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# DATA SHEET



## **PCF8591**

### 8-bit A/D and D/A converter

Product specification  
Supersedes data of 1997 Apr 02  
File under Integrated Circuits, IC12

1998 Jul 02

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**8-bit A/D and D/A converter****PCF8591**

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## 8-bit A/D and D/A converter

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**1 FEATURES**

- Single power supply
- Operating supply voltage 2.5 V to 6 V
- Low standby current
- Serial input/output via I<sup>2</sup>C-bus
- Address by 3 hardware address pins
- Sampling rate given by I<sup>2</sup>C-bus speed
- 4 analog inputs programmable as single-ended or differential inputs
- Auto-incremented channel selection
- Analog voltage range from  $V_{SS}$  to  $V_{DD}$
- On-chip track and hold circuit
- 8-bit successive approximation A/D conversion
- Multiplying DAC with one analog output.

**2 APPLICATIONS**

- Closed loop control systems
- Low power converter for remote data acquisition
- Battery operated equipment
- Acquisition of analog values in automotive, audio and TV applications.

**4 ORDERING INFORMATION**

| TYPE<br>NUMBER | PACKAGE |                                                             |          |
|----------------|---------|-------------------------------------------------------------|----------|
|                | NAME    | DESCRIPTION                                                 | VERSION  |
| PCA8591P       | DIP16   | plastic dual in-line package; 16 leads (300 mil); long body | SOT38-1  |
| PCA8591T       | SO16    | plastic small outline package; 16 leads; body width 7.5 mm  | SOT162-1 |

**3 GENERAL DESCRIPTION**

The PCF8591 is a single-chip, single-supply low power 8-bit CMOS data acquisition device with four analog inputs, one analog output and a serial I<sup>2</sup>C-bus interface. Three address pins A0, A1 and A2 are used for programming the hardware address, allowing the use of up to eight devices connected to the I<sup>2</sup>C-bus without additional hardware. Address, control and data to and from the device are transferred serially via the two-line bidirectional I<sup>2</sup>C-bus.

The functions of the device include analog input multiplexing, on-chip track and hold function, 8-bit analog-to-digital conversion and an 8-bit digital-to-analog conversion. The maximum conversion rate is given by the maximum speed of the I<sup>2</sup>C-bus.

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5 BLOCK DIAGRAM

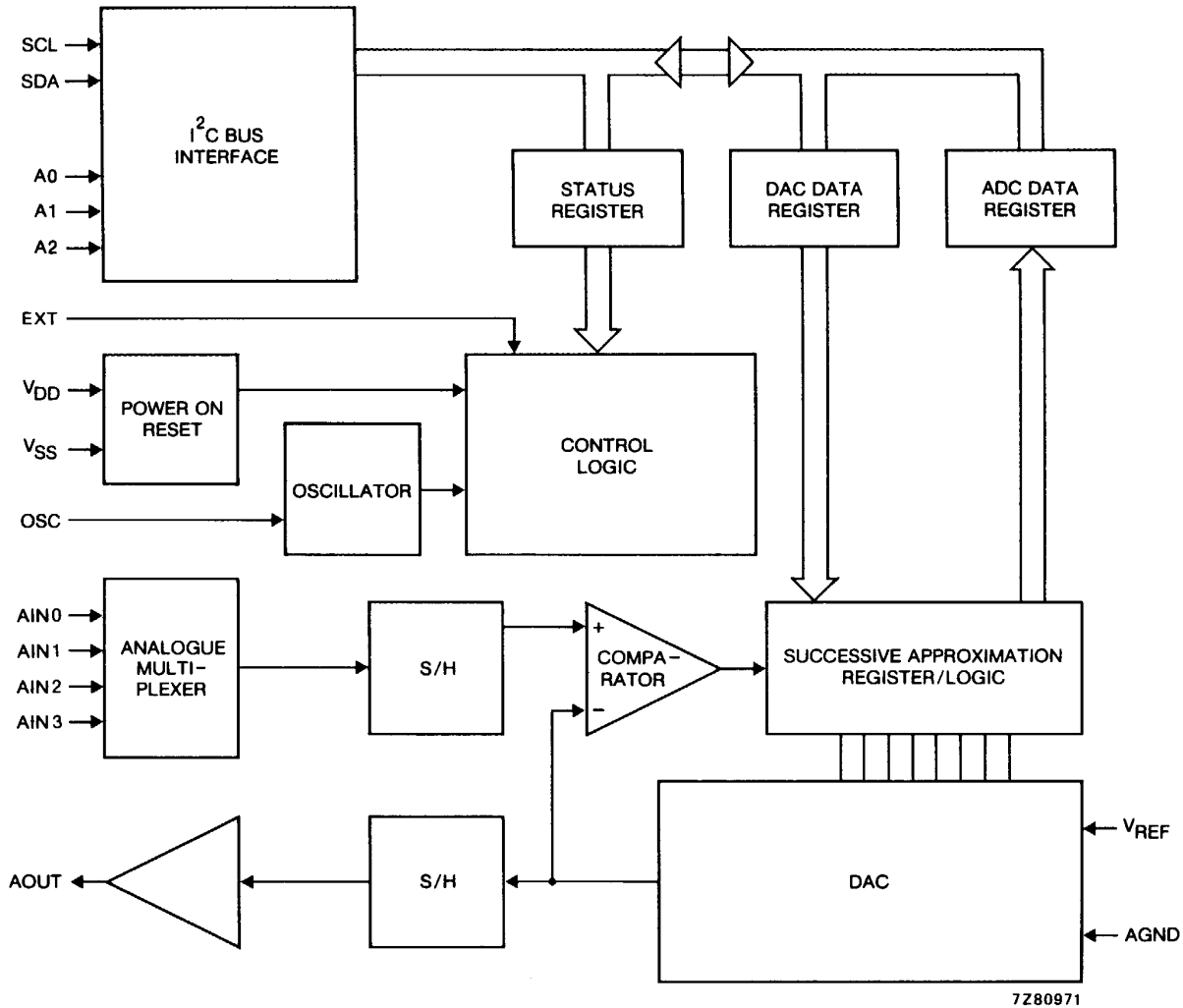


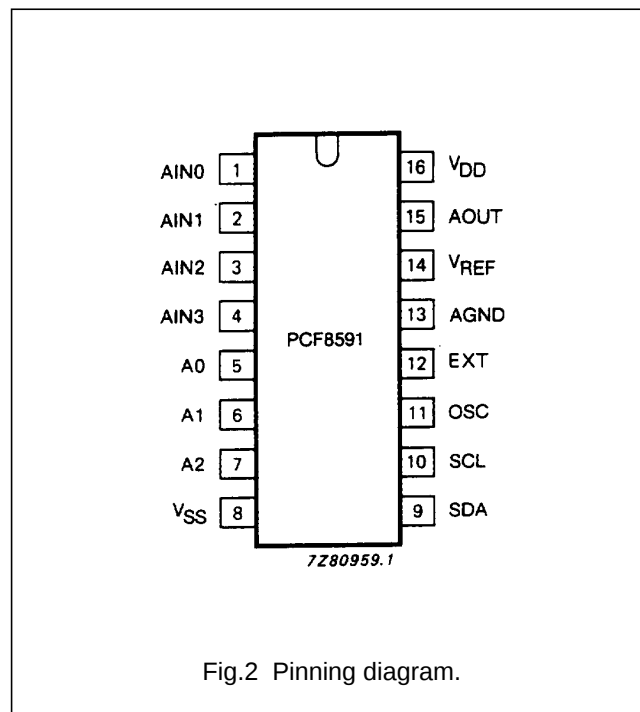
Fig.1 Block diagram.

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## 6 PINNING

| SYMBOL           | PIN | DESCRIPTION                                   |
|------------------|-----|-----------------------------------------------|
| AIN0             | 1   | analog inputs<br>(A/D converter)              |
| AIN1             | 2   |                                               |
| AIN2             | 3   |                                               |
| AIN3             | 4   |                                               |
| A0               | 5   | hardware address                              |
| A1               | 6   |                                               |
| A2               | 7   |                                               |
| V <sub>SS</sub>  | 8   |                                               |
| SDA              | 9   | I <sup>2</sup> C-bus data input/output        |
| SCL              | 10  | I <sup>2</sup> C-bus clock input              |
| OSC              | 11  | oscillator input/output                       |
| EXT              | 12  | external/internal switch for oscillator input |
| AGND             | 13  | analog ground                                 |
| V <sub>REF</sub> | 14  | voltage reference input                       |
| AOUT             | 15  | analog output (D/A converter)                 |
| V <sub>DD</sub>  | 16  | positive supply voltage                       |



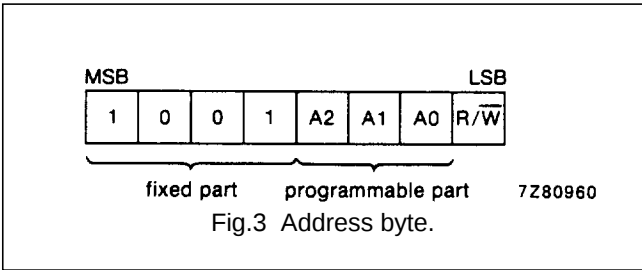
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7 FUNCTIONAL DESCRIPTION

7.1 Addressing

Each PCF8591 device in an I<sup>2</sup>C-bus system is activated by sending a valid address to the device. The address consists of a fixed part and a programmable part. The programmable part must be set according to the address pins A0, A1 and A2. The address always has to be sent as the first byte after the start condition in the I<sup>2</sup>C-bus protocol. The last bit of the address byte is the read/write-bit which sets the direction of the following data transfer (see Figs 3, 15 and 16).



7.2 Control byte

The second byte sent to a PCF8591 device will be stored in its control register and is required to control the device function.

