

DATA SHEET

TDA8029

Low power single card reader

Product specification

2003 Oct 30

Low power single card reader

TDA8029

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1 FEATURES

- 80C51 core with 16 kbytes ROM, 256 bytes RAM and 512 bytes XRAM
- Specific ISO7816 UART, accessible with MOVX instructions for automatic convention processing, variable baud rate, error management at character level for T = 0 and T = 1 protocols, extra guard time, etc.
- Specific versatile 24-bit Elementary Time Unit (ETU) counter for timing processing during Answer To Reset (ATR) and for T = 1 protocol
- V_{CC} generation (5 V ± 5 % or 3 V ± 5 % or 1.8 V), maximum current 65 mA with controlled rise and fall times
- Card clock generation up to 20 MHz with three times synchronous frequency doubling (f_{XTAL} , $1/2f_{XTAL}$, $1/4f_{XTAL}$ and $1/8f_{XTAL}$)
- Card clock stop HIGH or LOW or 1.25 MHz from an integrated oscillator for card power reduction modes
- Automatic activation and deactivation sequences through an independant sequencer
- Supports asynchronous protocols T = 0 and T = 1 in accordance with:
 - ISO 7816 and EMV 3.1.1 (TDA8029HL/C1 and TDA8029HL/C2)
 - ISO 7816 and EMV 2000 (TDA8029HL/C2).
- 1 to 8 characters FIFO in reception mode
- Parity error counter in reception mode and in transmission mode with automatic retransmission
- Versatile 24-bit time-out counter for ATR and waiting times processing
- Specific ETU counter for Block Guard Time (BGT) (22 ETU in T = 1 and 16 ETU in T = 0)
- Minimum delay between two characters in reception mode:
 - In protocol T = 0:
 - 12 ETU (TDA8029HL/C1)
 - 11.8 ETU (TDA8029HL/C2).
 - In protocol T = 1:
 - 11 ETU (TDA8029HL/C1)
 - 10.8 ETU (TDA8029HL/C2).

- Supports synchronous cards which do not use C4/C8
- Current limitations on card contacts
- Supply supervisor for power-on/off reset and spikes killing
- DC/DC converter (supply voltage from 2.7 to 6 V), doubler, tripler or follower according to V_{CC} and V_{DD}
- Shut-down input for very low power consumption
- Enhanced ESD protection on card contacts (6 kV minimum)
- Software library for easy integration
- Communication with the host through a standard full duplex serial link at programmable baud rates
- One external interrupt input and four general purpose I/Os.

2 GENERAL DESCRIPTION

The TDA8029 is a complete one chip, low cost, low power, robust smart card reader. Its different power reduction modes and its wide supply voltage range allow its use in portable equipment. Due to specific versatile hardware, a small embedded software program allows the control of most cards available in the market. The control from the host may be done through a standard serial interface.

The TDA8029 may be delivered with standard embedded software, or be masked with specific customer code. For details on software development and on available tools, please refer to application notes "AN01009" and "AN10134" for the TDA8029HL/C1. For standard embedded software, please refer to application note "AN10206" for the TDA8029HL/C2.

3 APPLICATIONS

- Portable card readers
- General purpose card readers
- EMV compliant card readers.

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4 QUICK REFERENCE DATA

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---------------|---------------------------------------|--|----------|------|------|--------------|
| V_{DD} | supply voltage | | 2.7 | – | 6.0 | V |
| V_{DCIN} | input voltage for the DC/DC converter | | V_{DD} | – | 6.0 | V |
| $I_{DD(sd)}$ | supply current in shut-down mode | $V_{DD} = 3.3$ V | – | – | 20 | μ A |
| $I_{DD(pd)}$ | supply current in Power-down mode | $V_{DD} = 3.3$ V; card inactive; microcontroller in Power-down mode | – | – | 110 | μ A |
| $I_{DD(sl)}$ | supply current in Sleep mode | $V_{DD} = 3.3$ V; card active at $V_{CC} = 5$ V; clock stopped; microcontroller in Power-down mode; $I_{CC} = 0$ μ A | – | – | 675 | μ A |
| $I_{DD(om)}$ | supply current in operating mode | $I_{CC} = 65$ mA; $f_{XTAL} = 20$ MHz; $f_{CLK} = 10$ MHz; 5 V card; $V_{DD} = 2.7$ V | – | – | 250 | mA |
| V_{CC} | card supply voltage | active mode including static loads; $I_{CC} < 65$ mA; 5 V card | 4.75 | 5.0 | 5.25 | V |
| | | active mode; current pulses of 40 nAs with $I < 200$ mA, $t < 400$ ns, $f < 20$ MHz; 5 V card | 4.6 | – | 5.4 | V |
| | | active mode including static loads; $I_{CC} < 65$ mA; $V_{DD} > 3.0$ V; 3 V card | 2.78 | 3 | 3.22 | V |
| | | active mode; current pulses of 24 nAs with $I < 200$ mA, $t < 400$ ns, $f < 20$ MHz; 3 V card | 2.75 | – | 3.25 | V |
| | | active mode including static loads; $I_{CC} < 30$ mA; 1.8 V card | 1.62 | 1.8 | 1.98 | V |
| | | active mode; current pulses of 12 nAs with $I < 200$ mA, $t < 400$ ns, $f < 20$ MHz; 1.8 V card | 1.62 | – | 1.98 | V |
| I_{CC} | card supply current | 5 V card; $V_{CC} = 0$ to 5 V | – | – | 65 | mA |
| | | 3 V card; $V_{CC} = 0$ to 3 V; $V_{DD} > 3.0$ V | – | – | 65 | mA |
| | | 1.8 V card; $V_{CC} = 0$ to 1.8 V | – | – | 30 | mA |
| $I_{CC(det)}$ | overload detection current | | – | 100 | – | mA |
| SR_r, SR_f | rise and fall slew rate on V_{CC} | maximum load capacitor 300 nF | 0.05 | 0.16 | 0.22 | V/ μ s |
| t_{de} | deactivation sequence duration | | – | – | 100 | μ s |
| t_{act} | activation sequence duration | | – | – | 130 | μ s |
| f_{XTAL} | crystal frequency | $V_{DD} = 5$ V | 4 | – | 27 | MHz |
| | | $V_{DD} < 3$ V | 4 | – | 16 | MHz |
| T_{amb} | ambient temperature | | –40 | – | +90 | $^{\circ}$ C |

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5 ORDERING INFORMATION

| TYPE NUMBER | PACKAGE | | |
|--------------|---------|--|----------|
| | NAME | DESCRIPTION | VERSION |
| TDA8029HL/C1 | LQFP32 | plastic low profile quad flat package; 32 leads; body 7 × 7 × 1.4 mm | SOT358-1 |
| TDA8029HL/C2 | | | |

6 BLOCK DIAGRAM

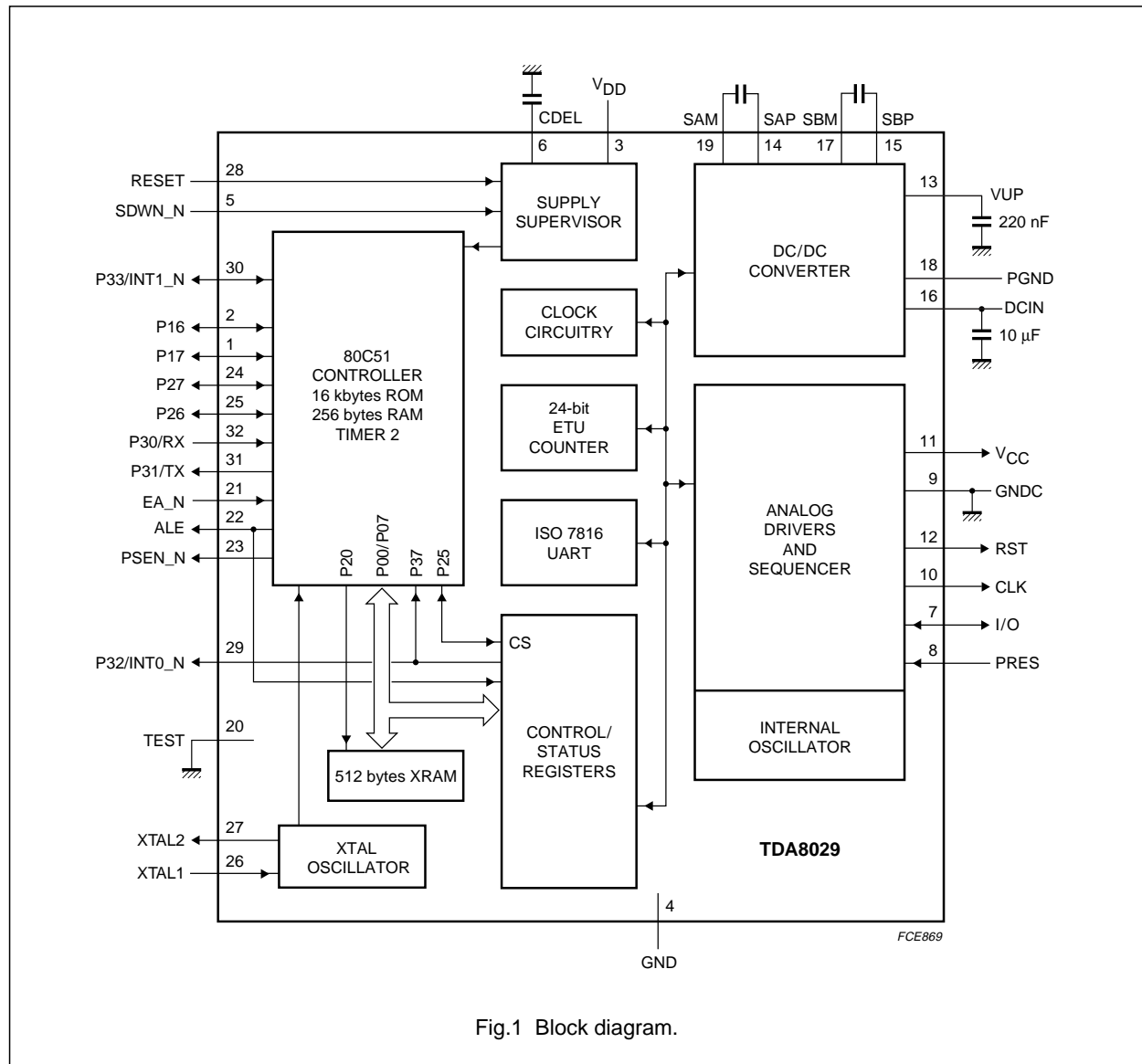


Fig.1 Block diagram.

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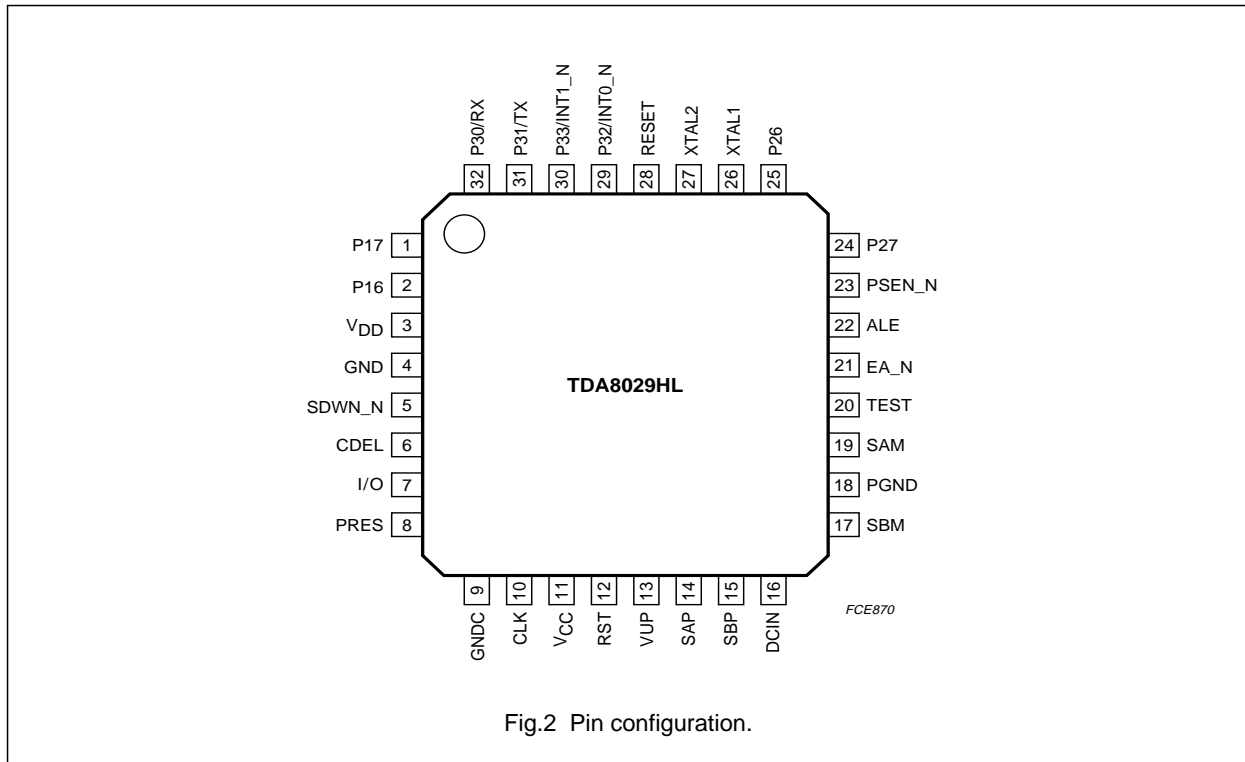
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7 PINNING

