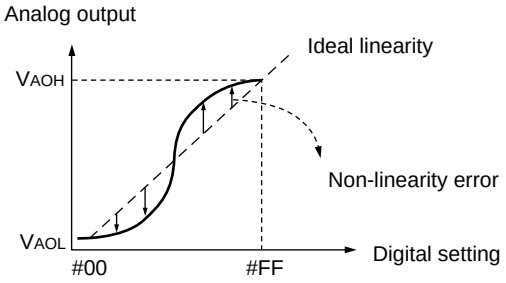
(2) Analog Circuits 1

(VCC = 5 V ± 10%, GND = 0 V, Ta = –20 °C to +85 °C)

Parameter	Symbol	Pin name	Conditions	Value			Unit
				Min.	Typ.	Max.	
Current consumption	I_{DD}	VDD1, VDD2	No load $I_{DD} = I_{DD1} + I_{DD2}$	—	1.2	2.5	mA
Analog voltage	V_{DD}		$V_{DD1} – V_{SS1} \geq 2.0$ V $V_{DD2} – V_{SS2} \geq 2.0$ V	2.0	—	V_{CC}	V
	V_{SS}	VSS1, VSS2		GND	—	3.5	V
Resolution	Res	AO1 to AO12	No load V_{DD1}, $V_{DD2} \leq V_{CC} – 0.1$ V V_{SS1}, $V_{SS2} \geq 0.1$ V	—	8	—	bit
Monotonic increase	Rem			—	8	—	bit
Non-linearity error	LE			–1.5	—	+1.5	LSB
Differential linearity error	DLE			–1.0	—	+1.0	LSB

Non-linearity error:
Error in the input/output curve with respect to a straight line connecting output voltage at “00” and output voltage at “FF” levels.

Differential linearity error:
Deviation from ideal voltage with respect to a 1-bit increase in digital value.



Note: V_{AOH} and V_{DD}, as well as V_{AOL} and V_{SS} are not necessarily the same values.

(3) Analog Circuits 2

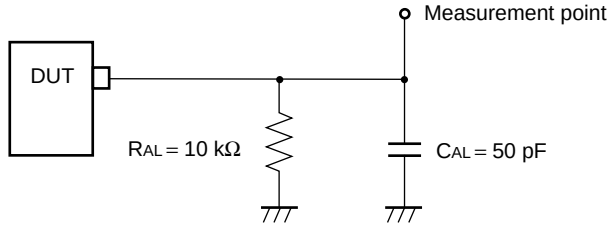
(VCC = VDD1 = VDD2 = 5.0 V, GND = VSS1 = VSS2 = 0.0 V, Ta = –20 °C to +85 °C)

Parameter	Symbol	Pin name	Conditions		Value			Unit
					Min.	Typ.	Max.	
Output minimum voltage 1	V_{AOL1}	AO1 to AO12	I_{AL} = 0 µA	Digital data “00”	V_{SS}	—	V_{SS} + 0.1	V
Output minimum voltage 2	V_{AOL2}		I_{AL} = 500 µA		V_{SS} – 0.2	V_{SS}	V_{SS} + 0.2	V
Output minimum voltage 3	V_{AOL3}		I_{AH} = 500 µA		V_{SS}	—	V_{SS} + 0.2	V
Output minimum voltage 4	V_{AOL4}		I_{AL} = 1.0 mA		V_{SS} – 0.3	V_{SS}	V_{SS} + 0.3	V
Output minimum voltage 5	V_{AOL5}		I_{AH} = 1.0 mA		V_{SS}	—	V_{SS} + 0.3	V
Output maximum voltage 1	V_{AOH1}		I_{AL} = 0 µA	Digital data “FF”	V_{DD} – 0.1	—	V_{DD}	V
Output maximum voltage 2	V_{AOH2}		I_{AL} = 500 µA		V_{DD} – 0.2	—	V_{DD}	V
Output maximum voltage 3	V_{AOH3}		I_{AH} = 500 µA		V_{DD} – 0.2	V_{DD}	V_{DD} + 0.2	V
Output maximum voltage 4	V_{AOH4}		I_{AL} = 1.0 mA		V_{DD} – 0.3	—	V_{DD}	V
Output maximum voltage 5	V_{AOH5}		I_{AH} = 1.0 mA		V_{DD} – 0.3	V_{DD}	V_{DD} + 0.3	V