The upper nibble of the control register is used for enabling the analog output, and for programming the analog inputs as single-ended or differential inputs. The lower nibble selects one of the analog input channels defined by the upper nibble (see Fig.4). If the auto-increment flag is set the channel number is incremented automatically after each A/D conversion.

If the auto-increment mode is desired in applications where the internal oscillator is used, the analog output enable flag in the control byte (bit 6) should be set. This allows the internal oscillator to run continuously, thereby preventing conversion errors resulting from oscillator start-up delay. The analog output enable flag may be reset at other times to reduce quiescent power consumption.

The selection of a non-existing input channel results in the highest available channel number being allocated. Therefore, if the auto-increment flag is set, the next selected channel will be always channel 0. The most significant bits of both nibbles are reserved for future functions and have to be set to 0. After a Power-on reset condition all bits of the control register are reset to 0. The D/A converter and the oscillator are disabled for power saving. The analog output is switched to a high-impedance state.

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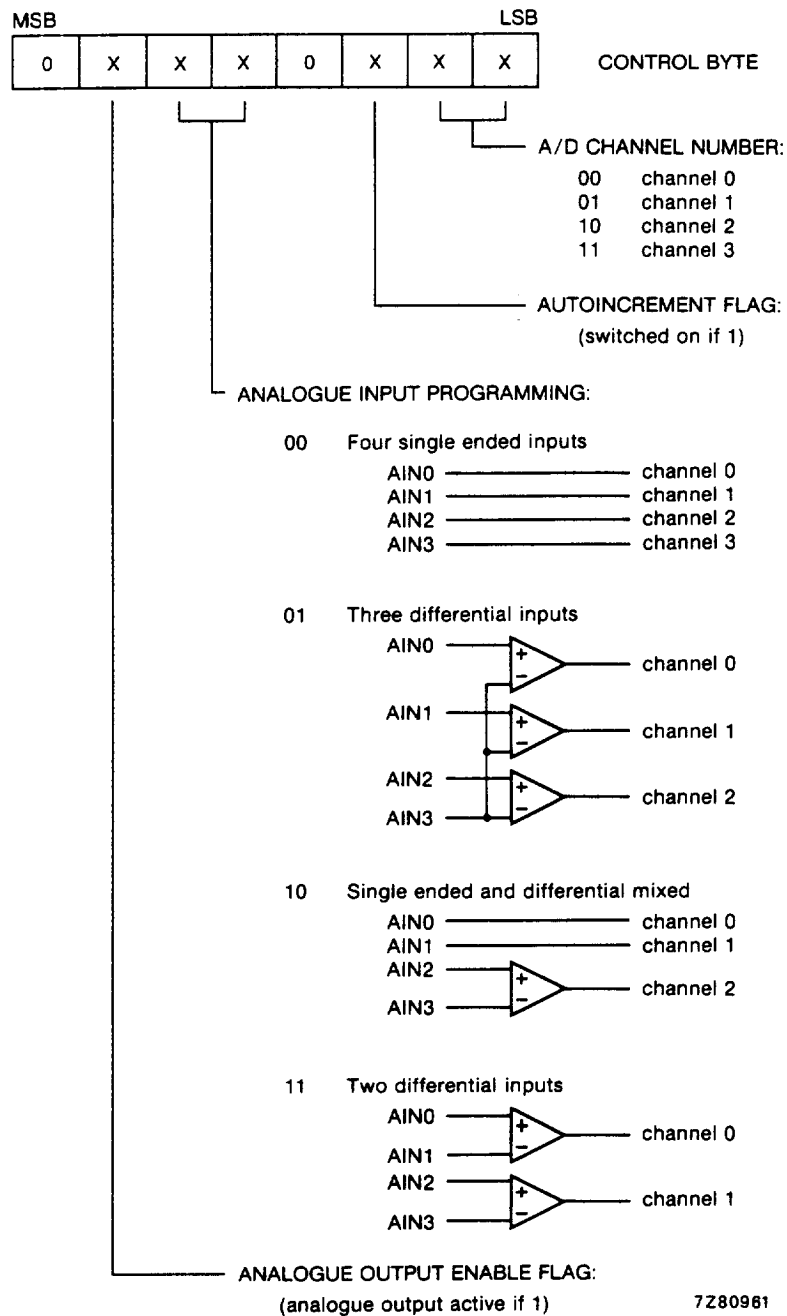


Fig.4 Control byte.

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## 7.3 D/A conversion

The third byte sent to a PCF8591 device is stored in the DAC data register and is converted to the corresponding analog voltage using the on-chip D/A converter. This D/A converter consists of a resistor divider chain connected to the external reference voltage with 256 taps and selection switches. The tap-decoder switches one of these taps to the DAC output line (see Fig.5).

The analog output voltage is buffered by an auto-zeroed unity gain amplifier. This buffer amplifier may be switched on or off by setting the analog output enable flag of the control register. In the active state the output voltage is held until a further data byte is sent.

The on-chip D/A converter is also used for successive approximation A/D conversion. In order to release the DAC for an A/D conversion cycle the unity gain amplifier is equipped with a track and hold circuit. This circuit holds the output voltage while executing the A/D conversion.

The output voltage supplied to the analog output AOUT is given by the formula shown in Fig.6. The waveforms of a D/A conversion sequence are shown in Fig.7.

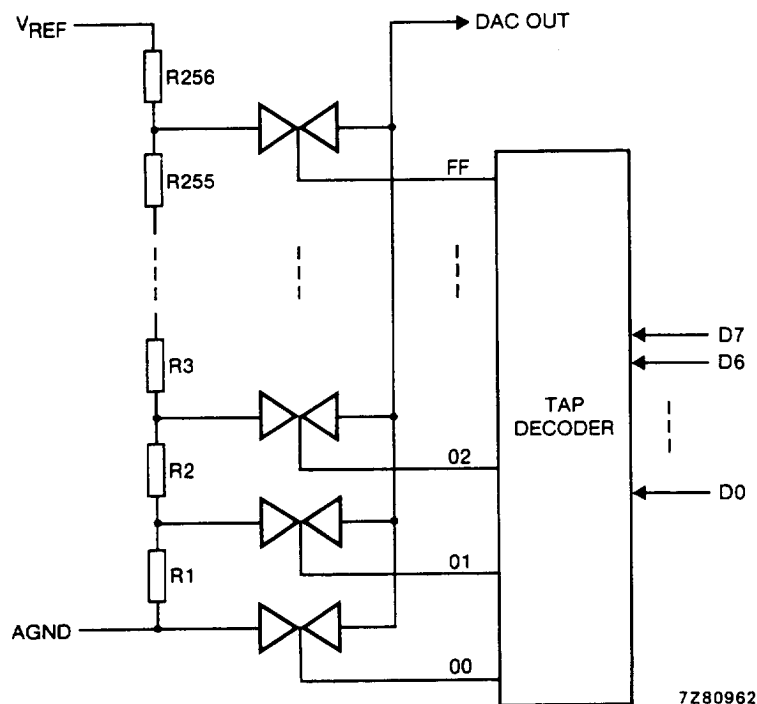


Fig.5 DAC resistor divider chain.

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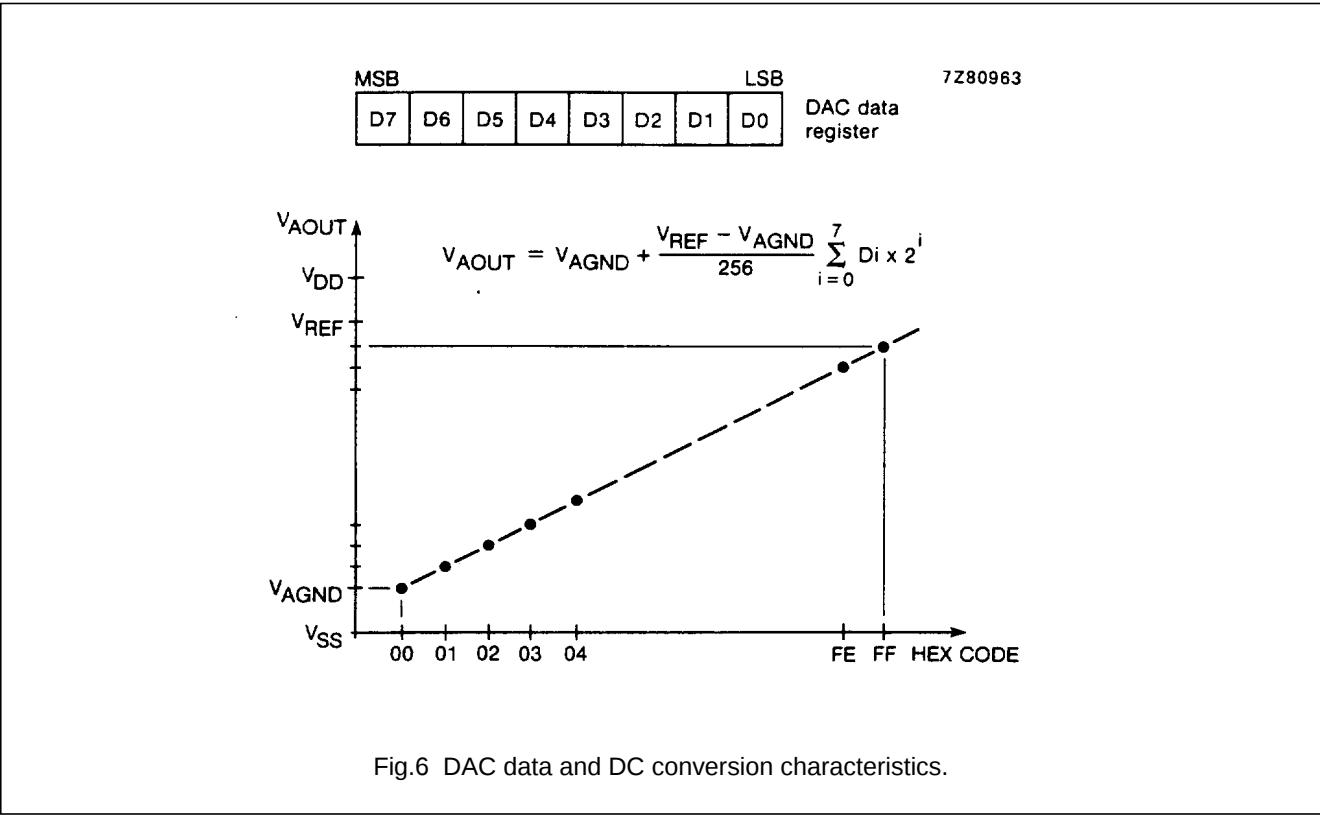


Fig.6 DAC data and DC conversion characteristics.