| SYMBOL | PIN | DESCRIPTION |
|-----------------|-----|--|
| P17 | 1 | general purpose I/O |
| P16 | 2 | general purpose I/O; card clock generation up to 20 MHz with three times synchronous frequency doubling (f_{XTAL} , $1/2f_{XTAL}$, $1/4f_{XTAL}$ and $1/8f_{XTAL}$) |
| V _{DD} | 3 | supply voltage |
| GND | 4 | ground connection |
| SDWN_N | 5 | shut-down signal input; active LOW |
| CDEL | 6 | connection for an external capacitor determining the Power-on reset pulse width (typically 1 ms per 2 nF) |
| I/O | 7 | data input/output to/from the card (C7); 14 k Ω integrated pull-up resistor to V _{CC} |
| PRES | 8 | card presence detection contact (active HIGH); do not connect to any external pull-up or pull-down resistor; use with a normally open presence switch |
| GNDC | 9 | card ground (C5); connect to GND in the application |
| CLK | 10 | clock to the card (C3) |
| V _{CC} | 11 | card supply voltage (C1) |
| RST | 12 | card reset (C2) |
| VUP | 13 | output of the DC/DC converter (low ESR 220 nF to PGND) |
| SAP | 14 | DC/DC converter capacitor connection (low ESR 220 nF between SAP and SAM) |
| SBP | 15 | DC/DC converter capacitor connection (low ESR 220 nF between SBP and SBM) |
| DCIN | 16 | power input for the DC/DC converter |
| SBM | 17 | DC/DC converter capacitor connection (low ESR 220 nF between SBP and SBM) |
| PGND | 18 | ground for the DC/DC converter |
| SAM | 19 | DC/DC converter capacitor connection (low ESR 220 nF between SAP and SAM) |
| TEST | 20 | used for test purpose; connect to GND in the application |
| EA_N | 21 | control signal for microcontroller; connect to V _{DD} in the application |
| ALE | 22 | control signal for the microcontroller; leave open in the application |
| PSEN_N | 23 | control signal for the microcontroller; leave open in the application |
| P27 | 24 | general purpose I/O |
| P26 | 25 | general purpose I/O |
| XTAL1 | 26 | external crystal connection or input for an external clock signal |
| XTAL2 | 27 | external crystal connection; leave open if an external clock is applied to XTAL1 |
| RESET | 28 | reset input from the host (active HIGH); integrated pull-down resistor to GND |
| P32/INT0_N | 29 | interrupt signal from the smart card interface; leave open in the application |
| P33/INT1_N | 30 | external interrupt input or general purpose I/O; may be left open if not used |
| P31/TX | 31 | transmission line for serial communication with the host |
| P30/RX | 32 | reception line for serial communication with the host |

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8 FUNCTIONAL DESCRIPTION

Throughout this specification, it is assumed that the reader is aware of ISO7816 norm terminology.

8.1 Microcontroller

The embedded microcontroller is an 80C51FB with internal 16 kbytes ROM, 256 bytes RAM and 512 bytes XRAM. It has the same instruction set as the 80C51.

The controller is clocked by the frequency present on pin XTAL1.

The controller may be reset by an active HIGH signal on pin RESET, but it is also reset by the Power-on reset signal generated by the supply supervisor.

The external interrupt INT0_N is used by the ISO UART, by the analog drivers and the ETU counters. It must be left open in the application.

The second external interrupt INT1_N is available for the application.

A general description as well as added features are described in this chapter.

The added features to the 80C51 controller are similar to the 8XC51FB controller, except on the wake-up from Power-down mode, which is possible by a falling edge on INT0_N (card reader problem) or on INT1_N or on RX due to the addition of an extra delay counter and enable configuration bits within register UCR2 (see detailed description in Section 8.10.3.2). For any further information please refer to the published specification of the 8XC51FB in "Data Handbook IC20; 80C51-Based 8-bit Microcontrollers".

The controller has four 8-bit I/O ports, three 16-bit timer/event counters, a multi-source, four-priority-level, nested interrupt structure, an enhanced UART and on-chip oscillator and timing circuits. For systems that require extra memory capability up to 64 kbytes, it can be expanded using standard TTL-compatible memories and logic.

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Additional features of the controller are:

- 80C51 central processing unit
- Full static operation
- Security bits: ROM 2 bits
- Encryption array of 64 bits
- 4-level priority structure
- 6 interrupt sources
- Full-duplex enhanced UART with framing error detection and automatic address recognition
- Power control modes; clock can be stopped and resumed, Idle mode and Power-down mode
- Wake-up from Power-down by falling edge on INT0_N, INT1_N and RX with an embedded delay counter
- Programmable clock out
- Second DPTR register
- Asynchronous port reset
- Low EMI by inhibit ALE.

Table 1 gives a list of main features to get a better understanding of the differences between a standard 80C51, an 8XC51FB and the embedded controller in the TDA8029.

Table 2 shows an overview of the special function registers.

Table 1 Principal blocks in 80C51, 8XC51FB and TDA8029

| FEATURE | 80C51 | 8XC51FB | TDA8029 |
|----------------------------|-----------|--|--|
| ROM | 4 kbytes | 16 kbytes | 16 kbytes |
| RAM | 128 bytes | 256 bytes | 256 bytes |
| ERAM (MOVX) | no | 256 bytes | 512 bytes |
| PCA | no | yes | no |
| WDT | no | yes | no |
| T0 | yes | yes | yes |
| T1 | yes | yes | yes |
| T2 | no | yes | yes |
| | | lowest interrupt priority-vector 002Bh | lowest interrupt priority-vector 002Bh |
| 4-level priority interrupt | no | yes | yes |
| enhanced UART | no | yes | yes |
| delay counter | no | no | yes |

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Table 2 Embedded controller Special Function Registers (SFRs)

| SYMBOL | DESCRIPTION | ADDR (HEX) | BIT ADDRESS, SYMBOL OR ALTERNATIVE PORT FUNCTION | | | | | | | | RESET VALUE (BINARY) |
|------------------------|-------------------------|------------|--|-----------------|------|--------------------|--------|--------|--------|------|----------------------|
| | | | E7 | E6 | E5 | E4 | E3 | E2 | E1 | E0 | |
| ACC ⁽¹⁾ | accumulator | E0 | E7 | E6 | E5 | E4 | E3 | E2 | E1 | E0 | 0000 0000 |
| AUXR ⁽²⁾ | auxiliary | 8E | – | – | – | – | – | – | EXTRAM | AO | XXXX XX00 |
| AUXR1 ⁽²⁾ | auxiliary | A2 | – | – | – | LPEP | GF | 0 | – | DPS | XXX0 00X0 |
| B ⁽¹⁾ | B register | F0 | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 | 0000 0000 |
| DPH | data pointer high | 83 | – | | | | | | | | 0000 0000 |
| DPL | data pointer low | 82 | – | | | | | | | | 0000 0000 |
| IE ⁽¹⁾ | interrupt enable | A8 | EA | – | ET2 | ES | ET1 | EX1 | ET0 | EX0 | 0X00 0000 |
| | | | AF | AE | AD | AC | AB | AA | A9 | A8 | |
| IP ⁽¹⁾ | interrupt priority | B8 | – | – | PT2 | PS | PT1 | PX1 | PT0 | PX0 | XX00 0000 |
| | | | BF | BE | BD | BC | BB | BA | B9 | B8 | |
| IPH ⁽²⁾ | interrupt priority high | B7 | – | – | PT2H | PSH | PT1H | PX1H | PT0H | PX0H | XX00 0000 |
| P0 ⁽¹⁾ | port 0 | 80 | AD7 | AD6 | AD5 | AD4 | AD3 | AD2 | AD1 | AD0 | 1111 1111 |
| | | | 87 | 86 | 85 | 84 | 83 | 82 | 81 | 80 | |
| P1 ⁽¹⁾ | port 1 | 90 | – | – | – | – | – | – | T2EX | T2 | 1111 1111 |
| | | | 97 | 96 | 95 | 94 | 93 | 92 | 91 | 90 | |
| P2 ⁽¹⁾ | port 2 | A0 | A15 | A14 | A13 | A12 | A11 | A10 | A9 | A8 | 1111 1111 |
| | | | A7 | A6 | A5 | A4 | A3 | A2 | A1 | A0 | |
| P3 ⁽¹⁾ | port 3 | B0 | \overline{RD} | \overline{WR} | T1 | T0 | INT1_N | INT0_N | TxD | RxD | 1111 1111 |
| | | | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | |
| PCON ⁽²⁾⁽³⁾ | power control | 87 | SMOD1 | SMOD0 | – | POF ⁽⁴⁾ | GF1 | GF0 | PD | IDL | 00XX 0000 |
| PSW ⁽¹⁾ | program status word | D0 | CY | AC | F0 | RS1 | RS0 | OV | – | P | 0000 00X0 |
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| RACAP2H ⁽²⁾ | timer 2 capture high | CB | – | | | | | | | | 0000 0000 |
| RACAP2L ⁽²⁾ | timer 2 capture low | CA | – | | | | | | | | 0000 0000 |
| SADDR ⁽²⁾ | slave address | A9 | – | | | | | | | | 0000 0000 |
| SADEN ⁽²⁾ | slave address mask | B9 | – | | | | | | | | 0000 0000 |

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| SYMBOL | DESCRIPTION | ADDR (HEX) | BIT ADDRESS, SYMBOL OR ALTERNATIVE PORT FUNCTION | | | | | | | | RESET VALUE (BINARY) |
|----------------------|----------------------|------------|--|------|------|------|-------|-----|------------------|--------------------|----------------------|
| SBUF | serial data buffer | 99 | - | | | | | | | | XXXX XXXX |
| SCON ⁽¹⁾ | serial control | 98 | SM0/FE | SM1 | SM2 | REN | TB8 | RB8 | TI | RI | 0000 0000 |
| | | | 9F | 9E | 9D | 9C | 9B | 9A | 99 | 98 | |
| SP | stack pointer | 81 | - | | | | | | | | 0000 0111 |
| TCON ⁽¹⁾ | timer control | 88 | TF1 | TR1 | TF0 | TE0 | IE1 | IT1 | IE0 | IT0 | 0000 0000 |
| | | | 8F | 8E | 8D | 8C | 8B | 8A | 89 | 88 | |
| T2CON ⁽¹⁾ | timer 2 control | C8 | TF2 | EXF2 | RCLK | TCLK | EXEN2 | TR2 | C/T ² | CP/RL ² | 0000 0000 |
| | | | CF | CE | CD | CC | CB | CA | C9 | C8 | |
| T2MOD ⁽²⁾ | timer 2 mode control | C9 | - | - | - | - | - | - | T2OE | DCEN | XXXX XX00 |
| TH0 | timer high 0 | 8C | - | | | | | | | | 0000 0000 |
| TH1 | timer high 1 | 8D | - | | | | | | | | 0000 0000 |
| TH2 ⁽²⁾ | timer high 2 | CD | - | | | | | | | | 0000 0000 |
| TL0 | timer low 0 | 8A | - | | | | | | | | 0000 0000 |
| TL1 | timer low 1 | 8B | - | | | | | | | | 0000 0000 |
| TL2 ⁽²⁾ | timer low 2 | CC | - | | | | | | | | 0000 0000 |
| TMOD | timer mode | 89 | GATE | C/T | M1 | M0 | GATE | C/T | M1 | M0 | 0000 0000 |

Notes

1. Register is bit addressable.
2. Register is modified from or added to the 80C51 SFRs.
3. Reset value depends on reset source.
4. Bit will not be affected by reset.

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8.1.1 PORT CHARACTERISTICS

Port 0 (P0.7 to P0.0): Port 0 is an open-drain, bidirectional, I/O timer 2 generated commonly used baud rates port. Port 0 pins that have logic 1s written to them float and can be used as high-impedance inputs. Port 0 is also the multiplexed low-order address and data bus during access to external program and data memory. In this application, it uses strong internal pull-ups when emitting logic 1s. Port 0 also outputs the code bytes during program verification and received code bytes during EPROM programming. External pull-ups are required during program verification.