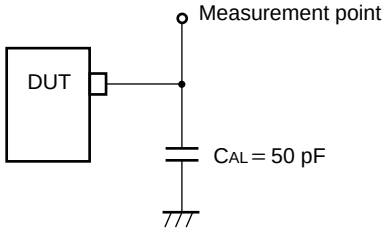
2. AC Characteristics

Parameter		Symbol	Condition	Value				Unit
				Standard mode		High speed mode		
				Min.	Max.	Min.	Max.	
SCL clock frequency		f_{SCL}	—	0	100	0	400	kHz
Bus free time between “stop” condition and “start” condition		t_{BUF}	—	4.7	—	1.3	—	µs
Hold time (resend) “start” condition. The first clock pulse is generated after this interval.		$t_{HD\ ;\ STA}$	—	4.0	—	0.6	—	µs
SCL clock low hold time		t_{LOW}	—	4.7	—	1.3	—	µs
SCL clock high hold time		t_{HIGH}	—	4.0	—	0.6	—	µs
Resend “start” condition setup time		$t_{SU\ ;\ STA}$	—	4.7	—	0.6	—	µs
Data hold time		$t_{HD\ ;\ DAT}$	—	0	—	0	0.9	µs
Data setup time		$t_{SU\ ;\ DAT}$	—	250	—	100	—	ns
SDA and SCL signal fall time		t_R	—	—	1000	20 + 0.1 Cb	300	ns
SDA and SCL signal rise time		t_F	—	—	300	20 + 0.1 Cb	300	ns
“Stop” condition setup time		$t_{SU\ ;\ STO}$	—	4.0	—	0.6	—	µs
Pulse width of spike suppressed by input filter		t_{SP}	—	—	—	0	50	ns
Output fall time when bus capacitance is between 10 pF and 400 pF	Sink current 3 mA	t_{OF}	—	—	250	20 + 0.1 Cb	250	ns
	Sink current 6 mA		—	—	—	20 + 0.1 Cb	250	ns
I^2C bus line capacitance load		Cb	—	—	400	—	400	pF
D/A	Analog output settling time	$t_{DL\ ;\ AO}$	*1	—	100	—	100	µs
I/O expander	Digital output delay time	$t_{DL\ ;\ DO}$	*2	—	300	—	300	ns
	Input open time	$t_{DZ\ ;\ DI}$	*3	200	—	200	—	ns
	Digital input setup time	$t_{SU\ ;\ DI}$	—	250	—	100	—	ns
	Digital input hold time	$t_{HD\ ;\ DI}$	—	0.9	—	0.9	—	µs