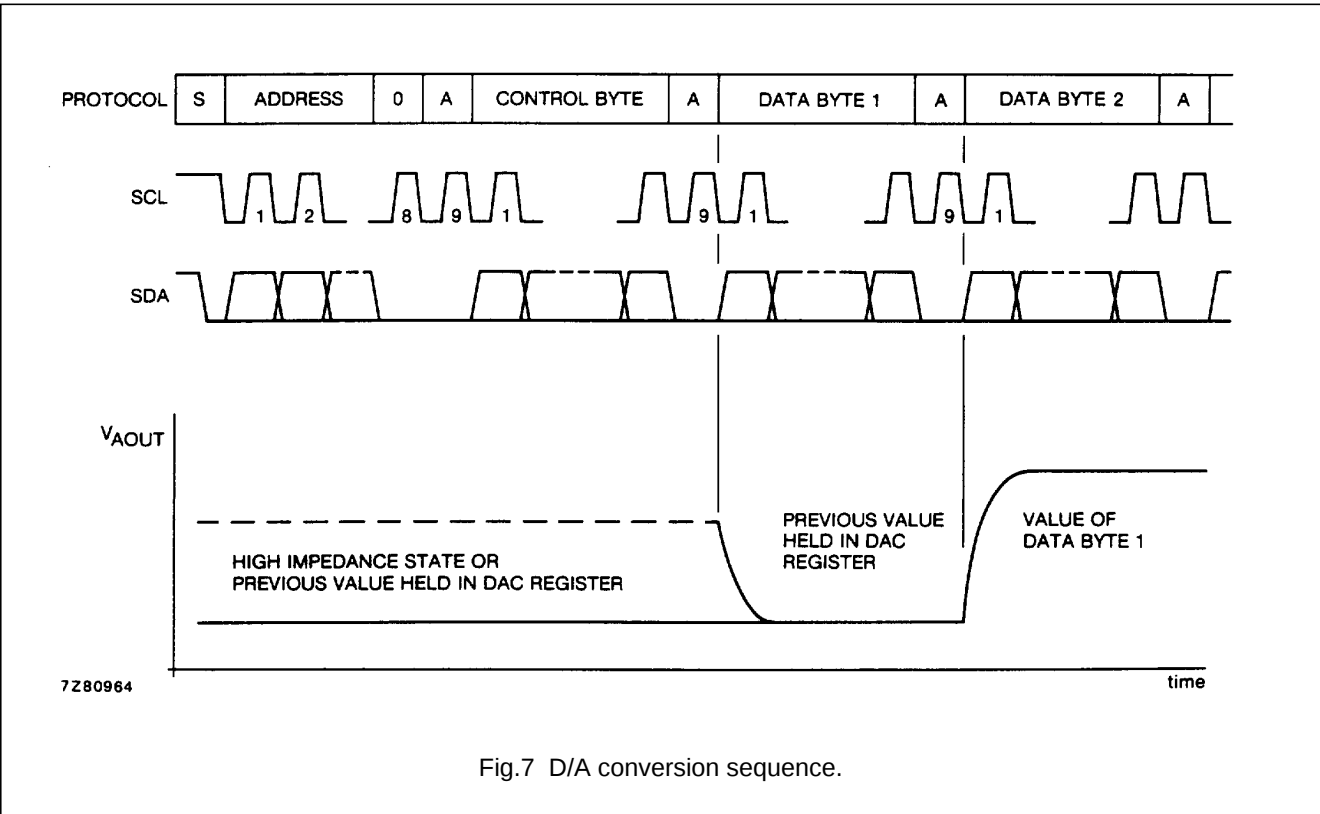


Fig.7 D/A conversion sequence.

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7.4 A/D conversion

The A/D converter makes use of the successive approximation conversion technique. The on-chip D/A converter and a high-gain comparator are used temporarily during an A/D conversion cycle.

An A/D conversion cycle is always started after sending a valid read mode address to a PCF8591 device. The A/D conversion cycle is triggered at the trailing edge of the acknowledge clock pulse and is executed while transmitting the result of the previous conversion (see Fig.8).

Once a conversion cycle is triggered an input voltage sample of the selected channel is stored on the chip and is converted to the corresponding 8-bit binary code. Samples picked up from differential inputs are converted to an 8-bit two's complement code (see Figs 9 and 10).

The conversion result is stored in the ADC data register and awaits transmission. If the auto-increment flag is set the next channel is selected.

The first byte transmitted in a read cycle contains the conversion result code of the previous read cycle. After a Power-on reset condition the first byte read is a hexadecimal 80. The protocol of an I<sup>2</sup>C-bus read cycle is shown in Chapter 8, Figs 15 and 16.

The maximum A/D conversion rate is given by the actual speed of the I<sup>2</sup>C-bus.

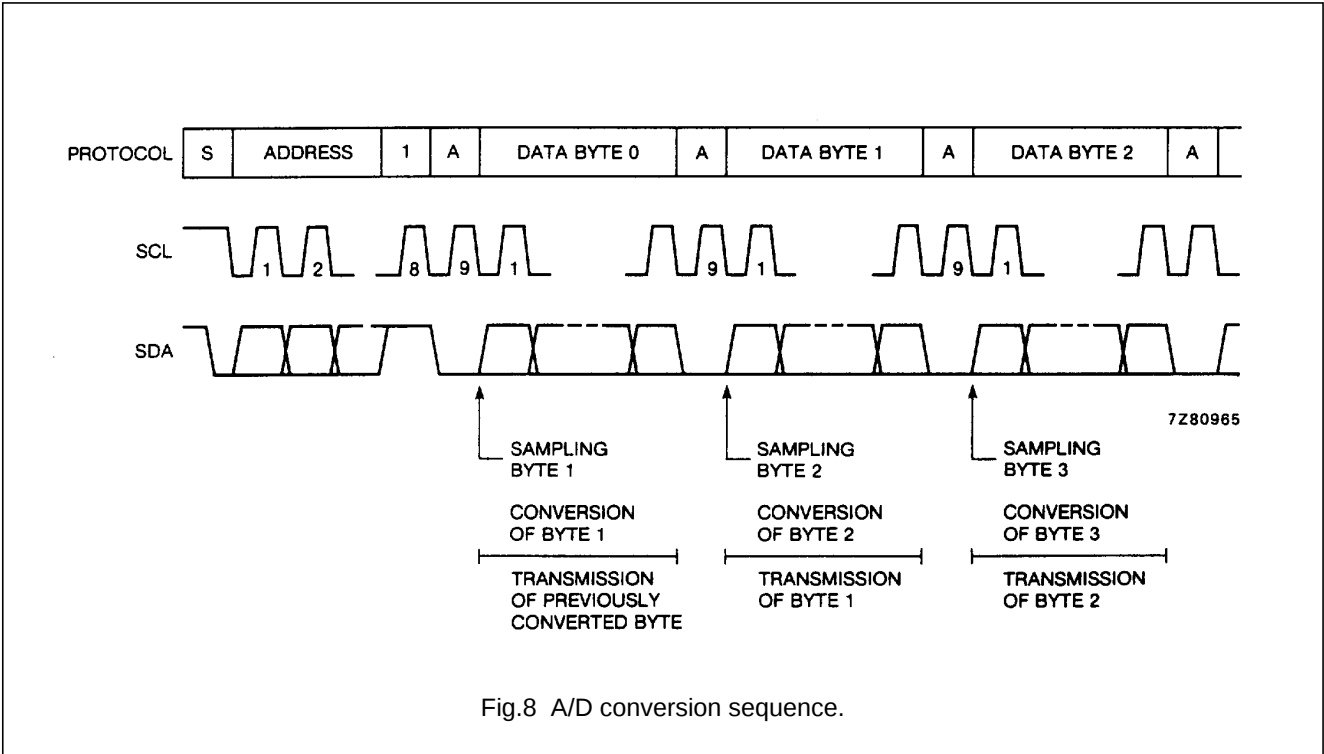


Fig.8 A/D conversion sequence.

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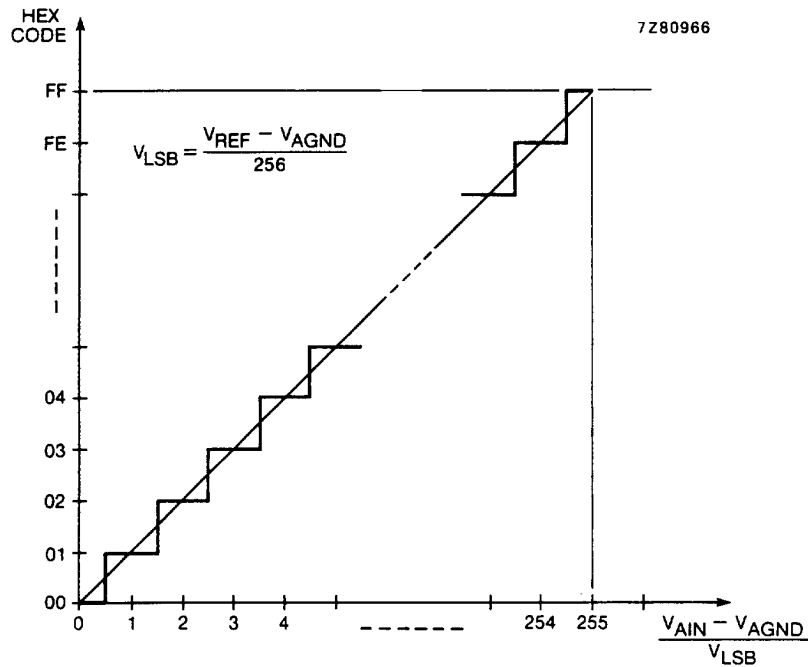


Fig.9 A/D conversion characteristics of single-ended inputs.