Port 1 (P1.7 to P1.0): Port 1 is an 8-bit bidirectional I/O-port with internal pull-ups. Port 1 pins that have logic 1s written to them are pulled to HIGH level by the internal pull-ups and can be used as inputs. As inputs, port 1 pins that are externally pulled LOW will source current because of the internal pull-ups. Port 1 also receives the low-order address byte during program memory verification. Alternate functions for port 1 include:

- T2 (P1.0): Timer/counter 2 external count input / clock out (see programmable clock out)
- T2EX (P1.1): Timer/counter 2 reload/capture/direction control.

Port 2 (P2.7 to P2.0): Port 2 is an 8-bit bidirectional I/O port with internal pull-ups. Port 2 pins that have logic 1s written to them are pulled to HIGH level by the internal pull-ups and can be used as inputs. As inputs, port 2 pins that are externally being pulled to LOW will source current because of the internal pull-ups. Port 2 emits the high-order address byte during fetches from external program memory and during access to external data memory that use 16-bit addresses (MOVX @DPTR). In this application, it uses strong internal pull-ups when emitting logic 1s. During access to external data memory that use 8-bit addresses (MOV @Ri), port 2 emits the contents of the P2 special function register. Some port 2 pins receive the high order address bits during EPROM programming and verification.

Port 3 (P3.7 to P3.3, P3.1 and P3.0): Port 3 is a 7-bit bidirectional I/O port with internal pull-ups. Port 3 pins that have logic 1s written to them are pulled to HIGH level by the internal pull-ups and can be used as inputs. As inputs, port 3 pins that are externally being pulled LOW will source current because of the pull-ups.

Port 3 also serves the special features of the 80C51 family:

- RxD (P3.0): Serial input port
- TxD (P3.1): Serial output port
- $\overline{\text{INT0}}$ (P3.2): External interrupt 0 (pin INT0_N)
- $\overline{\text{INT1}}$ (P3.3): External interrupt 1 (pin INT1_N)
- T0 (P3.4): Timer 0 external input
- T1 (P3.5): Timer 1 external input
- WR (P3.6): External data memory write strobe
- RD (P3.7): External data memory read strobe.

8.1.2 OSCILLATOR CHARACTERISTICS

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier. The pins can be configured for use as an on-chip oscillator. To drive the device from an external clock source, XTAL1 should be driven while XTAL2 is left unconnected. There are no requirements on the duty cycle of the external clock signal, because the input to the internal clock circuitry is through a divide-by-two flip-flop. However, minimum and maximum HIGH and LOW times specified must be observed.

8.1.3 RESET

The microcontroller is reset when the TDA8029 is reset, as described in Section 8.11.

8.1.4 LOW POWER MODES

This section describes the low power modes of the microcontroller. Please refer to Section 8.15 for additional information of the TDA8029 power reduction modes.

Stop clock mode: The static design enables the clock speed to be reduced down to 0 MHz (stopped). When the oscillator is stopped, the RAM and special function registers retain their values. This mode allows step-by-step utilization and permits reduced system power consumption by lowering the clock frequency down to any value. For lowest power consumption the Power-down mode is suggested.

Idle mode: In the Idle mode, the CPU puts itself to sleep while all of the on-chip peripherals stay active. The instruction to invoke the Idle mode is the last instruction executed in the normal operating mode before the Idle mode is activated. The CPU contents, the on-chip RAM, and all of the special function registers remain intact during

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this mode. The Idle mode can be terminated either by any enabled interrupt (at which time the process is picked up at the interrupt service routine and continued), or by a hardware reset which starts the processor in the same manner as a Power-on reset.

Power-down mode: To save even more power, a Power-down mode can be invoked by software. In this mode, the oscillator is stopped and the instruction that invoked Power-down is the last instruction executed.

Either a hardware reset, external interrupt or reception on RX can be used to exit from Power-down mode. Reset redefines all the SFRs but does not change the on-chip RAM. An external interrupt allows both the SFRs and the on-chip RAM to retain their values.

With INTO_N, INT1_N or RX, the bits in register IE must be enabled. Within the INTO_N interrupt service routine, the controller has to read out the Hardware Status Register

(HSR @ 0Fh) and/or the UART Status register (USR @ 0Eh) by means of MOVX-instructions in order to know the exact interrupt reason and to reset the interrupt source.

For enabling a wake up by INT1_N, the bit ENINT1 within UCR2 must be set.

For enabling a wake up by RX, the bits ENINT1 and ENRX within UCR2 must be set.

An integrated delay counter maintains internally INTO_N and INT1_N LOW long enough to allow the oscillator to restart properly, so a falling edge on pins RX, INTO_N and INT1_N is enough for awaking the whole circuit.

Once the interrupt is serviced, the next instruction to be executed after RETI will be the one following the instruction that put the device into power-down.

Table 3 External pin status during Idle and Power-down mode

| MODE | PROGRAM MEMORY | ALE | PSEN_N | PORT 0 | PORT 1 | PORT 2 | PORT 3 |
|------------|----------------|-----|--------|--------|--------|---------|--------|
| Idle | internal | 1 | 1 | data | data | data | data |
| | external | 1 | 1 | float | data | address | data |
| Power-down | internal | 0 | 0 | data | data | data | data |
| | external | 0 | 0 | float | data | data | data |

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8.2 Timer 2 operation

Timer 2 is a 16-bit timer and counter which can operate as either an event timer or an event counter, as selected by bit C/T2 in the special function register T2CON. Timer 2 has three operating modes: capture, auto-reload (up-or down counting), and baud rate generator, which are selected by bits in register T2CON.

8.2.1 TIMER/COUNTER 2 CONTROL REGISTER (T2CON)**Table 4** Timer/counter 2 control register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|-----|------|------|------|-------|-----|------|--------|
| Symbol | TF2 | EXF2 | RCLK | TCLK | EXEN2 | TR2 | C/T2 | CP/RL2 |

Table 5 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|--------|--|
| 7 | TF2 | Timer 2 overflow flag. Set by a timer 2 overflow and must be cleared by software. TF2 will not be set when either RCLK = 1 or TCLK = 1. |
| 6 | EXF2 | Timer 2 external flag. Set when either a capture or reload is caused by a negative transition on controller input T2EX and EXEN2 = 1. When timer 2 interrupt is enabled, EXF2 = 1 will cause the CPU to vector to the timer 2 interrupt routine. EXF2 must be cleared by software. EXF2 does not cause an interrupt in up- or down-counter mode (DCEN = 1). |
| 5 | RCLK | Receive clock flag. When set, causes the serial port to use timer 2 overflow pulses for its receive clock in modes 1 and 3. When reset, causes timer 1 overflow to be used for the receive clock. |
| 4 | TCLK | Transmit clock flag. When set, causes the serial port to use timer 2 overflow pulses for its transmit clock in modes 1 and 3. When reset, causes timer 1 overflows to be used for the transmit clock. |
| 3 | EXEN2 | Timer 2 external enable flag. When set, allows a capture or reload to occur as a result of a negative transition on T2EX if timer 2 is not being used to clock the serial port. When reset, causes timer 2 to ignore events at T2EX. |
| 2 | TR2 | Start/stop control for timer 2. TR2 = 1 starts the timer. |
| 1 | C/T2 | Counter or Timer select timer 2. If C/T2 = 0 the internal timer at $1/12f_{XTAL1}$ is selected; C/T2 = 1 selects the external event counter (falling edge triggered). |
| 0 | CP/RL2 | Capture or reload flag. When set, captures will occur on negative transitions at T2EX if EXEN2 = 1. When reset, auto-reloads will occur either with timer 2 overflows or negative transitions at T2EX when EXEN2 = 1. When either RCLK = 1 or TCLK = 1, this bit is ignored and the timer is forced to auto-reload on timer 2 overflow. |

Table 6 Timer 2 operating modes

| MODE | RCLK AND TCLK | CP/RL2 | TR2 |
|---------------------|---------------|--------|-----|
| 16-bit auto-reload | 0 | 0 | 1 |
| Baud rate generator | 1 | X | 1 |
| Off | X | X | 0 |

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8.2.2 TIMER/COUNTER 2 MODE CONTROL REGISTER (T2MOD)

Table 7 Timer/counter 2 mode control register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|---|---|---|---|---|---|------|------|
| Symbol | – | – | – | – | – | – | T2OE | DCEN |

Table 8 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|--------|--|
| 7 to 2 | – | Not implemented. Reserved for future use; note 1. |
| 1 | T2OE | Timer 2 Output Enable. |
| 0 | DCEN | Down Counter Enable. When set, allows timer 2 to be configured as up-/down-counter. |

Note

- Do not write logic 1s to reserved bits. These bits may be used in future 80C51 family products to invoke new features. In that case, the reset or inactive value of the new bit will be logic 0, and its active value will be logic 1. The value read from a reserved bit is indeterminate.

8.2.3 AUTO-RELOAD MODE (UP- OR DOWN-COUNTER)

In the 16-bit auto-reload mode, timer 2 can be configured as either a timer or counter (bit $C/\overline{T2}$ in register T2CON) and programmed to count up or down. The counting direction is determined by bit DCEN (down-counter enable) which is located in the T2MOD register. When reset, DCEN = 0 and timer 2 will default to counting up. If DCEN = 1, timer 2 can count up or down depending on the value of T2EX.