*1: Load condition 1

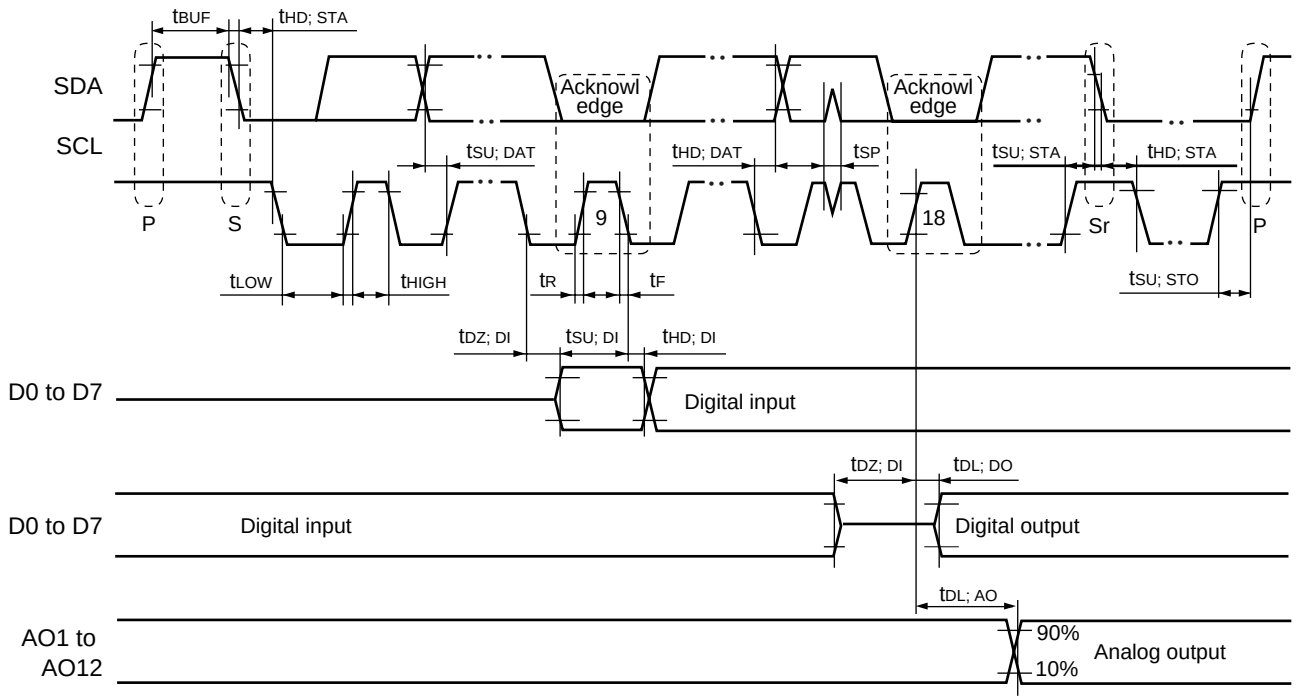


*2: Load condition 2



*3: The I/O expander input open time value applies to read operation following an I/O write operation, or to an I/O write operation following a read operation.