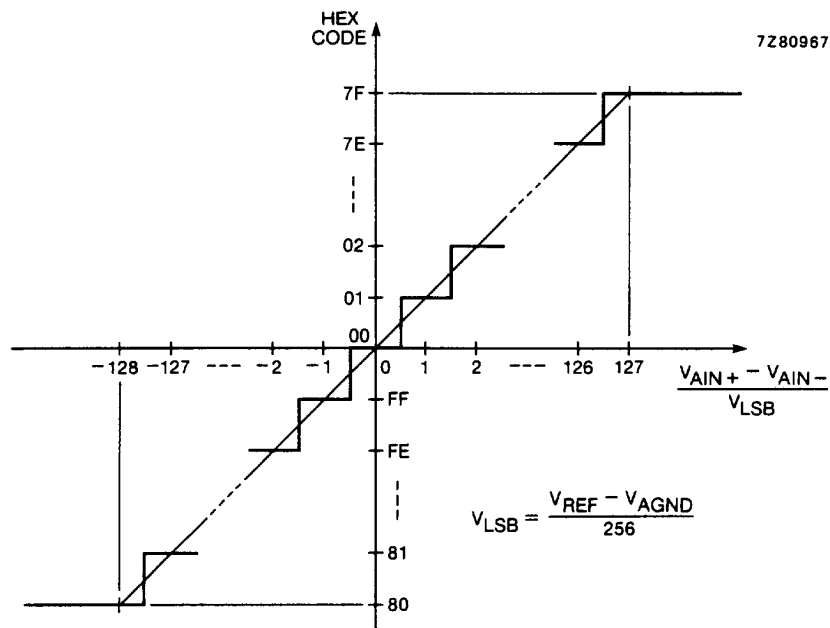


Fig.10 A/D conversion characteristics of differential inputs.

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8-bit A/D and D/A converter

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**7.5 Reference voltage**

For the D/A and A/D conversion either a stable external voltage reference or the supply voltage has to be applied to the resistor divider chain (pins  $V_{REF}$  and AGND).

The AGND pin has to be connected to the system analog ground and may have a DC off-set with reference to  $V_{SS}$ .

A low frequency may be applied to the  $V_{REF}$  and AGND pins. This allows the use of the D/A converter as a one-quadrant multiplier; see Chapter 15 and Fig.6.

The A/D converter may also be used as a one or two quadrant analog divider. The analog input voltage is divided by the reference voltage. The result is converted to a binary code. In this application the user has to keep the reference voltage stable during the conversion cycle.

**7.6 Oscillator**

An on-chip oscillator generates the clock signal required for the A/D conversion cycle and for refreshing the auto-zeroed buffer amplifier. When using this oscillator the EXT pin has to be connected to  $V_{SS}$ . At the OSC pin the oscillator frequency is available.

If the EXT pin is connected to  $V_{DD}$  the oscillator output OSC is switched to a high-impedance state allowing the user to feed an external clock signal to OSC.

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**8 CHARACTERISTICS OF THE I<sup>2</sup>C-BUS**

The I<sup>2</sup>C-bus is for bidirectional, two-line communication between different ICs or modules. The two lines are a serial data line (SDA) and a serial clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor. Data transfer may be initiated only when the bus is not busy.

**8.1 Bit transfer**

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as a control signal.

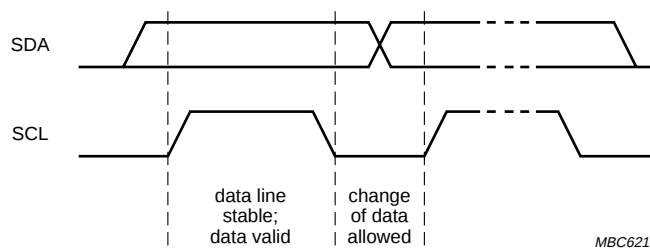


Fig.11 Bit transfer.

**8.2 Start and stop conditions**

Both data and clock lines remain HIGH when the bus is not busy. A HIGH-to-LOW transition of the data line, while the clock is HIGH, is defined as the start condition (S). A LOW-to-HIGH transition of the data line while the clock is HIGH, is defined as the stop condition (P).

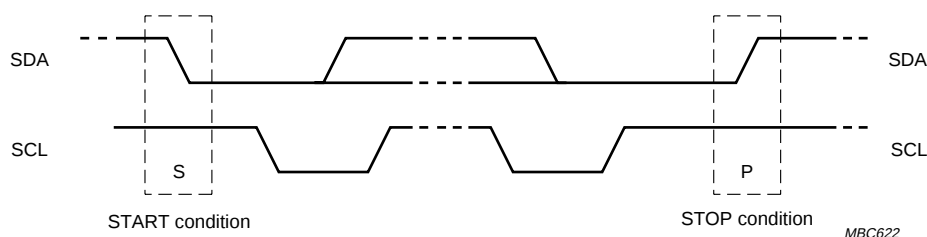


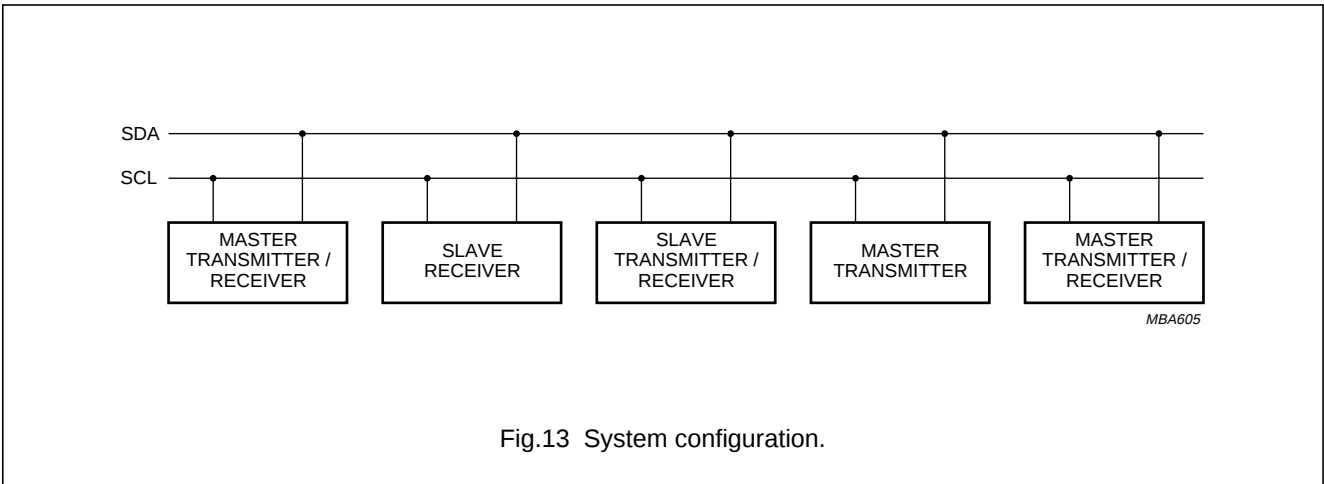
Fig.12 Definition of START and STOP condition.

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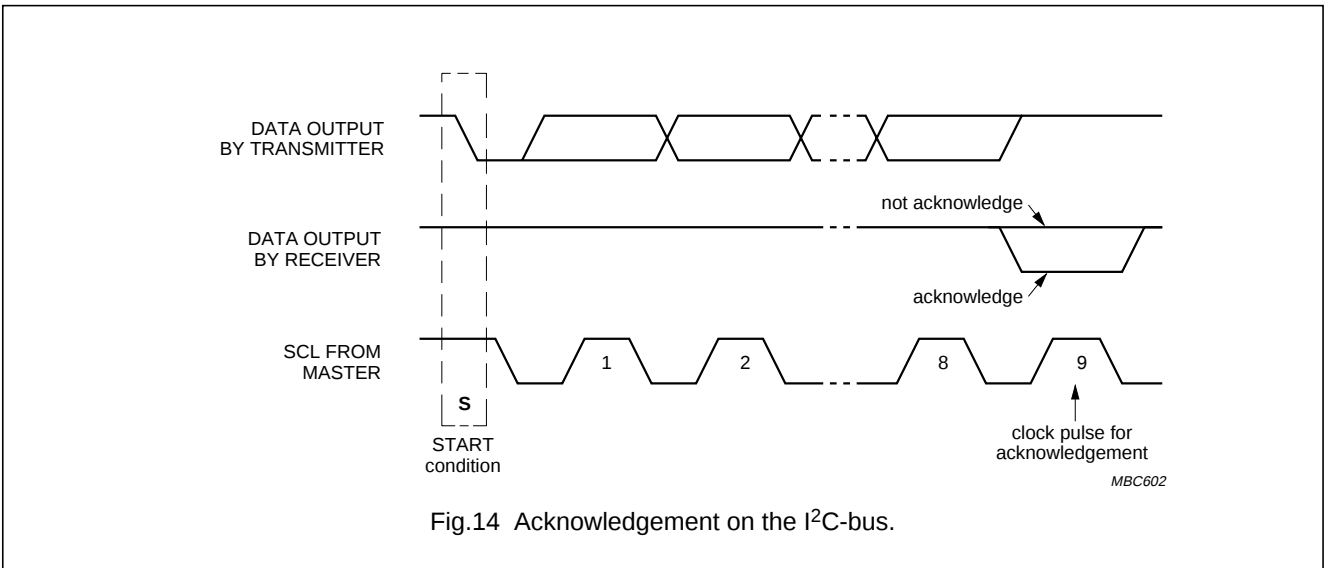
8.3 System configuration

A device generating a message is a 'transmitter', a device receiving a message is the 'receiver'. The device that controls the message is the 'master' and the devices which are controlled by the master are the 'slaves'.