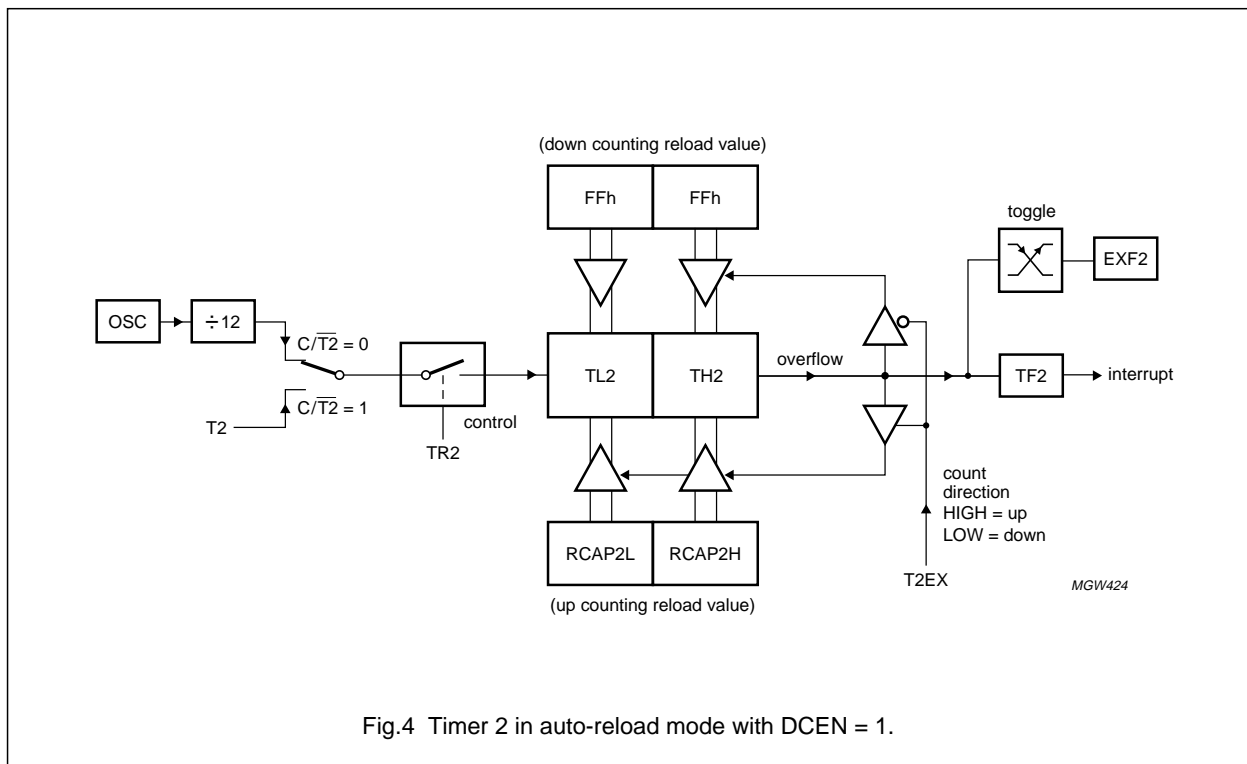
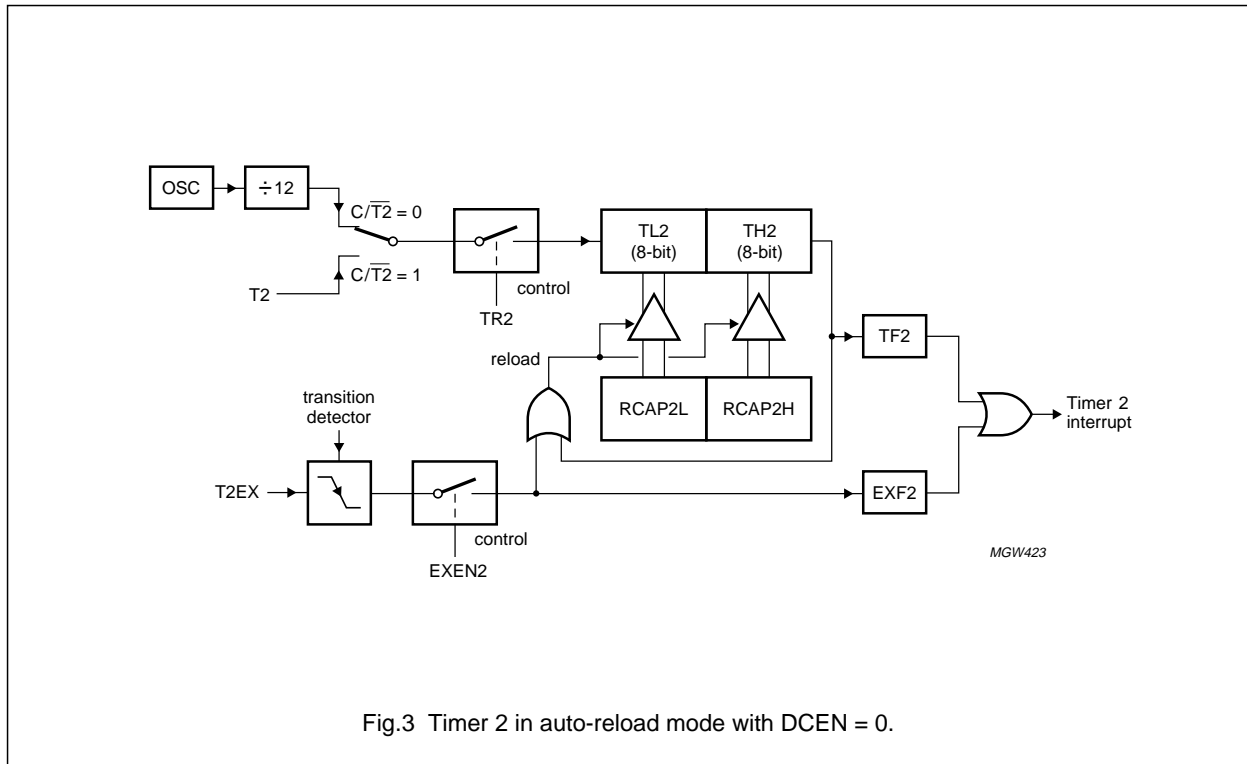
When DCEN = 0, timer 2 will count up automatically. In this mode there are two options selected by bit EXEN2 in register T2CON. If EXEN2 = 0, then timer 2 counts up to 0FFFFh and sets the TF2 overflow flag upon overflow. This causes the timer 2 registers to be reloaded with the 16-bit value in RCAP2L and RCAP2H. The values in RCAP2L and RCAP2H are preset by software. If EXEN2 = 1, then a 16-bit reload can be triggered either by an overflow or by a HIGH to LOW transition at controller input T2EX. This transition also sets the EXF2 bit. The timer 2 interrupt, if enabled, can be generated when either TF2 or EXF2 are logic 1. See Fig.3 for an overview.

DCEN = 1 enables timer 2 to count up- or down. This mode allows T2EX to control the direction of count. When a HIGH level is applied at T2EX timer 2 will count up. Timer 2 will overflow at 0FFFFh and set the TF2 flag, which can then generate an interrupt, if the interrupt is enabled. This timer overflow also causes the 16-bit value in RCAP2L and RCAP2H to be reloaded into the timer registers TL2 and TH2. When a LOW level is applied at T2EX this causes timer 2 to count down. The timer will underflow when TL2 and TH2 become equal to the value stored in RCAP2L and RCAP2H. Timer 2 underflow sets the TF2 overflow flag and causes 0FFFFh to be reloaded into the timer registers TL2 and TH2. See Fig.4 for an overview.

The external flag EXF2 toggles when timer 2 underflows or overflows. This EXF2 bit can be used as a 17th bit of resolution if needed. The EXF2 flag does not generate an interrupt in this mode of operation.

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8.2.4 BAUD RATE GENERATOR MODE

Bits TCLK and/or RCLK in register T2CON allow the serial port transmit and receive baud rates to be derived from either timer 1 or 2. When TCLK = 0, timer 1 is used as the serial port transmit baud rate generator. When TCLK = 1, timer 2 is used. RCLK has the same effect for the serial port receive baud rate. With these two bits, the serial port can have different receive and transmit baud rates, one generated by timer 1, the other by timer 2.

The baud rate generation mode is like the auto-reload mode, in that a rollover in TH2 causes the timer 2 registers to be reloaded with the 16-bit value in registers RCAP2H and RCAP2L, which are preset by software.

The baud rates in modes 1 and 3 are determined by the overflow rate of timer 2, given by equation (1):

$$\text{Baud rate} = \frac{\text{Timer 2 overflow rate}}{16} \quad (1)$$

The timer can be configured for either timer or counter operation. In many applications, it is configured for timer operation ($C/\overline{T2} = 0$). Timer operation is different for timer 2 when it is being used as a baud rate generator.

Usually, as a timer it would increment every machine cycle (i.e. $1/12 f_{osc}$). As a baud rate generator, it increments every state time (i.e. $1/2 f_{osc}$). Thus the modes 1 and 3 baud rate formula is as Equation (2):

$$\text{Baud rate} = \frac{\text{Oscillator frequency}}{32 \times [65536 - (\text{RCAP2H}, \text{RCAP2L})]} \quad (2)$$

Where (RCAP2H, RCAP2L) is the contents of RCAP2H and RCAP2L registers taken as a 16-bit unsigned integer.

The timer 2 as a baud rate generator is valid only if RCLK = 1 and/or TCLK = 1 in the T2CON register. Note that a rollover in TH2 does not set TF2, and will not generate an interrupt. Thus, the timer 2 interrupt does not have to be disabled when timer 2 is in the baud rate generator mode. Also if the EXEN2 (T2 external enable) flag is set, a HIGH to LOW transition on T2EX (Timer/counter 2 trigger input) will set the EXF2 (T2 external) flag but will not cause a reload from (RCAP2H and RCAP2L) to (TH2 and TL2). Therefore, when timer 2 is used as a baud rate generator, T2EX can be used as an additional external interrupt, if needed.

When timer 2 is in the baud rate generator mode, never try to read or write TH2 and TL2. As a baud rate generator, timer 2 is incremented every state time ($1/2 f_{osc}$) or asynchronously from controller I/O T2; under these conditions, a read or write of TH2 or TL2 may not be accurate. The RCAP2 registers may be read, but should not be written to, because a write might overlap a reload and cause write and/or reload errors. The timer should be turned off (clear TR2) before accessing the timer 2 or RCAP2 registers. See Fig.5 for an overview.

Table 9 Timer 2 generated commonly used baud rates

| BAUD RATE | CRYSTAL OSCILLATOR FREQUENCY | TIMER | |
|-----------|------------------------------|--------------|--------------|
| | | RCAP2H (HEX) | RCAP2L (HEX) |
| 375k | 12 MHz | FF | FF |
| 9.6k | 12 MHz | FF | D9 |
| 2.8k | 12 MHz | FF | B2 |
| 2.4k | 12 MHz | FF | 64 |
| 1.2k | 12 MHz | FE | C8 |
| 300 | 12 MHz | FB | 1E |
| 110 | 12 MHz | F2 | AF |
| 300 | 6 MHz | FD | 8F |
| 110 | 6 MHz | F9 | 57 |

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Summary of baud rate equations: Timer 2 is in baud rate generating mode. If timer 2 is being clocked through T2 (P1.0) the baud rate is:

$$\text{Baud rate} = \frac{\text{Timer 2 overflow rate}}{16} \tag{3}$$

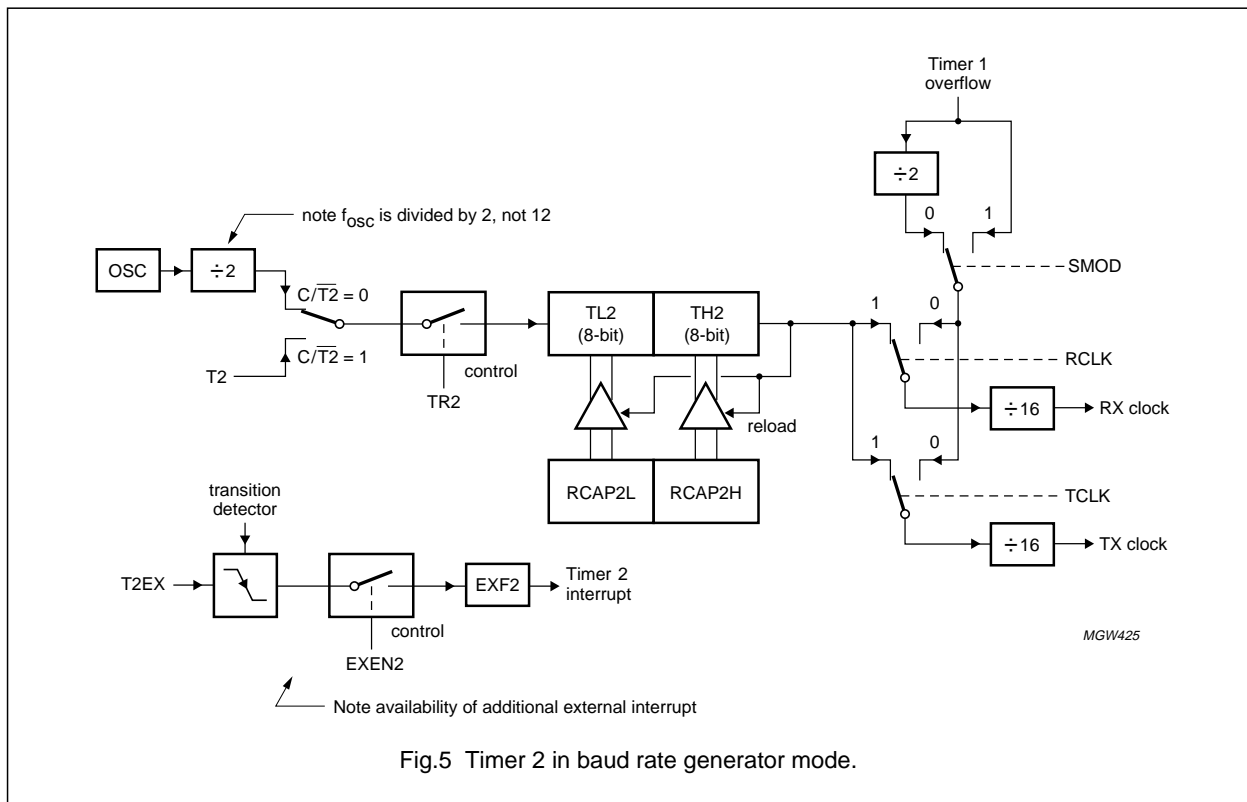
If timer 2 is being clocked internally, the baud rate is:

$$\text{Baud rate} = \frac{\text{Oscillator frequency}}{32 \times [65536 - (\text{RCAP2H}, \text{RCAP2L})]} \tag{4}$$

To obtain the reload value for RCAP2H and RCAP2L, the above equation can be rewritten as:

$$\text{RCAP2H}, \text{RCAP2L} = 65536 - \frac{f_{\text{osc}}}{32 \times \text{baud rate}} \tag{5}$$

Where f_{osc} = oscillator frequency.



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8.2.5 TIMER/COUNTER 2 SET-UP

Except for the baud rate generator mode, the values given for T2CON do not include the setting of the TR2 bit. Therefore, bit TR2 must be set, separately, to turn the timer on.

Table 10 Timer 2 as a timer

| MODE | T2CON | |
|---|---------------------------------------|---------------------------------------|
| | INTERNAL CONTROL ⁽¹⁾ (HEX) | EXTERNAL CONTROL ⁽²⁾ (HEX) |
| 16-bit auto-reload | 00 | 08 |
| Baud rate generator receive and transmit same baud rate | 34 | 36 |
| Receive only | 24 | 26 |
| Transmit only | 14 | 16 |

Notes

1. Capture/reload occurs only on timer/counter overflow.
2. Capture/reload on timer/counter overflow and a HIGH to LOW transition on T2EX, except when timer 2 is used in the baud rate generator mode.