- **Input/output Timing**



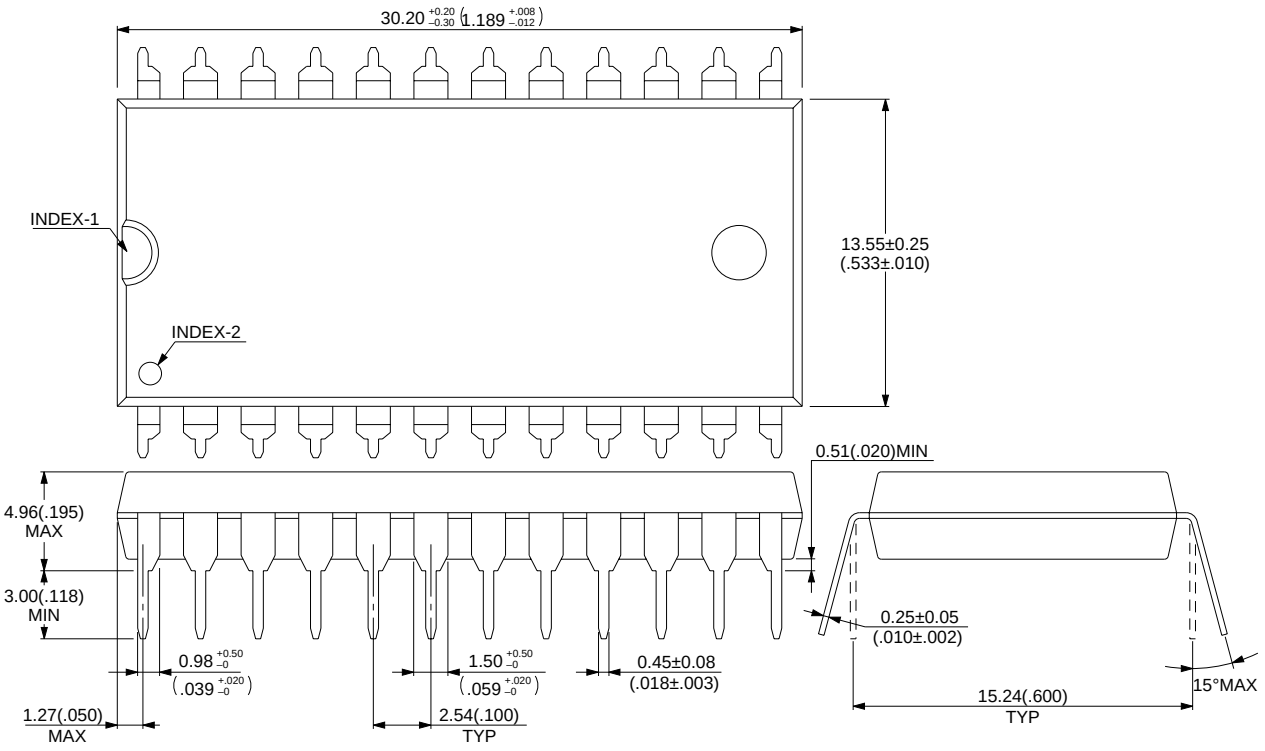
Note: The discrimination levels are 70% and 30% of V_{CC}.

■ ORDERING INFORMATION

Part number	Package	Remarks
MB88141P	24-pin plastic DIP (DIP-24P-M02)	
MB88141PF	24-pin plastic SOP (FPT-24P-M01)	
MB88141PFV	24-pin plastic SSOP (FPT-24P-M03)	

■ PACKAGE DIMENSIONS

24-pin plastic DIP
(DIP-24P-M02)