8.4 Acknowledge

The number of data bytes transferred between the start and stop conditions from transmitter to receiver is not limited. Each data byte of eight bits is followed by one acknowledge bit. The acknowledge bit is a HIGH level put on the bus by the transmitter whereas the master also generates an extra acknowledge related clock pulse. A slave receiver which is addressed must generate an acknowledge after the reception of each byte. Also a master must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter. The device that acknowledges has to pull down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period of the acknowledge related clock pulse. A master receiver must signal an end of data to the transmitter by **not** generating an acknowledge on the last byte that has been clocked out of the slave. In this event the transmitter must leave the data line HIGH to enable the master to generate a stop condition.



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8.5 I<sup>2</sup>C-bus protocol

After a start condition a valid hardware address has to be sent to a PCF8591 device. The read/write bit defines the direction of the following single or multiple byte data transfer. For the format and the timing of the start condition (S), the stop condition (P) and the acknowledge bit (A) refer to the I<sup>2</sup>C-bus characteristics. In the write mode a data transfer is terminated by sending either a stop condition or the start condition of the next data transfer.

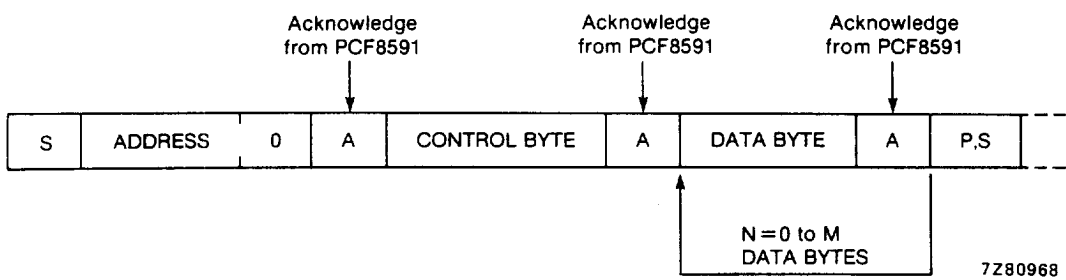


Fig.15 Bus protocol for write mode, D/A conversion.

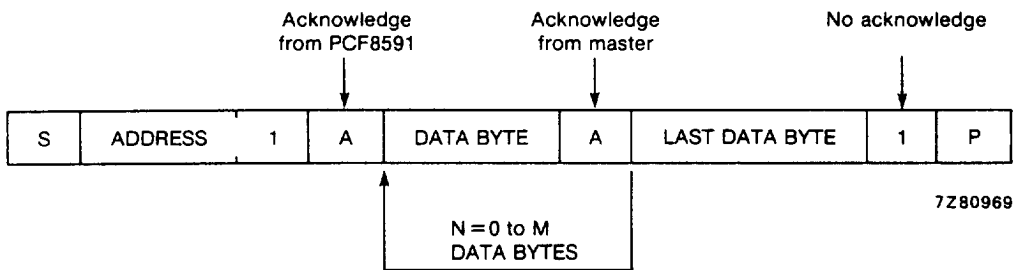


Fig.16 Bus protocol for read mode, A/D conversion.

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**9 LIMITING VALUES**

In accordance with the Absolute Maximum Rating System (IEC 134).

| SYMBOL           | PARAMETER                           | MIN. | MAX.           | UNIT |
|------------------|-------------------------------------|------|----------------|------|
| $V_{DD}$         | supply voltage (pin 16)             | -0.5 | +8.0           | V    |
| $V_I$            | input voltage (any input)           | -0.5 | $V_{DD} + 0.5$ | V    |
| $I_I$            | DC input current                    | –    | ±10            | mA   |
| $I_O$            | DC output current                   | –    | ±20            | mA   |
| $I_{DD}, I_{SS}$ | $V_{DD}$ or $V_{SS}$ current        | –    | ±50            | mA   |
| $P_{tot}$        | total power dissipation per package | –    | 300            | mW   |
| $P_O$            | power dissipation per output        | –    | 100            | mW   |
| $T_{amb}$        | operating ambient temperature       | -40  | +85            | °C   |
| $T_{stg}$        | storage temperature                 | -65  | +150           | °C   |

**10 HANDLING**

Inputs and outputs are protected against electrostatic discharge in normal handling. However, to be totally safe, it is desirable to take precautions appropriate to handling MOS devices. Advice can be found in Data Handbook IC12 under “Handling MOS Devices”.

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**11 DC CHARACTERISTICS**

$V_{DD} = 2.5\text{ V to }6\text{ V}$ ;  $V_{SS} = 0\text{ V}$ ;  $T_{amb} = -40\text{ °C to }+85\text{ °C}$  unless otherwise specified.

| SYMBOL                                             | PARAMETER                    | CONDITIONS                           | MIN.                | TYP. | MAX.                | UNIT             |
|----------------------------------------------------|------------------------------|--------------------------------------|---------------------|------|---------------------|------------------|
| <b>Supply</b>                                      |                              |                                      |                     |      |                     |                  |
| $V_{DD}$                                           | supply voltage (operating)   |                                      | 2.5                 | –    | 6.0                 | V                |
| $I_{DD}$                                           | supply current               |                                      |                     |      |                     |                  |
|                                                    | standby                      | $V_I = V_{SS}$ or $V_{DD}$ ; no load | –                   | 1    | 15                  | $\mu\text{A}$    |
|                                                    | operating, AOUT off          | $f_{SCL} = 100\text{ kHz}$           | –                   | 125  | 250                 | $\mu\text{A}$    |
|                                                    | operating, AOUT active       | $f_{SCL} = 100\text{ kHz}$           | –                   | 0.45 | 1.0                 | $\text{mA}$      |
| $V_{POR}$                                          | Power-on reset level         | note 1                               | 0.8                 | –    | 2.0                 | V                |
| <b>Digital inputs/output: SCL, SDA, A0, A1, A2</b> |                              |                                      |                     |      |                     |                  |
| $V_{IL}$                                           | LOW level input voltage      |                                      | 0                   | –    | $0.3 \times V_{DD}$ | V                |
| $V_{IH}$                                           | HIGH level input voltage     |                                      | $0.7 \times V_{DD}$ | –    | $V_{DD}$            | V                |
| $I_L$                                              | leakage current              |                                      |                     |      |                     |                  |
|                                                    | A0, A1, A2                   | $V_I = V_{SS}$ to $V_{DD}$           | –250                | –    | +250                | nA               |
|                                                    | SCL, SDA                     | $V_I = V_{SS}$ to $V_{DD}$           | –1                  | –    | +1                  | $\mu\text{A}$    |
| $C_i$                                              | input capacitance            |                                      | –                   | –    | 5                   | pF               |
| $I_{OL}$                                           | LOW level SDA output current | $V_{OL} = 0.4\text{ V}$              | 3.0                 | –    | –                   | $\text{mA}$      |
| <b>Reference voltage inputs</b>                    |                              |                                      |                     |      |                     |                  |
| $V_{REF}$                                          | reference voltage            | $V_{REF} > V_{AGND}$ ; note 2        | $V_{SS} + 1.6$      | –    | $V_{DD}$            | V                |
| $V_{AGND}$                                         | analog ground voltage        | $V_{REF} > V_{AGND}$ ; note 2        | $V_{SS}$            | –    | $V_{DD} - 0.8$      | V                |
| $I_{LI}$                                           | input leakage current        |                                      | –250                | –    | +250                | nA               |
| $R_{REF}$                                          | input resistance             | pins $V_{REF}$ and AGND              | –                   | 100  | –                   | $\text{k}\Omega$ |
| <b>Oscillator: OSC, EXT</b>                        |                              |                                      |                     |      |                     |                  |
| $I_{LI}$                                           | input leakage current        |                                      | –                   | –    | 250                 | nA               |
| $f_{OSC}$                                          | oscillator frequency         |                                      | 0.75                | –    | 1.25                | MHz              |

**Notes**

1. The power on reset circuit resets the I<sup>2</sup>C-bus logic when  $V_{DD}$  is less than  $V_{POR}$ .
2. A further extension of the range is possible, if the following conditions are fulfilled:

$$\frac{V_{REF} + V_{AGND}}{2} \geq 0.8\text{ V}, V_{DD} - \frac{V_{REF} + V_{AGND}}{2} \geq 0.4\text{ V}$$

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**12 D/A CHARACTERISTICS**

$V_{DD} = 5.0\text{ V}$ ;  $V_{SS} = 0\text{ V}$ ;  $V_{REF} = 5.0\text{ V}$ ;  $V_{AGND} = 0\text{ V}$ ;  $R_L = 10\text{ k}\Omega$ ;  $C_L = 100\text{ pF}$ ;  $T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$  unless otherwise specified.