Table 11 Timer 2 as a counter

| MODE | T2CON | |
|-------------|---------------------------------------|---------------------------------------|
| | INTERNAL CONTROL ⁽¹⁾ (HEX) | EXTERNAL CONTROL ⁽²⁾ (HEX) |
| 16-bit | 02 | 04 |
| Auto-reload | 03 | 0B |

Notes

1. Capture/reload occurs only on timer/counter overflow.
2. Capture/reload on timer/counter overflow and a HIGH to LOW transition on T2EX (P1.1) pin except when timer 2 is used in the baud rate generator mode.

8.3 Enhanced UART

The UART operates in all of the usual modes that are described in the first section of "*Data Handbook IC20, 80C51-based 8-bit microcontrollers*". In addition the UART can perform framing error detection by looking for missing stop bits and automatic address recognition. The UART also fully supports multiprocessor communication as does the standard 80C51 UART.

When used for framing error detection the UART looks for missing stop bits in the communication. A missing bit will set the bit FE or bit 7 in the SCON register. Bit FE is shared with bit SM0. The function of SCON bit 7 is determined by bit 6 in register PCON (bit SMOD0). If SMOD0 is set then bit 7 of register SCON functions as FE and as SM0 when SMOD0 is cleared. When used as FE this bit can only be cleared by software.

8.3.1 SERIAL PORT CONTROL REGISTER (SCON)

Table 12 Serial port control register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|--------|-----|-----|-----|-----|-----|----|----|
| Symbol | SM0/FE | SM1 | SM2 | REN | TB8 | RB8 | TI | RI |

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Table 13 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|--------|--|
| 7 | SM0/FE | The function of this bit is determined by SMOD0, bit 6 of register PCON. If SMOD0 is set then this bit functions as FE. This bit functions as SM0 when SMOD0 is reset. When used as FE, this bit can only be cleared by software. SM0: Serial port mode bit 0. See Table 14. FE: Framing Error bit. This bit is set by the receiver when an invalid stop bit is detected; see Fig.6. The FE bit is not cleared by valid frames but should be cleared by software. The SMOD0 bit in register PCON must be set to enable access to FE. |
| 6 | SM1 | Serial port mode bit 1. See Table 14. |
| 5 | SM2 | Serial port mode bit 2. Enables the automatic address recognition feature in modes 2 or 3. If SM2 = 1, bit RI will not be set unless the received 9th data bit (RB8) is logic 1; indicating an address and the received byte is a given or broadcast address. In mode 1, if SM2 = 1 then RI will not be activated unless a valid stop bit was received, and the received byte is a given or broadcast address. In mode 0, SM2 should be logic 0. |
| 4 | REN | Enables serial reception. Set by software to enable reception. Cleared by software to disable reception. |
| 3 | TB8 | The 9th data bit transmitted in modes 2 and 3. Set or cleared by software as desired. In mode 0, TB8 is not used. |
| 2 | RB8 | The 9th data bit received in modes 2 and 3. In mode 1, if SM2 = 0, RB8 is the stop bit that was received. In mode 0, RB8 is not used. |
| 1 | TI | Transmit interrupt flag. Set by hardware at the end of the 8th bit time in mode 0, or at the beginning of the stop bit in the other modes, in any serial transmission. Must be cleared by software. |
| 0 | RI | Receive interrupt flag. Set by hardware at the end of the 8th bit time in mode 0, or halfway through the stop bit time in the other modes, in any serial reception (except if SM2 = 1, as described for SM2). Must be cleared by software. |

Table 14 Enhanced UART modes

| SM0 | SM1 | MODE | DESCRIPTION | BAUD RATE |
|-----|-----|------|----------------|---------------------------|
| 0 | 0 | 0 | shift register | $1/12f_{XTAL1}$ |
| 0 | 1 | 1 | 8-bit UART | variable |
| 1 | 0 | 2 | 9-bit UART | $1/32$ or $1/64f_{XTAL1}$ |
| 1 | 1 | 3 | 9-bit UART | variable |

8.3.2 AUTOMATIC ADDRESS RECOGNITION

Automatic address recognition is a feature which allows the UART to recognize certain addresses in the serial bit stream by using hardware to make the comparisons. This feature saves a great deal of software overhead by eliminating the need for the software to examine every serial address which passes by the serial port. This feature is enabled by setting the SM2 bit in register SCON. In the 9-bit UART modes (modes 2 and 3), the Receive Interrupt flag (RI) will be automatically set when the received byte contains either the 'given' address or the 'broadcast' address. The 9-bit mode requires that the 9th information

bit is a logic 1 to indicate that the received information is an address and not data. Figure 7 gives a summary.

The 8-bit mode is called mode 1. In this mode the RI flag will be set if SM2 is enabled and the information received has a valid stop bit following the 8 address bits and the information is either a given or a broadcast address.

Mode 0 is the Shift Register mode and SM2 is ignored.

Using the automatic address recognition feature allows a master to selectively communicate with one or more slaves by invoking the given slave address or addresses. All of the slaves may be contacted by using the broadcast

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address. Two special function registers are used to define the slave addresses, SADDR, and the address mask, SADEN. SADEN is used to define which bits in the SADDR are to be used and which bits are 'don't cares'. The SADEN mask can be logically AND-ed with the SADDR to create the given address which the master will use for addressing each of the slaves. Use of the given address allows multiple slaves to be recognized while excluding others. The following examples will help to show the versatility of this scheme.

Table 15 Slave 0

| REGISTER | VALUE (BINARY) |
|----------|----------------|
| SADDR | 1100 0000 |
| SADEN | 1111 1101 |
| Given | 1100 00X0 |

Table 16 Slave 1

| REGISTER | VALUE (BINARY) |
|----------|----------------|
| SADDR | 1100 0000 |
| SADEN | 1111 1110 |
| Given | 1100 000X |

In the above example SADDR is the same and the SADEN data is used to differentiate between the two slaves. Slave 0 requires that bit 0 = 0 and ignores bit 1. Slave 1 requires that bit 1 = 0 and bit 0 is ignored. A unique address for slave 0 would be 1100 0010 since slave 1 requires bit 1 = 0. A unique address for slave 1 would be 1100 0001 since bit 0 = 1 will exclude slave 0. Both slaves can be selected at the same time by an address which has bit 0 = 0 (for slave 0) and bit 1 = 0 (for slave 1). Thus, both could be addressed with 1100 0000.

In a more complex system the following could be used to select slaves 1 and 2 while excluding slave 0.

Table 17 Slave 0

| REGISTER | VALUE (BINARY) |
|----------|----------------|
| SADDR | 1100 0000 |
| SADEN | 1111 1001 |
| Given | 1100 0XX0 |

Table 18 Slave 1

| REGISTER | VALUE (BINARY) |
|----------|----------------|
| SADDR | 1110 0000 |
| SADEN | 1111 1010 |
| Given | 1110 0X0X |

Table 19 Slave 2

| REGISTER | VALUE (BINARY) |
|----------|----------------|
| SADDR | 1110 0000 |
| SADEN | 1111 1100 |
| Given | 1110 00XX |

In the above example the differentiation among the 3 slaves is in the lower 3 address bits. Slave 0 requires that bit 0 = 0 and it can be uniquely addressed by 1110 0110. Slave 1 requires that bit 1 = 0 and it can be uniquely addressed by 1110 and 0101. Slave 2 requires that bit 2 = 0 and its unique address is 1110 0011. To select slaves 0 and 1 and exclude slave 2 use address 1110 0100, since it is necessary to make bit 2 = 1 to exclude slave 2.

The broadcast address for each slave is created by taking the logical OR of SADDR and SADEN. Zeros in this result are treated as don't cares. In most cases, interpreting the don't cares as ones, the broadcast address will be FFh.

Upon reset SADDR (SFR address 0A9h) and SADEN (SFR address 0B9h) are loaded with 0s. This produces a given address of all 'don't cares' as well as a broadcast address of all 'don't cares'. This effectively disables the automatic addressing mode and allows the microcontroller to use standard 80C51 type UART drivers which do not make use of this feature.

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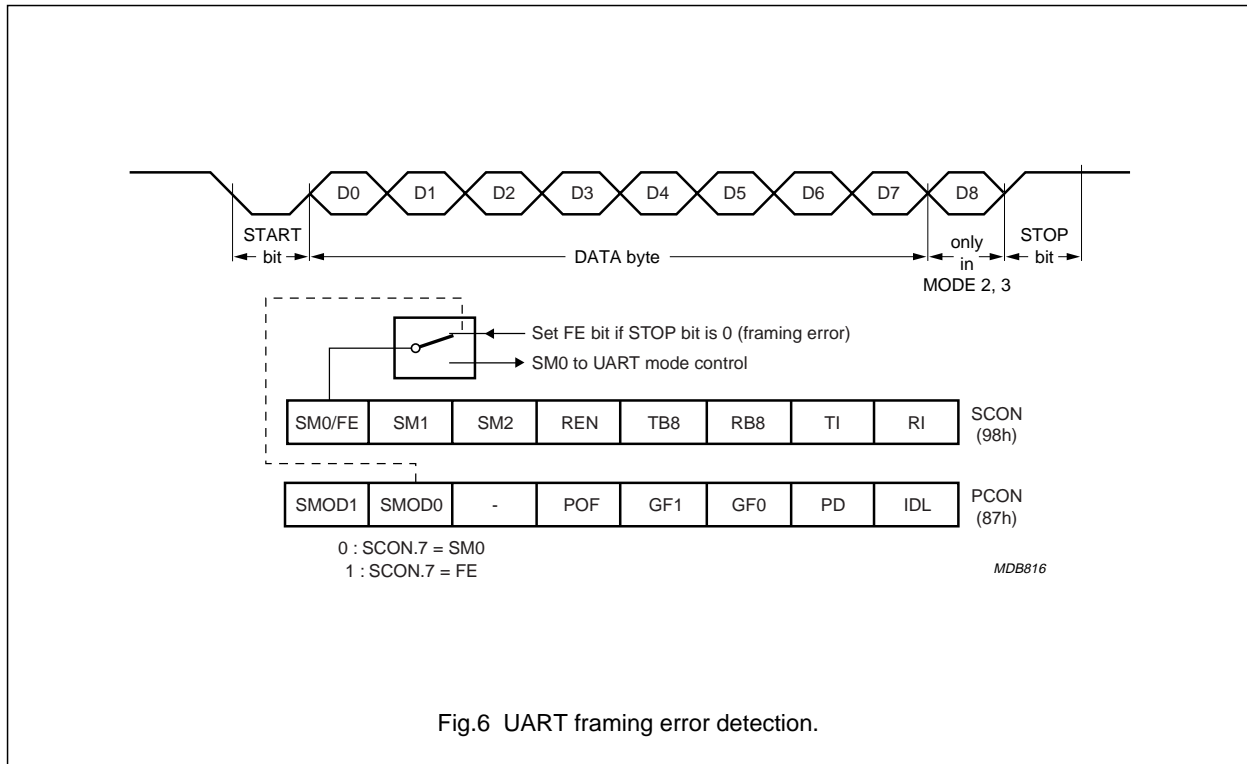
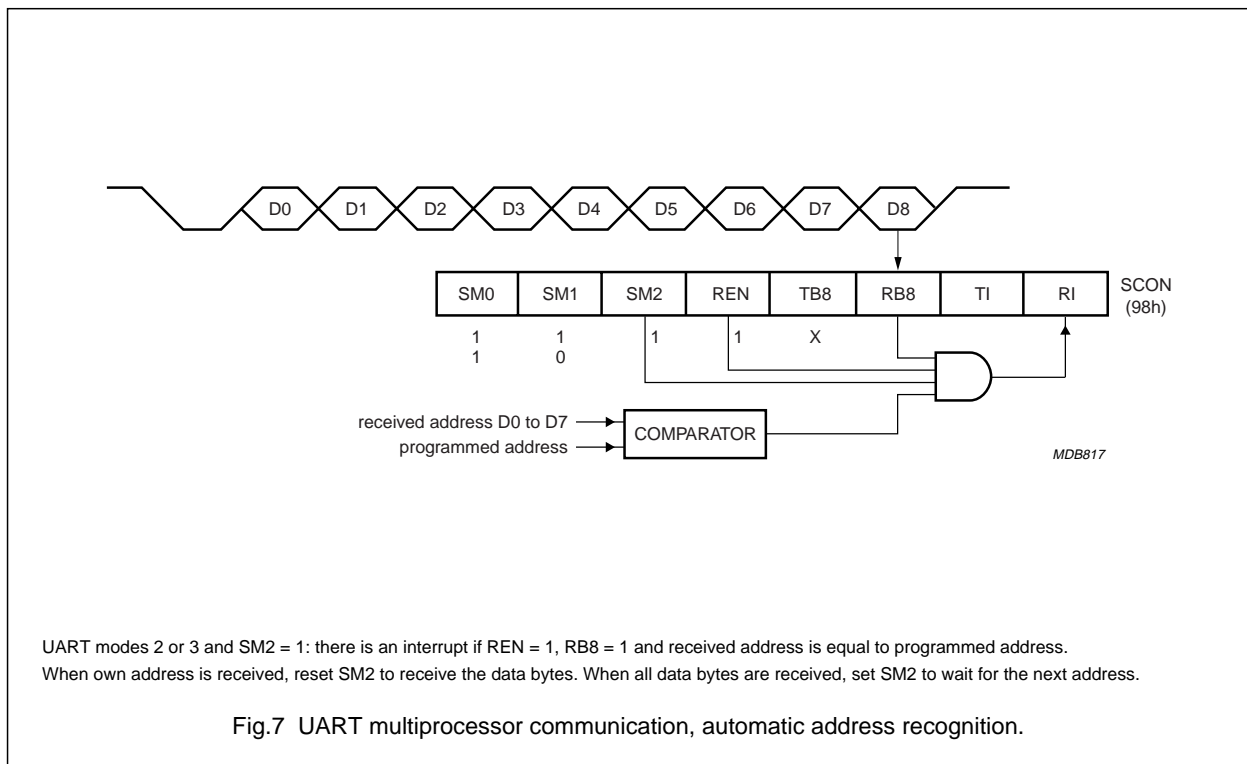


Fig.6 UART framing error detection.