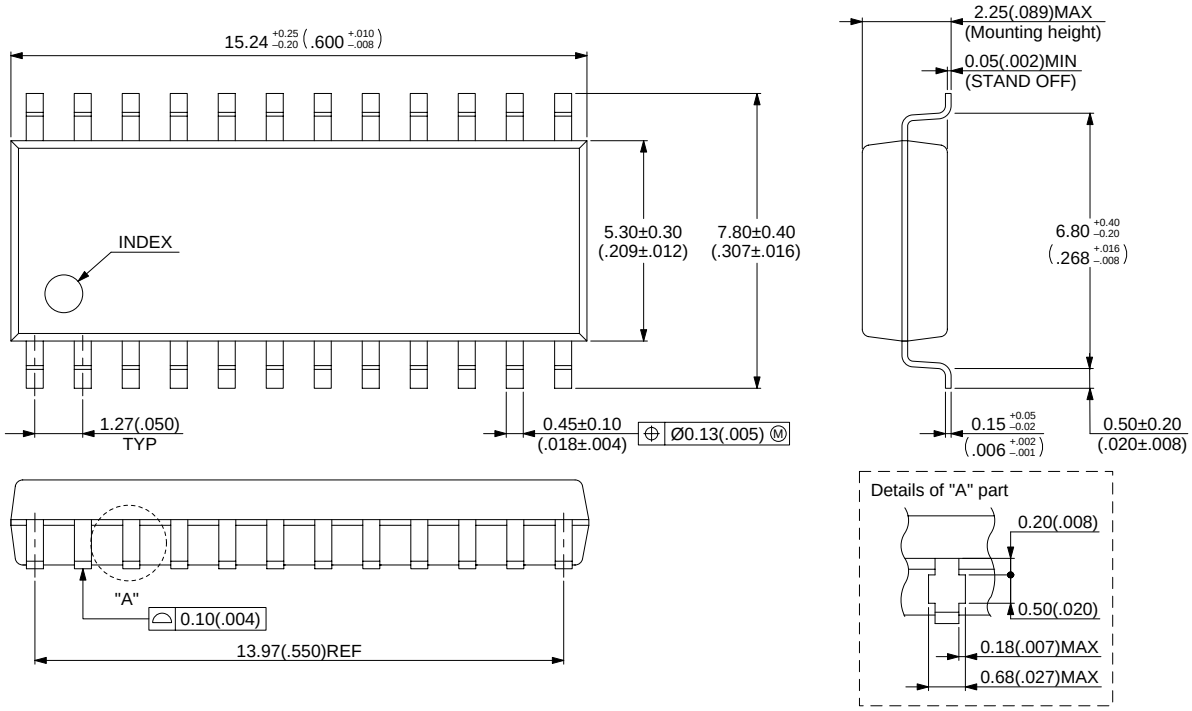


Dimensions in mm (inches)

(Continued)

(Continued)

24-pin plastic SOP
(FPT-24P-M01)



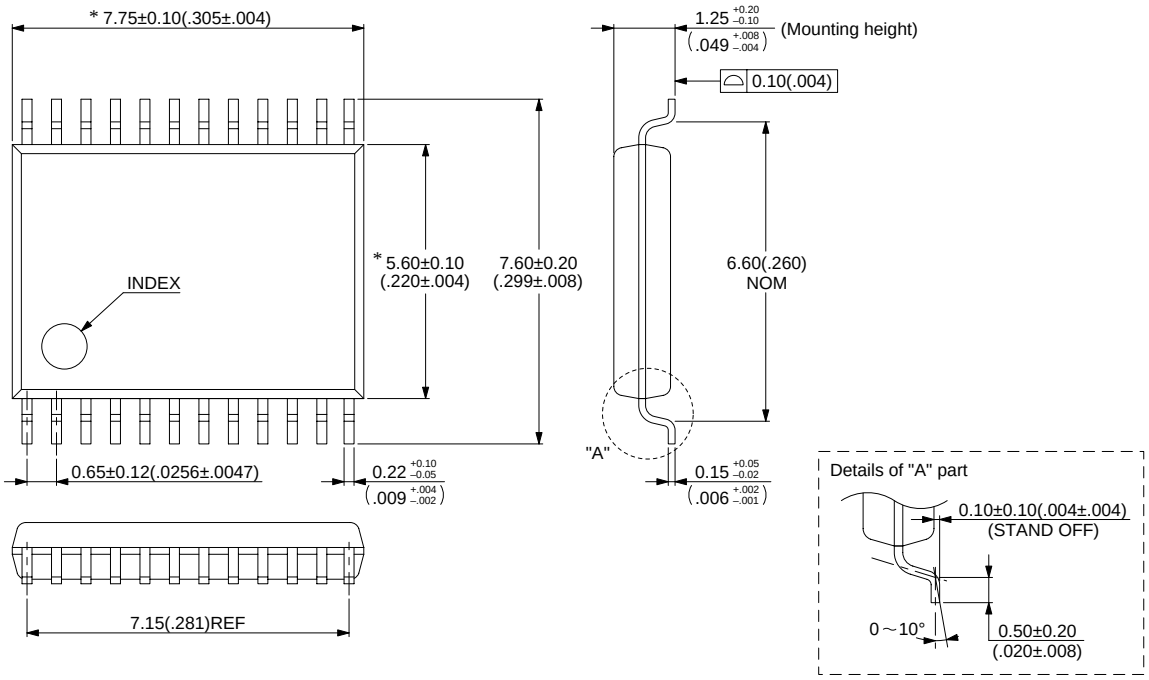
Dimensions in mm (inches)

(Continued)

(Continued)

24-pin plastic SSOP
(FPT-24P-M03)

Note) * marked dimensions do not include resin residues.



Dimensions in mm (inches)

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