| SYMBOL               | PARAMETER                    | CONDITIONS                                             | MIN.     | TYP. | MAX.                | UNIT          |
|----------------------|------------------------------|--------------------------------------------------------|----------|------|---------------------|---------------|
| <b>Analog output</b> |                              |                                                        |          |      |                     |               |
| $V_{OA}$             | output voltage               | no resistive load                                      | $V_{SS}$ | –    | $V_{DD}$            | V             |
|                      |                              | $R_L = 10\text{ k}\Omega$                              | $V_{SS}$ | –    | $0.9 \times V_{DD}$ | V             |
| $I_{LO}$             | output leakage current       | AOUT disabled                                          | –        | –    | 250                 | nA            |
| <b>Accuracy</b>      |                              |                                                        |          |      |                     |               |
| $OS_e$               | offset error                 | $T_{amb} = 25\text{ }^{\circ}\text{C}$                 | –        | –    | 50                  | mV            |
| $L_e$                | linearity error              |                                                        | –        | –    | $\pm 1.5$           | LSB           |
| $G_e$                | gain error                   | no resistive load                                      | –        | –    | 1                   | %             |
| $t_{DAC}$            | settling time                | to $\frac{1}{2}$ LSB full scale step                   | –        | –    | 90                  | $\mu\text{s}$ |
| $f_{DAC}$            | conversion rate              |                                                        | –        | –    | 11.1                | kHz           |
| SNRR                 | supply noise rejection ratio | $f = 100\text{ Hz}$ ;<br>$V_{DDN} = 0.1 \times V_{PP}$ | –        | 40   | –                   | dB            |

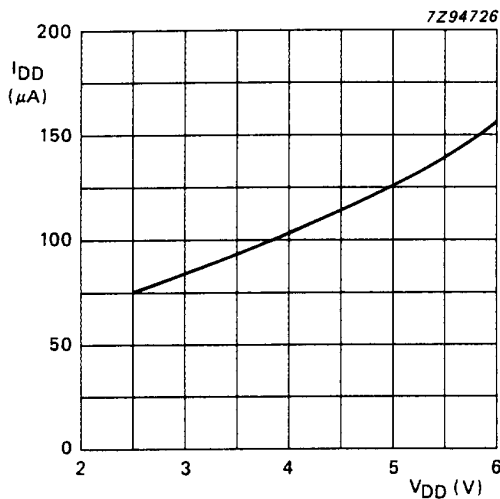
**13 A/D CHARACTERISTICS**

$V_{DD} = 5.0\text{ V}$ ;  $V_{SS} = 0\text{ V}$ ;  $V_{REF} = 5.0\text{ V}$ ;  $V_{AGND} = 0\text{ V}$ ;  $R_S = 10\text{ k}\Omega$ ;  $T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$  unless otherwise specified.

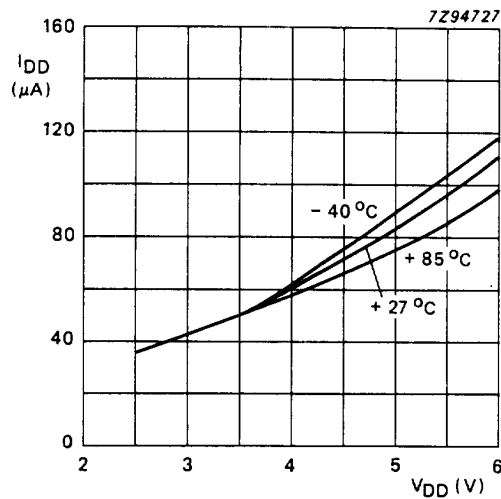
| SYMBOL               | PARAMETER                      | CONDITIONS                                             | MIN.                | TYP. | MAX.                | UNIT          |
|----------------------|--------------------------------|--------------------------------------------------------|---------------------|------|---------------------|---------------|
| <b>Analog inputs</b> |                                |                                                        |                     |      |                     |               |
| $V_{IA}$             | analog input voltage           |                                                        | $V_{SS}$            | –    | $V_{DD}$            | V             |
| $I_{LIA}$            | analog input leakage current   |                                                        | –                   | –    | 100                 | nA            |
| $C_{IA}$             | analog input capacitance       |                                                        | –                   | 10   | –                   | pF            |
| $C_{ID}$             | differential input capacitance |                                                        | –                   | 10   | –                   | pF            |
| $V_{IS}$             | single-ended voltage           | measuring range                                        | $V_{AGND}$          | –    | $V_{REF}$           | V             |
| $V_{ID}$             | differential voltage           | measuring range;<br>$V_{FS} = V_{REF} - V_{AGND}$      | $-\frac{V_{FS}}{2}$ | –    | $+\frac{V_{FS}}{2}$ | V             |
| <b>Accuracy</b>      |                                |                                                        |                     |      |                     |               |
| $OS_e$               | offset error                   | $T_{amb} = 25\text{ }^{\circ}\text{C}$                 | –                   | –    | 20                  | mV            |
| $L_e$                | linearity error                |                                                        | –                   | –    | $\pm 1.5$           | LSB           |
| $G_e$                | gain error                     |                                                        | –                   | –    | 1                   | %             |
| $GS_e$               | small-signal gain error        | $\Delta V_i = 16\text{ LSB}$                           | –                   | –    | 5                   | %             |
| CMRR                 | common-mode rejection ratio    |                                                        | –                   | 60   | –                   | dB            |
| SNRR                 | supply noise rejection ratio   | $f = 100\text{ Hz}$ ;<br>$V_{DDN} = 0.1 \times V_{PP}$ | –                   | 40   | –                   | dB            |
| $t_{ADC}$            | conversion time                |                                                        | –                   | –    | 90                  | $\mu\text{s}$ |
| $f_{ADC}$            | sampling/conversion rate       |                                                        | –                   | –    | 11.1                | kHz           |

8-bit A/D and D/A converter

PCF8591

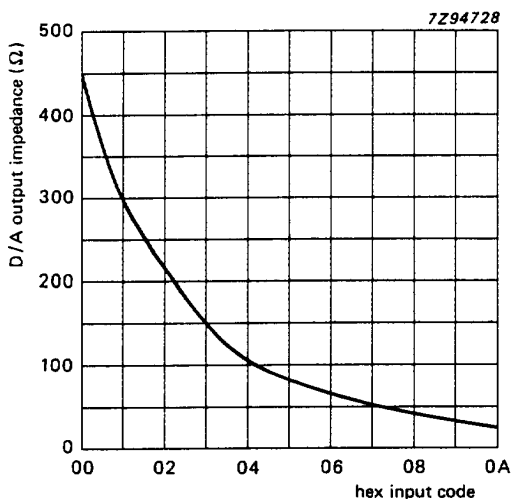


(a) Internal oscillator;  $T_{amb} = +27^\circ C$ .

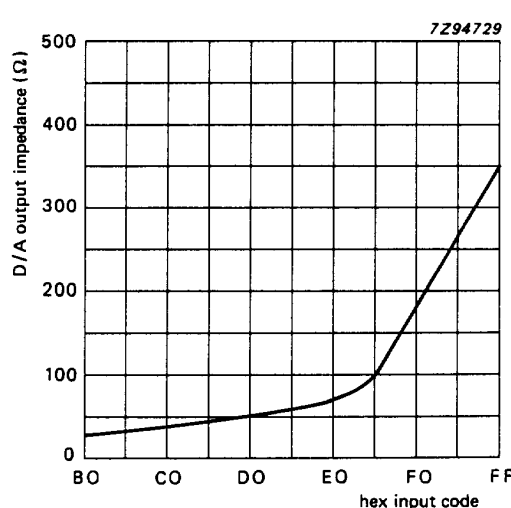


(b) External oscillator.

Fig.17 Operating supply current as a function of supply voltage (analog output disabled).



(a) Output impedance near negative power rail;  $T_{amb} = +27^\circ C$ .



(b) Output impedance near positive power rail;  $T_{amb} = +27^\circ C$ .

The x-axis represents the hex input-code equivalent of the output voltage.

Fig.18 Output impedance of analog output buffer (near power rails).

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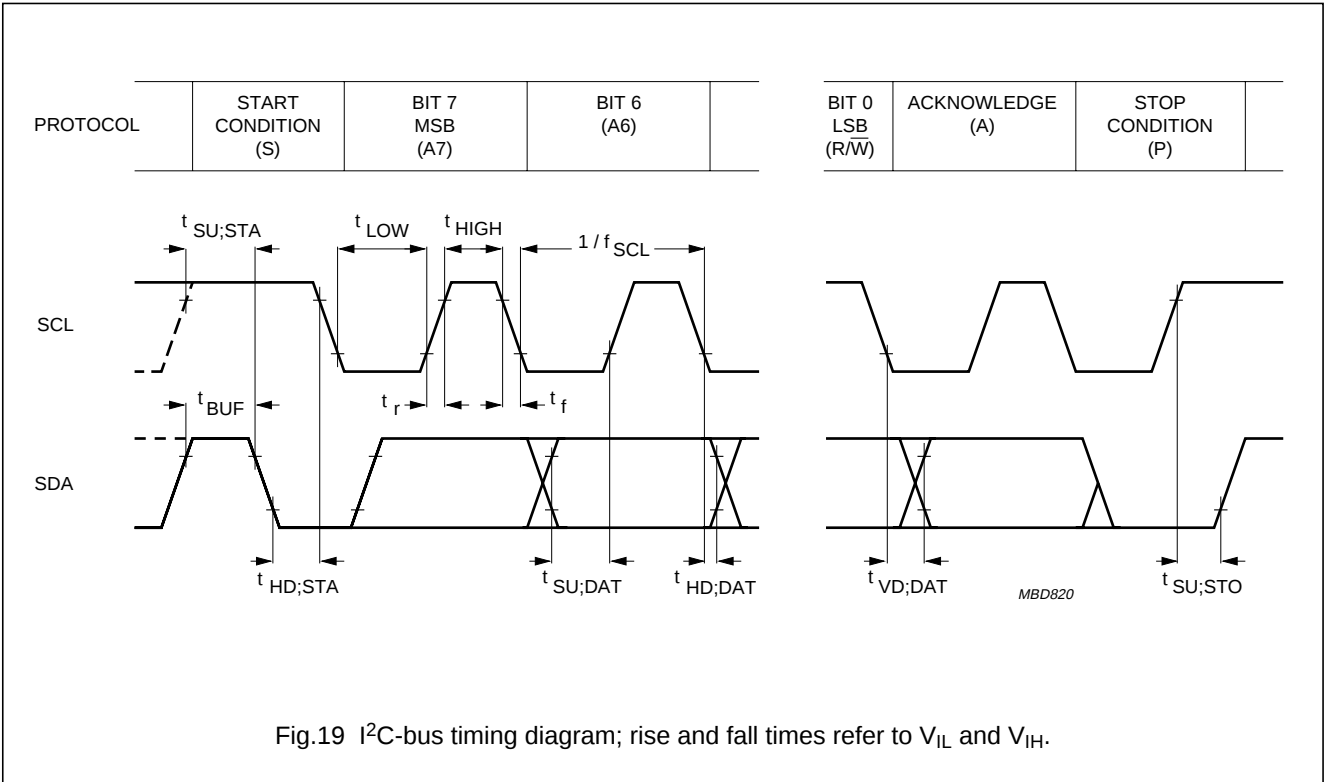
14 AC CHARACTERISTICS