UART modes 2 or 3 and SM2 = 1: there is an interrupt if REN = 1, RB8 = 1 and received address is equal to programmed address. When own address is received, reset SM2 to receive the data bytes. When all data bytes are received, set SM2 to wait for the next address.

Fig.7 UART multiprocessor communication, automatic address recognition.

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8.4 Interrupt priority structure

The TDA8029 has a 6-source 4-level interrupt structure.

There are three SFRs associated with the 4-level interrupt: IE, IP and IPH. The Interrupt Priority High (IPH) register implements the 4-level interrupt structure. The IPH is located at SFR address B7h.

The function of the IPH is simple and when combined with the IP determines the priority of each interrupt. The priority of each interrupt is determined as shown in Table 20.

Table 20 Priority bits

| IPH BIT n | IP BIT n | INTERRUPT PRIORITY LEVEL |
|-----------|----------|----------------------------|
| 0 | 0 | level 0 (lowest priority) |
| 0 | 1 | level 1 |
| 1 | 0 | level 2 |
| 1 | 1 | level 3 (highest priority) |

Table 21 Interrupt table

| SOURCE | POLLING PRIORITY | REQUEST BITS | HARDWARE CLEAR | VECTOR ADDRESS (HEX) |
|--------|------------------|--------------|-------------------------------------|----------------------|
| X0 | 1 | IE0 | N ⁽¹⁾ ; Y ⁽²⁾ | 03 |
| T0 | 2 | TF0 | Y | 0B |
| X1 | 3 | IE1 | N ⁽¹⁾ ; Y ⁽²⁾ | 13 |
| T1 | 4 | TF1 | Y | 1B |
| SP | 5 | RI, TI | N | 23 |
| T2 | 6 | TF2, EXF2 | N | 2B |

Notes

- Level activated.
- Transition activated.

8.4.1 INTERRUPT ENABLE (IE) REGISTER**Table 22** Interrupt enable register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|----|---|-----|----|-----|-----|-----|-----|
| Symbol | EA | – | ET2 | ES | ET1 | EX1 | ET0 | EX0 |

Table 23 Description of register bits

| BIT | SYMBOL | DESCRIPTION ⁽¹⁾ |
|-----|--------|---|
| 7 | EA | Global disable. If EA = 0, all interrupts are disabled; If EA = 1, each interrupt can be individually enabled or disabled by setting or clearing its enable bit. |
| 6 | – | Not implemented. Reserved for future use; note 2. |
| 5 | ET2 | Timer 2 interrupt enable. ET2 = 1 enables the interrupt; ET2 = 0 disables the interrupt. |
| 4 | ES | Serial port interrupt enable. ES = 1 enables the interrupt; ES = 0 disables the interrupt. |
| 3 | ET1 | Timer 1 interrupt enable. ET1 = 1 enables the interrupt; ET1 = 0 disables the interrupt. |

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| BIT | SYMBOL | DESCRIPTION ⁽¹⁾ |
|-----|--------|--|
| 2 | EX1 | External interrupt 1 enable. EX1 = 1 enables the interrupt; EX1 = 0 disables the interrupt. |
| 1 | ET0 | Timer 0 interrupt enable. ET0 = 1 enables the interrupt; ET0 = 0 disables the interrupt. |
| 0 | EX0 | External interrupt 0 enable. EX0 = 1 enables the interrupt; EX0 = 0 disables the interrupt. |

Notes

- Details on interaction with the UART behaviour in Power-down mode are described in Section 8.15.
- Do not write logic 1s to reserved bits. These bits may be used in future 80C51 family products to invoke new features. In that case, the reset or inactive value of the new bit will be logic 0, and its active value will be logic 1. The value read from a reserved bit is indeterminate.

8.4.2 INTERRUPT PRIORITY (IP) REGISTER

Table 24 Interrupt priority register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|---|---|-----|----|-----|-----|-----|-----|
| Symbol | – | – | PT2 | PS | PT1 | PX1 | PT0 | PX0 |

Table 25 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|---------|--------|--|
| 7 and 6 | – | Not implemented. Reserved for future use; note 1. |
| 5 | PT2 | Timer 2 interrupt priority. See Table 20. |
| 4 | PS | Serial port interrupt priority. See Table 20. |
| 3 | PT1 | Timer 1 interrupt priority. See Table 20. |
| 2 | PX1 | External interrupt 1 priority. See Table 20. |
| 1 | PT0 | Timer 0 interrupt priority. See Table 20. |
| 0 | PX0 | External interrupt 0 priority. See Table 20. |

Note

- Do not write logic 1s to reserved bits. These bits may be used in future 80C51 family products to invoke new features. In that case, the reset or inactive value of the new bit will be logic 0, and its active value will be logic 1. The value read from a reserved bit is indeterminate.

8.4.3 INTERRUPT PRIORITY HIGH (IPH) REGISTER

Table 26 Interrupt priority high register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|---|---|------|-----|------|------|------|------|
| Symbol | – | – | PT2H | PSH | PT1H | PX1H | PT0H | PX0H |

Table 27 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|---------|--------|--|
| 7 and 6 | – | Not implemented. Reserved for future use; note 1. |
| 5 | PT2H | Timer 2 interrupt priority. See Table 20. |
| 4 | PSH | Serial port interrupt priority. See Table 20. |
| 3 | PT1H | Timer 1 interrupt priority. See Table 20. |

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| BIT | SYMBOL | DESCRIPTION |
|-----|--------|---|
| 2 | PX1H | External interrupt 1 priority. See Table 20. |
| 1 | PT0H | Timer 0 interrupt priority. See Table 20. |
| 0 | PX0H | External interrupt 0 priority. See Table 20. |

Note

- Do not write logic 1s to reserved bits. These bits may be used in future 80C51 family products to invoke new features. In that case, the reset or inactive value of the new bit will be logic 0, and its active value will be logic 1. The value read from a reserved bit is indeterminate.

8.5 Dual Data Pointer (DPTR)

The dual DPTR structure is a way by which the TDA8029 will specify the address of an external data memory location. There are two 16-bit DPTR registers that address the external memory, and a single bit called DPS (bit 0 of the AUXR1 register) that allows the program code to switch between them.

The DPS bit should be saved by software when switching between DPTR0 and DPTR1.

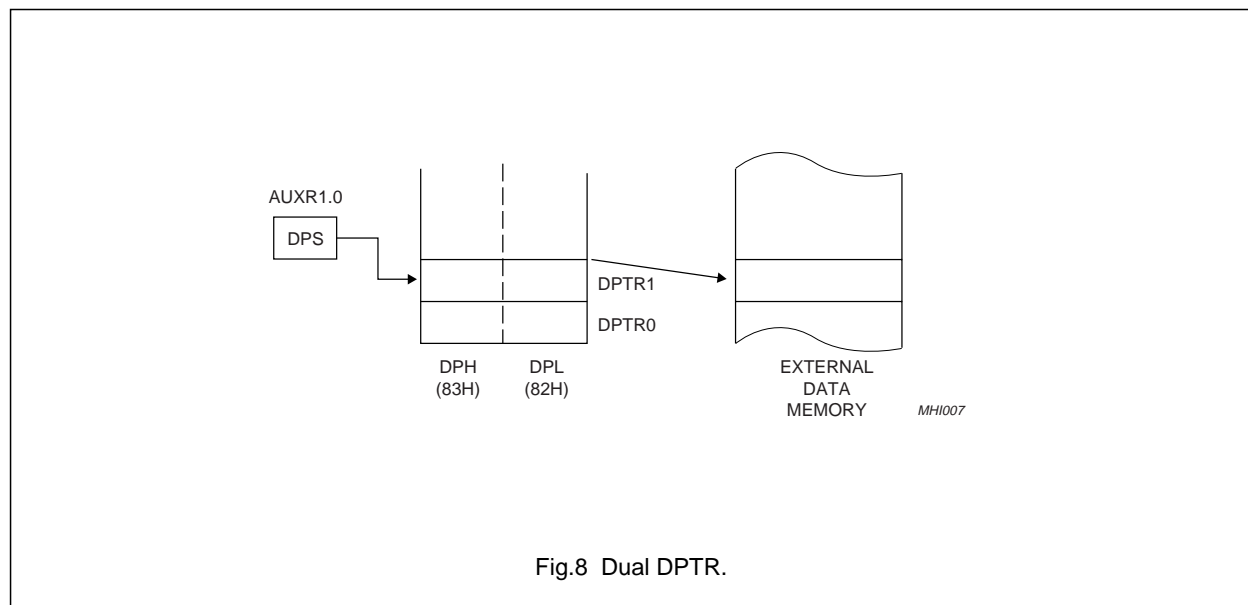
The GF bit (bit 2 in register AUXR1) is a general purpose user-defined flag. Note that bit 2 is not writable and is always read as a logic 0. This allows the DPS bit to be quickly toggled simply by executing an INC AUXR1 instruction without affecting the GF or LPEP bits.

The instructions that refer to DPTR refer to the data pointer that is currently selected using bit 0 of the AUXR1 register. The six instructions that use the DPTR are listed in Table 28 and an illustration is given in Fig.8.

Table 28 DPTR instructions

| INSTRUCTION | COMMENT |
|--------------------|---|
| INC DPTR | increments the data pointer by 1 |
| MOV DPTR, #data 16 | loads the DPTR with a 16-bit constant |
| MOV A, @A + DPTR | move code byte relative to DPTR to ACC |
| MOVX A, @DPTR | move external RAM (16-bit address) to ACC |
| MOVX @DPTR, A | move ACC to external RAM (16-bit address) |
| JMP @A + DPTR | jump indirect relative to DPTR |

The data pointer can be accessed on a byte-by-byte basis by specifying the low or high byte in an instruction which accesses the SFRs.

**Fig.8** Dual DPTR.

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8.6 Expanded data RAM addressing

The TDA8029 has internal data memory that is mapped into four separate segments.

The four segments, shown in Fig.9, are:

1. The lower 128 bytes of RAM (addresses 00h to 7Fh), which are directly and indirectly addressable.
2. The upper 128 bytes of RAM (addresses 80h to FFh), which are indirectly addressable only.
3. The Special Function Registers, SFRs, (addresses 80h to FFh), which are directly addressable only.
4. The 512 bytes expanded RAM (XRAM 00h to 1FFh) are indirectly accessed by move external instructions, MOVX, if the EXTRAM bit (bit 1 of register AUXR) is cleared.

The lower 128 bytes can be accessed by either direct or indirect addressing. The upper 128 bytes can be accessed by indirect addressing only. The upper 128 bytes occupy the same address space as the SFRs. That means they have the same address, but are physically separate from SFR space.

When an instruction accesses an internal location above address 7Fh, the CPU knows whether the access is to the upper 128 bytes of data RAM or to the SFR space by the addressing mode used in the instruction. Instructions that use direct addressing access SFR space. For example: MOV A0h, #data accesses the SFR at location 0A0h (which is register P2).

Instructions that use indirect addressing access the upper 128 bytes of data RAM. For example: MOV @R0, #data where R0 contains 0A0h, accesses the data byte at address 0A0h, rather than P2 (whose address is 0A0h).

The XRAM can be accessed by indirect addressing, with EXTRAM bit (register AUXR bit 1) cleared and MOVX instructions. This part of memory is physically located on-chip, logically occupies the first 512 bytes of external data memory.