All timing values are valid within the operating supply voltage and ambient temperature range and reference to  $V_{IL}$  and  $V_{IH}$  with an input voltage swing of  $V_{SS}$  to  $V_{DD}$ .

| SYMBOL                                                | PARAMETER                    | MIN. | TYP. | MAX. | UNIT |
|-------------------------------------------------------|------------------------------|------|------|------|------|
| <b>I<sup>2</sup>C-bus timing</b> (see Fig.19; note 1) |                              |      |      |      |      |
| f <sub>SCL</sub>                                      | SCL clock frequency          | –    | –    | 100  | kHz  |
| t <sub>SP</sub>                                       | tolerable spike width on bus | –    | –    | 100  | ns   |
| t <sub>BUF</sub>                                      | bus free time                | 4.7  | –    | –    | μs   |
| t <sub>SU;STA</sub>                                   | START condition set-up time  | 4.7  | –    | –    | μs   |
| t <sub>HD;STA</sub>                                   | START condition hold time    | 4.0  | –    | –    | μs   |
| t <sub>LOW</sub>                                      | SCL LOW time                 | 4.7  | –    | –    | μs   |
| t <sub>HIGH</sub>                                     | SCL HIGH time                | 4.0  | –    | –    | μs   |
| t <sub>r</sub>                                        | SCL and SDA rise time        | –    | –    | 1.0  | μs   |
| t <sub>f</sub>                                        | SCL and SDA fall time        | –    | –    | 0.3  | μs   |
| t <sub>SU;DAT</sub>                                   | data set-up time             | 250  | –    | –    | ns   |
| t <sub>HD;DAT</sub>                                   | data hold time               | 0    | –    | –    | ns   |
| t <sub>VD;DAT</sub>                                   | SCL LOW-to-data out valid    | –    | –    | 3.4  | μs   |
| t <sub>SU;STO</sub>                                   | STOP condition set-up time   | 4.0  | –    | –    | μs   |

Note

1. A detailed description of the I<sup>2</sup>C-bus specification, with applications, is given in brochure “The I<sup>2</sup>C-bus and how to use it”. This brochure may be ordered using the code 9398 393 40011.



## 8-bit A/D and D/A converter

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## 15 APPLICATION INFORMATION

Inputs must be connected to  $V_{SS}$  or  $V_{DD}$  when not in use. Analog inputs may also be connected to AGND or  $V_{REF}$ .

In order to prevent excessive ground and supply noise and to minimize cross-talk of the digital to analog signal paths the user has to design the printed-circuit board layout very carefully. Supply lines common to a PCF8591 device and noisy digital circuits and ground loops should be avoided. Decoupling capacitors ( $>10\ \mu\text{F}$ ) are recommended for power supply and reference voltage inputs.

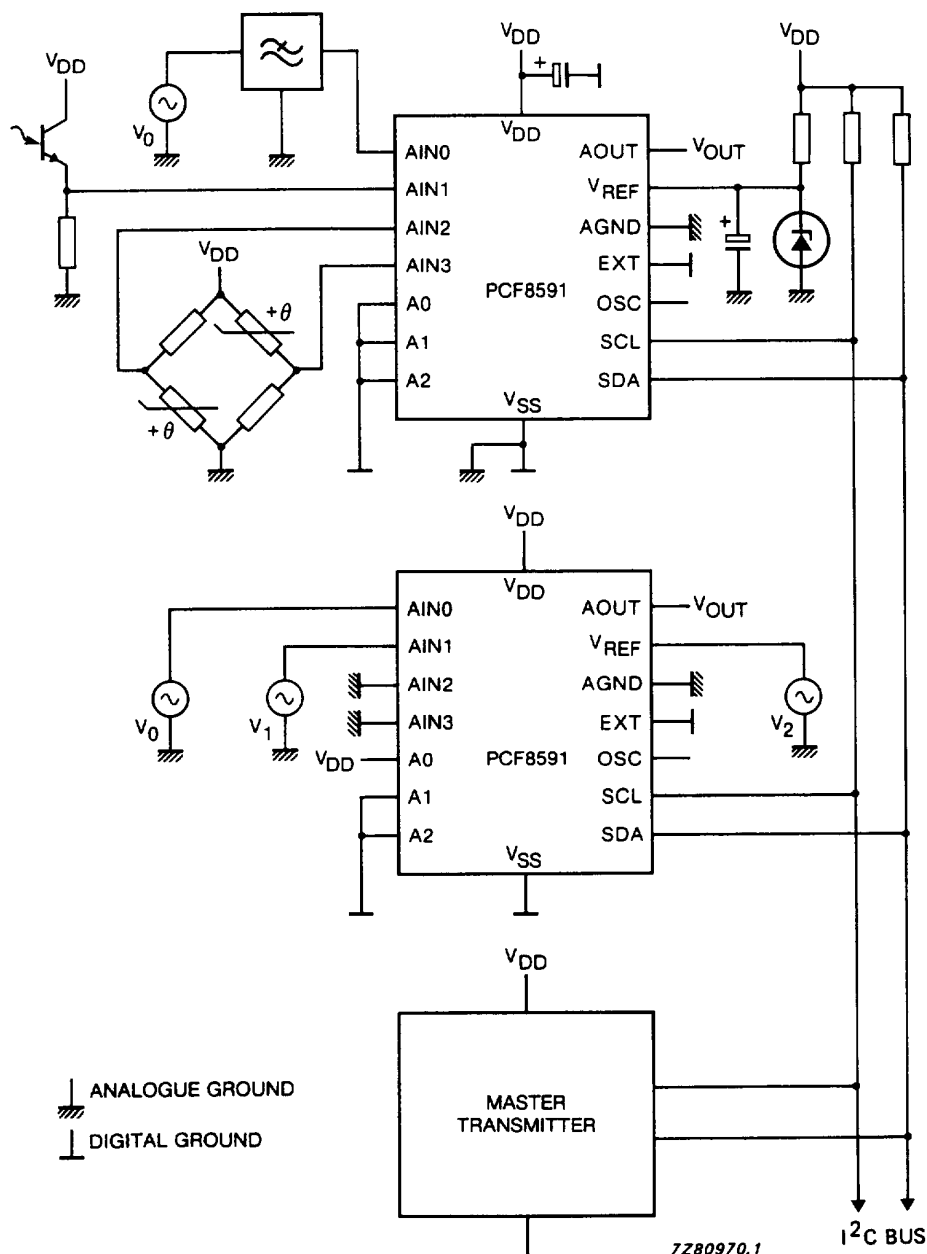


Fig.20 Application diagram.

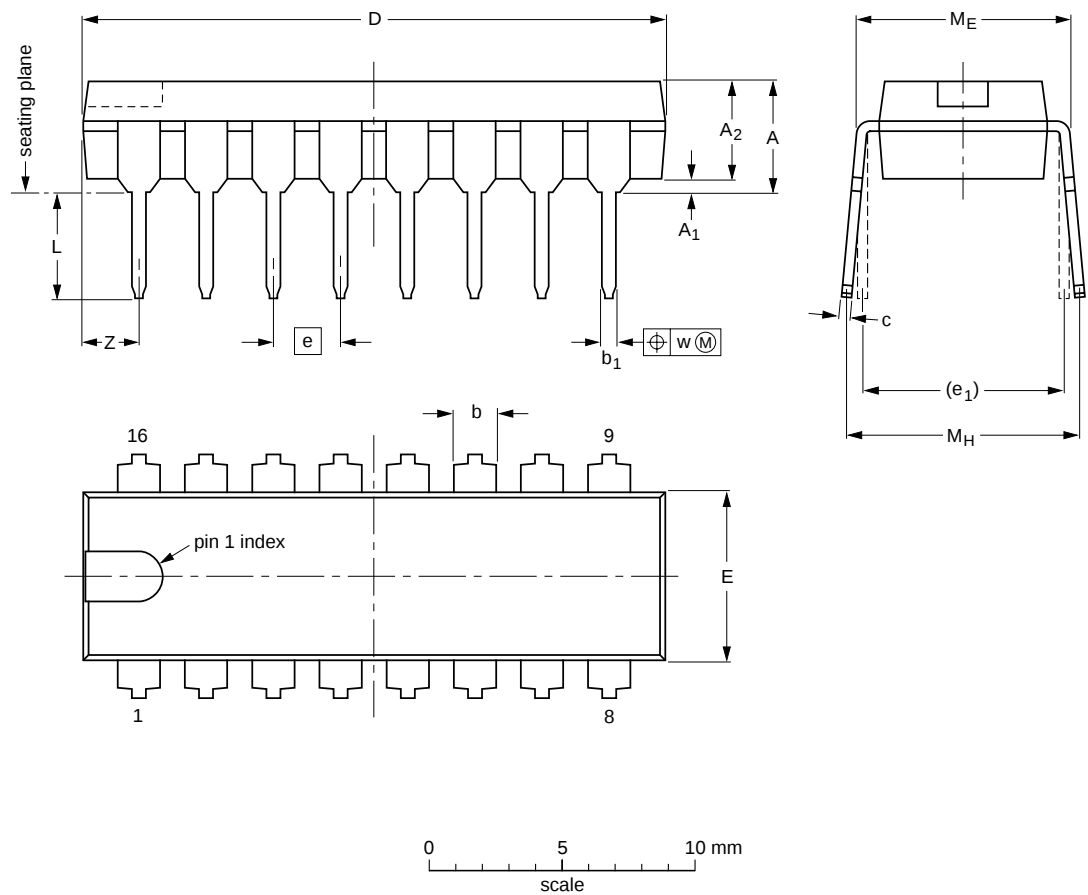
8-bit A/D and D/A converter

PCF8591

16 PACKAGE OUTLINES

DIP16: plastic dual in-line package; 16 leads (300 mil); long body

SOT38-1

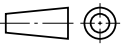


DIMENSIONS (inch dimensions are derived from the original mm dimensions)