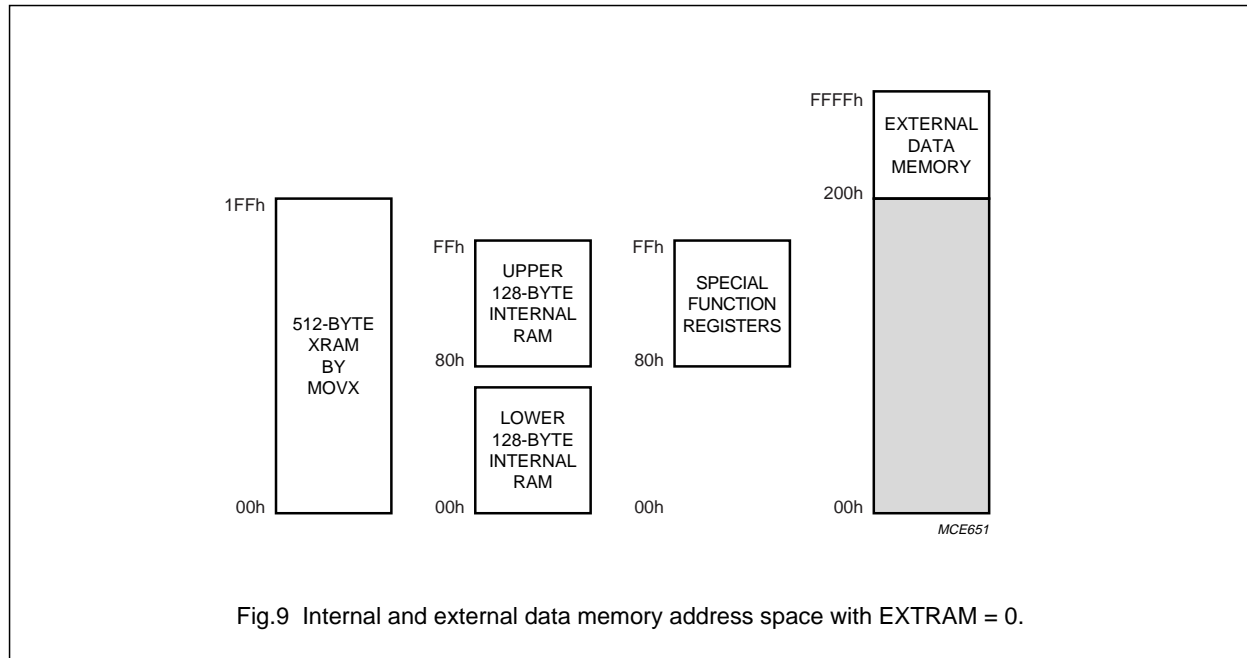
When EXTRAM = 0, the XRAM is indirectly addressed, using the MOVX instruction in combination with any of the registers R0, R1 of the selected bank or DPTR. An access to XRAM will not affect ports P0, P3.6 (WR) and P3.7 (RD). P2 is output during external addressing. For example: MOVX @R0, A where R0 contains 0A0h, access the EXTRAM at address 0A0h rather than external memory. An access to external data memory locations higher than 1FFh (i.e., 0200h to FFFFh) will be performed with the MOVX DPTR instructions in the same way as in the standard 80C51, so with P0 and P2 as data/address bus, and P3.6 and P3.7 as write and read timing signals.

When EXTRAM = 1, MOVX @Ri and MOVX @DPTR will be similar to the standard 80C51. MOVX @Ri will provide an 8-bit address multiplexed with data on port 0 and any output port pins can be used to output higher order address bits. This is to provide the external paging capability. MOVX @DPTR will generate a 16-bit address. Port 2 outputs the high order eight address bits (the contents of DPH) while port 0 multiplexes the low-order eight address bits (DPL) with data. MOVX @Ri and MOVX @DPTR will generate either read or write signals on P3.6 (WR) and P3.7 (RD).

The stack pointer (SP) may be located anywhere in the 256 bytes RAM (lower and upper RAM) internal data memory. The stack must not be located in the XRAM.

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8.6.1 AUXILIARY REGISTER (AUXR)

Table 29 Auxiliary register bits

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|---|---|---|---|---|---|--------|----|
| Symbol | – | – | – | – | – | – | EXTRAM | AO |

Table 30 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|--------|--|
| 7 to 2 | – | Not implemented. Reserved for future use; note 1. |
| 1 | EXTRAM | External RAM access. Internal or external RAM access using MOVX @Ri/@DPTR. If EXTRAM = 0, internal expanded RAM (0000h to 01FFh) access using MOVX @Ri/@DPTR; if EXTRAM = 1, external data memory access. |
| 0 | AO | ALE enable or disable. If AO = 0, ALE is emitted at a constant rate of $1/6f_{XTAL}$; if AO = 1, ALE is active only during a MOVX or MOVC instruction. |

Note

- Do not write logic 1s to reserved bits. These bits may be used in future 80C51 family products to invoke new features. In that case, the reset or inactive value of the new bit will be logic 0, and its active value will be logic 1. The value read from a reserved bit is indeterminate.

8.7 Reduced EMI mode

When bit AO = 1 (bit 0 in the AUXR register), the ALE output is disabled.

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8.8 Mask ROM devices

When none of the security bits SB1 and SB2 are programmed, the code in the program memory can be verified. If the encryption table is programmed, the code will be encrypted when verified. When only security bit 1 is programmed, MOVC instructions executed from external program memory are disabled from fetching code bytes from the internal memory. When security bits SB1 and SB2 are programmed, in addition to the above, verify mode is disabled.

The 64 bytes of the encryption array are initially not programmed (all logic 1s).

Table 31 Program security bits for TDA8029

| LOCK BIT PROGRAMMED ⁽¹⁾ | | PROTECTION DESCRIPTION |
|------------------------------------|-----|--|
| SB1 | SB2 | |
| no | no | no program security features enabled. If the encryption array is programmed, code verify will be encrypted. |
| yes | no | MOVC instructions executed from external program memory are disabled from fetching code bytes from internal memory |
| yes | yes | same as above, also verify is disabled |

Note

- Any other combination of the security bits is not defined.

8.9 ROM code submission for 16 kbytes ROM device TDA8029

When submitting ROM code for 16 kbytes ROM devices, the following must be specified:

- 16 kbyte user ROM data
- 64 byte ROM encryption key
- ROM security bits.

8.10 Smart card reader control registers

The TDA8029 has one analog interface for five contacts cards. The data to or from the card are fed into an ISO UART.

The Card Select Register (CSR) contains a bit for resetting the ISO UART (logic 0 = active). This bit is reset after

power-on, and must be set to logic 1 before starting any operation. It may be reset by software when necessary.

Dedicated registers allow to set the parameters of the ISO UART:

- Programmable Divider Register (PDR)
- Guard Time Register (GTR)
- UART Control Registers (UCR1 and UCR2)
- Clock Configuration Register (CCR).

The parameters of the ETU counters are set by:

- Time-Out Configuration register (TOC)
- Time-Out Registers (TOR1, TOR2 and TOR3).

The Power Control Register (PCR) is a dedicated register for controlling the power to the card.

When the specific parameters of the card have been programmed, the UART may be used with the following registers:

- UART Receive and Transmit Registers (URR and UTR)
- UART Status Register (USR)
- Mixed Status Register (MSR).

In reception mode, a FIFO of 1 to 8 characters may be used, and is configured with the FIFO Control Register (FCR). This register is also used for the automatic retransmission of NAKed characters in transmission mode.

The Hardware Status Register (HSR) gives the status of the supply voltage, the hardware protections, the SDWN request and the card movements.

USR and HSR give interrupts on INT0_N when some of their bits have been changed.

MSR does not give interrupts, and may be used in polling mode for some operations. For this use, the bit TBE/RBF within USR may be masked.

A 24-bit time-out counter may be started for giving an interrupt after a number of ETU programmed in registers TOR1, TOR2 and TOR3. It will help the controller for processing different real time tasks (ATR, WWT, BWT, etc.) mainly if controllers and card clock are asynchronous.

This counter is configured with register TOC, that may be used as a 24-bit or as a 16-bit + 8-bit counter. Each counter may be set for starting to count once data written, on detection of a start bit on I/O, or as auto-reload.

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8.10.1 GENERAL REGISTERS

8.10.1.1 Card Select Register (CSR)

This register is used for resetting the ISO UART.

Table 32 Card select register, address 0h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|---|-----|---|---|---|
| Symbol | – | – | – | – | RIU | – | – | – |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 33 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|--------|---|
| 7 to 4 | – | Not used. |
| 3 | RIU | Reset ISO UART. If $\overline{\text{RIU}} = 0$, this bit resets a large part of the UART registers to their initial value. Bit $\overline{\text{RIU}}$ must be reset to logic 0 for at least 10 ns duration before any activation. Bit $\overline{\text{RIU}}$ must be set to logic 1 by software before any action on the UART can take place. |
| 2 to 0 | – | Not used. |

8.10.1.2 Hardware Status Register (HSR)

This register gives the status of the chip after a hardware problem has been signalled or when pin SDWN_N has been activated.

When PRTL1, PRL1, PTL or SDWN is logic 1, then pin INT0_N is LOW. The bits having caused the interrupt are cleared when HSR is read (two f_{int} cycles after the rising edge of signal RD).

In case of emergency deactivation by PRTL1, SUPL, PRL1 and PTL, bit START in the power control register is automatically reset by hardware.

Table 34 Hardware Status Register, address Fh, read

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|---|-------|------|---|------|---|-----|
| Symbol | SDWN | – | PRTL1 | SUPL | – | PRL1 | – | PTL |
| Reset value | – | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 35 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|--------|---|
| 7 | SDWN | Enter shut-down mode. This bit is used for entering the shut-down mode. SDWN is set when the SDWN_N pin is active (LOW). When the software reads the status, it must: <ul style="list-style-type: none"> • Deactivate the card if active • Set all ports to logic 1 (for minimizing the current consumption) • Inhibit the interrupts • Go to Power-down mode. The same must be done when the chip is powered-on with SDWN_N pin active. The only way to leave shut-down mode is when pin SDWN_N is HIGH. |
| 6 | – | Not used. |

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| BIT | SYMBOL | DESCRIPTION |
|-----|--------|--|
| 5 | PRTL1 | Protection 1. PRTL1 = 1 when a fault has been detected on the card reader. PRTL1 is the OR of the protection on V _{CC} and on RST. |
| 4 | SUPL | Supervisor Latch. SUPL = 1 when the supervisor has been active. At power-on, or after a supply voltage dropout, then SUPL is set, and INTO_N is LOW. INTO_N will return to HIGH at the end of the internal Power-on reset pulse defined by CDEL, except if pin SDWN_N was active during power-on. SUPL will be reset only after a status register read-out outside the Power-on reset pulse (see Fig.11). When leaving shut-down mode, the same situation occurs. |
| 3 | – | Not used. |
| 2 | PRL1 | Presence Latch. PRL1 = 1 when bit PR1 in the mixed status register has changed state. |
| 1 | – | Not used. |
| 0 | PTL | Overheat. PTL = 1 if an overheating has occurred. |

8.10.1.3 Time-Out Registers (TOR1, TOR2 and TOR3)

Table 36 Time-out register 1, address 9h, write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|------|------|------|------|------|------|------|
| Symbol | TOL7 | TOL6 | TOL5 | TOL4 | TOL3 | TOL2 | TOL1 | TOL0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 37 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|----------|---|
| 7 to 0 | TOL[7:0] | The 8-bit value for the auto-reload counter or the lower 8-bits of the 24-bits counter. |

Table 38 Time-out register 2, address Ah, write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------|-------|-------|-------|-------|-------|------|------|
| Symbol | TOL15 | TOL14 | TOL13 | TOL12 | TOL11 | TOL10 | TOL9 | TOL8 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 39 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|-----------|--|
| 7 to 0 | TOL[15:8] | The lower 8-bits of the 16-bits counter or the middle 8-bits of the 24-bits counter. |

Table 40 Time-out register 3, address Bh, write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Symbol | TOL23 | TOL22 | TOL21 | TOL20 | TOL19 | TOL18 | TOL17 | TOL16 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 41 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|------------|---|
| 7 to 0 | TOL[23:16] | The upper 8-bits of the 16-bits counter or the upper 8-bits of the 24-bits counter. |

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8.10.1.4 Time-Out Configuration register (TOC)

The time-out counter is very useful for processing the clock counting during ATR, the Work Waiting Time (WWT) or the waiting times defined in protocol T = 1. It should be noted that the 200 and n_{max} clock counter ($n_{max} = 384$ for TDA8029HL/C1 and $n_{max} = 368$ for TDA8029HL/C2) used during ATR is done by hardware when the start session is set. Specific hardware controls the functionality of BGT in T = 1 and T = 0 protocols and a specific register is available for processing the extra guard time.

Writing to register TOC is not allowed as long as the card is not activated with a running clock.