| UNIT   | A<br>max. | A <sub>1</sub><br>min. | A <sub>2</sub><br>max. | b              | b <sub>1</sub> | c              | D <sup>(1)</sup> | E <sup>(1)</sup> | e    | e <sub>1</sub> | L            | M <sub>E</sub> | M <sub>H</sub> | w     | Z <sup>(1)</sup><br>max. |
|--------|-----------|------------------------|------------------------|----------------|----------------|----------------|------------------|------------------|------|----------------|--------------|----------------|----------------|-------|--------------------------|
| mm     | 4.7       | 0.51                   | 3.7                    | 1.40<br>1.14   | 0.53<br>0.38   | 0.32<br>0.23   | 21.8<br>21.4     | 6.48<br>6.20     | 2.54 | 7.62           | 3.9<br>3.4   | 8.25<br>7.80   | 9.5<br>8.3     | 0.254 | 2.2                      |
| inches | 0.19      | 0.020                  | 0.15                   | 0.055<br>0.045 | 0.021<br>0.015 | 0.013<br>0.009 | 0.86<br>0.84     | 0.26<br>0.24     | 0.10 | 0.30           | 0.15<br>0.13 | 0.32<br>0.31   | 0.37<br>0.33   | 0.01  | 0.087                    |

Note

1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

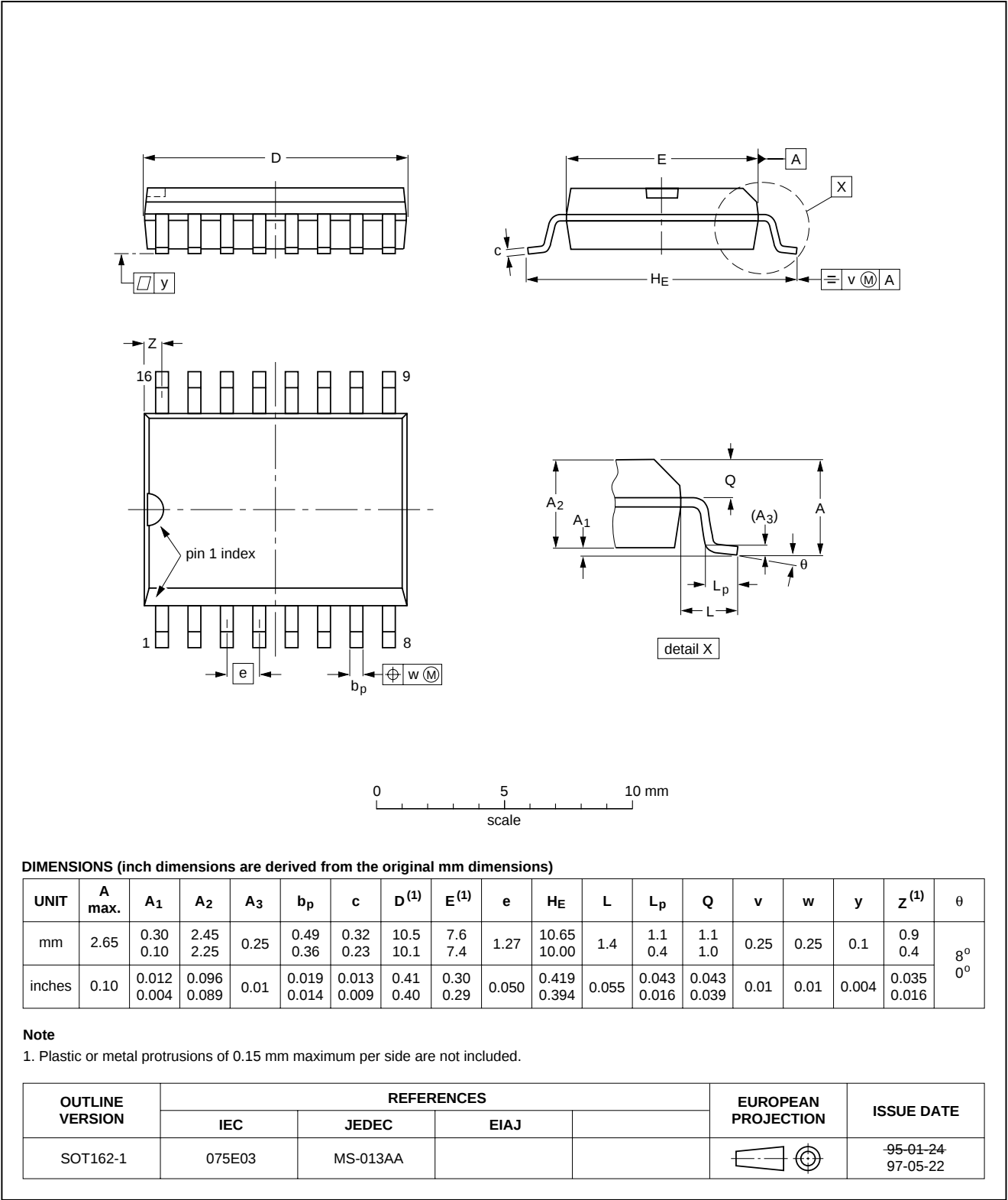
| OUTLINE<br>VERSION | REFERENCES |          |      |  | EUROPEAN<br>PROJECTION                                                                | ISSUE DATE           |
|--------------------|------------|----------|------|--|---------------------------------------------------------------------------------------|----------------------|
|                    | IEC        | JEDEC    | EIAJ |  |                                                                                       |                      |
| SOT38-1            | 050G09     | MO-001AE |      |  |  | 92-10-02<br>95-01-19 |

8-bit A/D and D/A converter

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SO16: plastic small outline package; 16 leads; body width 7.5 mm

SOT162-1



## 8-bit A/D and D/A converter

## PCF8591

### 17 SOLDERING

#### 17.1 Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (order code 9398 652 90011).

#### 17.2 DIP

##### 17.2.1 SOLDERING BY DIPPING OR BY WAVE

The maximum permissible temperature of the solder is 260 °C; solder at this temperature must not be in contact with the joint for more than 5 seconds. The total contact time of successive solder waves must not exceed 5 seconds.

The device may be mounted up to the seating plane, but the temperature of the plastic body must not exceed the specified maximum storage temperature ( $T_{stg\ max}$ ). If the printed-circuit board has been pre-heated, forced cooling may be necessary immediately after soldering to keep the temperature within the permissible limit.

##### 17.2.2 REPAIRING SOLDERED JOINTS

Apply a low voltage soldering iron (less than 24 V) to the lead(s) of the package, below the seating plane or not more than 2 mm above it. If the temperature of the soldering iron bit is less than 300 °C it may remain in contact for up to 10 seconds. If the bit temperature is between 300 and 400 °C, contact may be up to 5 seconds.

#### 17.3 SO

##### 17.3.1 REFLOW SOLDERING

Reflow soldering techniques are suitable for all SO packages.

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several techniques exist for reflowing; for example, thermal conduction by heated belt. Dwell times vary between 50 and 300 seconds depending on heating method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 minutes at 45 °C.

##### 17.3.2 WAVE SOLDERING

Wave soldering techniques can be used for all SO packages if the following conditions are observed:

- A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.
- The longitudinal axis of the package footprint must be parallel to the solder flow.
- The package footprint must incorporate solder thieves at the downstream end.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. Typical dwell time is 4 seconds at 250 °C.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

##### 17.3.3 REPAIRING SOLDERED JOINTS

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C. When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

## 8-bit A/D and D/A converter

PCF8591

**18 DEFINITIONS**

| <b>Data sheet status</b>                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Objective specification                                                                                                                                                                                                                                                                                                                                                                                                                                   | This data sheet contains target or goal specifications for product development.       |
| Preliminary specification                                                                                                                                                                                                                                                                                                                                                                                                                                 | This data sheet contains preliminary data; supplementary data may be published later. |
| Product specification                                                                                                                                                                                                                                                                                                                                                                                                                                     | This data sheet contains final product specifications.                                |
| <b>Limiting values</b>                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |
| Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability. |                                                                                       |
| <b>Application information</b>                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                       |
| Where application information is given, it is advisory and does not form part of the specification.                                                                                                                                                                                                                                                                                                                                                       |                                                                                       |

**19 LIFE SUPPORT APPLICATIONS**

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

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Purchase of Philips I<sup>2</sup>C components conveys a license under the Philips' I<sup>2</sup>C patent to use the components in the I<sup>2</sup>C system provided the system conforms to the I<sup>2</sup>C specification defined by Philips. This specification can be ordered using the code 9398 393 40011.

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**NOTES**

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**NOTES**

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