Before restarting the 16-bit counter (counters 3 and 2) by writing 61h, 65h, 71h, 75h, F1h or F5h in the TOC register, or the 24-bit counter (counters 3, 2 and 1) by writing 68h or 7C in the TOC register, it is mandatory to stop them by writing 00h in the TOC register.

Detailed examples of how to use these specific timers can be found in application note "AN01010".

The time-out configuration register is used for setting different configurations of the time-out counter as given in Table 43, all other configurations are undefined.

Table 42 Time-out configuration register, address 8h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|------|------|------|------|------|------|------|------|
| Symbol | TOC7 | TOC6 | TOC5 | TOC4 | TOC3 | TOC2 | TOC1 | TOC0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 43 Time-out counter configurations

| TOC [7:0] (HEX) | OPERATING MODE |
|--------------------|---|
| 00 | All counters are stopped. |
| 05 | Counters 2 and 3 are stopped; counter 1 continues to operate in auto-reload mode. |
| 61 | Counter 1 is stopped, and counters 3 and 2 form a 16-bit counter. Counting the value stored in registers TOR3 and TOR2 is started after 61h is written in register TOC. When the terminal count is reached, an interrupt is given, and bit TO3 in register USR is set. The counter is stopped by writing 00h in register TOC, and should be stopped before reloading new values in registers TOR2 and TOR3. |
| 65 | Counter 1 is an 8-bit auto-reload counter, and counters 3 and 2 form a 16-bit counter. Counter 1 starts counting the content of register TOR1 on the first start-bit (reception or transmission) detected on pin I/O after 65h is written in register TOC. When counter 1 reaches its terminal count, an interrupt is given, bit TO1 in register USR is set and the counter automatically restarts the same count until it is stopped. It is not allowed to change the content of register TOR1 during a count. Counters 3 and 2 are wired as a single 16-bit counter and start counting the value in registers TOR3 and TOR2 when 65h is written in register TOC. When the counter reaches its terminal count, an interrupt is given and bit TO3 is set within register USR. Both counters are stopped when 00h is written in register TOC. Counters 3 and 2 shall be stopped by writing 05h in register TOC before reloading new values in registers TOR2 and TOR3. |
| 68 | Counters 3, 2 and 1 are wired as a single 24-bit counter. Counting the value stored in registers TOR3, TOR2 and TOR1 is started after 68h is written in register TOC. The counter is stopped by writing 00h in register TOC. It is not allowed to change the content of registers TOR3, TOR2 and TOR1 within a count. |
| 71 | Counter 1 is stopped, and counters 3 and 2 form a 16-bit counter. After writing this value, counting the value stored in registers TOR3 and TOR2 is started on the first start-bit detected on pin I/O (reception or transmission) and then on each subsequent start-bit. It is possible to change the content of registers TOR3 and TOR2 during a count, the current count will not be affected and the new count value will be taken into account at the next start-bit. The counter is stopped by writing 00h in register TOC. In this configuration, registers TOR3, TOR2 and TOR1 must not be all zero. |

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| TOC [7:0] (HEX) | OPERATING MODE |
|--------------------|---|
| 75 | Counter 1 is an 8-bit auto-reload counter, and counters 3 and 2 form a 16-bit counter. After 75h is written in register TOC, counter 1 starts counting the content of register TOR1 on the first start-bit (reception or transmission) detected on pin I/O. When counter 1 reaches its terminal count, an interrupt is given, bit TO1 in register USR is set and the counter automatically restarts the same count until it is stopped. Changing the content of register TOR1 during a count is not allowed. Counting the value stored in registers TOR3 and TOR2 is started on the first start-bit detected on pin I/O (reception or transmission) after 75h is written, and then on each subsequent start-bit. It is possible to change the content of registers TOR3 and TOR2 during a count, the current count will not be affected and the new count value will be taken into account at the next start-bit. The counter is stopped by writing 00h in register TOC. In this configuration, registers TOR3, TOR2 and TOR1 must not be all zero. |
| 7C | Counters 3, 2 and 1 are wired as a single 24-bit counter. Counting the value stored in registers TOR3, TOR2 and TOR1 is started on the first start-bit detected on pin I/O (reception or transmission) after the value has been written, and then on each subsequent start-bit. It is possible to change the content of registers TOR3, TOR2 and TOR1 during a count. The current count will not be affected and the new count value will be taken into account at the next start-bit. The counter is stopped by writing 00h in register TOC. In this configuration, registers TOR3, TOR2 and TOR1 must not be all zero. |
| 85 | Same as value 05h, except that all the counters will be stopped at the end of the 12th ETU following the first received start-bit detected after 85h has been written in register TOC. |
| E5 | Same configuration as value 65h, except that counter 1 will be stopped at the end of the 12th ETU following the first start-bit detected after E5h has been written in register TOC. |
| F1 | Same configuration as value 71h, except that the 16-bit counter will be stopped at the end of the 12th ETU following the first start-bit detected after F1h has been written in register TOC. |
| F5 | Same configuration as value 75h, except the two counters will be stopped at the end of the 12th ETU following the first start-bit detected after F5h has been written in register TOC. |

8.10.2 ISO UART REGISTERS

8.10.2.1 UART Transmit Register (UTR)

Table 44 UART transmit register, address Dh, write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Symbol | UT7 | UT6 | UT5 | UT4 | UT3 | UT2 | UT1 | UT0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 45 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|---------|--|
| 7 to 0 | UT[7:0] | <p>UART transmit bits. When the microcontroller wants to transmit a character to the card, it writes the data in direct convention in this register. The transmission:</p> <ul style="list-style-type: none"> • Starts at the end of writing (on the rising edge of signal WR) if the previous character has been transmitted and if the extra guard time has expired • Starts at the end of the extra guard time if this one has not expired • Does not start if the transmission of the previous character is not completed • With a synchronous card (bit SAN within register UCR2 is set), only UT0 is relevant and is copied on pin I/O of the card. |

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8.10.2.2 UART Receive Register (URR)

Table 46 UART receive register, address Dh, read

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Symbol | UR7 | UR6 | UR5 | UR4 | UR3 | UR2 | UR1 | UR0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 47 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|---------|---|
| 7 to 0 | UR[7:0] | <p>UART receive bits. When the microcontroller wants to read data from the card, it reads it from this register in direct convention:</p> <ul style="list-style-type: none"> • With a synchronous card, only UR0 is relevant and is a copy of the state of the selected card I/O • When needed, this register may be tied to a FIFO whose length 'n' is programmable between 1 and 8; if $n > 1$, then no interrupt is given until the FIFO is full and the controller may empty the FIFO when required • With a parity error: <ul style="list-style-type: none"> – In protocol $T = 0$, the received byte is not stored in the FIFO and the error counter is incremented. The error counter is programmable between 1 and 8. When the programmed number is reached, then bit PE is set in the status register USR and INT0_N falls LOW. The error counter must be reprogrammed to the desired value after its count has been reached – In protocol $T = 1$, the character is loaded in the FIFO and the bit PE is set to the programmed value in the parity error counter. • When the FIFO is full, then bit RBF in the status register USR is set. This bit is reset when at least one character has been read from URR • When the FIFO is empty, then bit FE is set in the status register USR as long as no character has been received. |

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8.10.2.3 Mixed Status Register (MSR)

This register relates the status of the card presence contact PR1, the BGT counter, the FIFO empty indication, the transmit/receive ready indicator TBE/RBF and the completion of clock switching to or from $1/2f_{int}$.

No bit within register MSR act upon INT0_N.

Table 48 Mixed status register, address Ch, read

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-------|----|-----|---|---|-----|---|---------|
| Symbol | CLKSW | FE | BGT | – | – | PR1 | – | TBE/RBF |
| Reset value | – | 1 | 0 | – | – | – | 0 | 0 |

Table 49 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|---------|--------|---|
| 7 | CLKSW | Clock Switch. CLKSW is set when the TDA8029 has performed a required clock switch from $1/nf_{XTAL}$ to $1/2f_{int}$ and is reset when the TDA8029 has performed a required clock switch from $1/2f_{int}$ to $1/nf_{XTAL}$. The application shall wait this bit before entering power-down mode or restarting sending commands after leaving power-down (only needed when the clock is not stopped during power-down). This bit is also reset by RIU and at power-on. When the microcontroller wants to transmit a character to the card, it writes the data in direct convention to this register. |
| 6 | FE | FIFO Empty. FE is set when the reception FIFO is empty. It is reset when at least one character has been loaded in the FIFO. |
| 5 | BGT | Block Guard Time. In T = 1 protocol, the bit BGT is linked with a 22 ETU counter, which is started at every start-bit on pin I/O. If the count is finished before the next start-bit, BGT is set. This helps checking that the card has not answered before 22 ETU after the last transmitted character, or that the reader is not transmitting a character before 22 ETU after the last received character. In T = 0 protocol, the bit BGT is linked to a 16 ETU counter, which is started at every start-bit on I/O. If the count is finished before the next start-bit, then the bit BGT is set. This helps checking that the reader is not transmitting too early after the last received character. |
| 4 and 3 | – | Not used. |
| 2 | PR1 | Presence 1. PR1 = 1 when the card is present. |
| 1 | – | Not used. |

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| BIT | SYMBOL | DESCRIPTION |
|-----|---------|--|
| 0 | TBE/RBF | <p>Transmit Buffer Empty/Receive Buffer Full. This bit is set when:</p> <ul style="list-style-type: none"> • Changing from reception mode to transmission mode • A character has been transmitted by the UART (except when a character has been parity error free transmitted whilst LCT = 1) • The reception buffer is full. <p>This bit is reset:</p> <ul style="list-style-type: none"> • After power-on • When bit $\overline{\text{RIU}}$ in register CSR is reset • When a character has been written in register UTR • When the character has been read from register URR • When changing from transmission mode to reception mode. |

8.10.2.4 FIFO Control Register (FCR)

Table 50 FIFO control register, address Ch, write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|------|------|------|---|-----|-----|-----|
| Symbol | – | PEC2 | PEC1 | PEC0 | – | FL2 | FL1 | FL0 |
| Reset value | – | 0 | 0 | 0 | – | 0 | 0 | 0 |

Table 51 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|----------|--|
| 7 | – | Not used. |
| 6 to 4 | PEC[2:0] | <p>Parity Error Counter. These bits determine the number of parity errors before setting bit PE in register USR and pulling INT0_N LOW. PEC[2:0] = 000 means that if only one parity error has occurred, bit PE is set; PEC[2:0] = 111 means that bit PE will be set after 8 parity errors.</p> <p>In protocol T = 0:</p> <ul style="list-style-type: none"> • If a correct character is received before the programmed error number is reached, the error counter will be reset • If the programmed number of allowed parity errors is reached, bit PE in register USR will be set as long as the USR has not been read • If a transmitted character is NAKed by the card, then the TDA8029 will automatically retransmit it a number of times equal to the value programmed in PEC[2:0]. The character will be resent at 15 ETU. • In transmission mode, if PEC[2:0] = 000, then the automatic retransmission is invalidated. The character manually rewritten in register UTR will start at 13.5 ETU. <p>In protocol T = 1:</p> <ul style="list-style-type: none"> • The error counter has no action (bit PE is set at the first wrong received character). |
| 3 | – | Not used. |
| 2 to 0 | FL[2:0] | <p>FIFO Length. These bits determine the depth of the FIFO: FL[2:0] = 000 means length 1, FL[2:0] = 111 means length 8.</p> |

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8.10.2.5 UART Status Register (USR)

The UART Status Register (USR) is used by the microcontroller to monitor the activity of the ISO UART and that of the time-out counter. If any of the status bits FER, OVR, PE, EA, TO1, TO2 or TO3 are set, then signal INT0_N = LOW. The bit having caused the interrupt is reset 2 μ s after the rising edge of signal \overline{RD} during a read operation of register USR.

If bit TBE/RBF is set and if the mask bit DISTBE/RBF within register UCR2 is not set, then also signal INT0_N = LOW. Bit TBE/RBF is reset three clock cycles after data has been written in register UTR, or three clock cycles after data has been read from register URR, or when changing from transmission mode to reception mode.

If LCT mode is used for transmitting the last character, then bit TBE is not set at the end of the transmission.

Table 52 UART status register, address Eh, read

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-----|-----|----|----|-----|-----|---------|
| Symbol | TO3 | TO2 | TO1 | EA | PE | OVR | FER | TBE/RBF |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 53 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|--------|---|
| 7 | TO3 | Time-out counter 3. TO3 = 1 when counter 3 has reached its terminal count. |
| 6 | TO2 | Time-out counter 2. TO2 = 1 when counter 2 has reached its terminal count. |
| 5 | TO1 | Time-out counter 1. TO1 = 1 when counter 1 has reached its terminal count. |
| 4 | EA | Early Answer. EA = 1 if the first start-bit on the I/O pin during ATR has been detected between the first 200 and n_{max} clock pulses with pin RST in LOW state (all activities on the I/O during the first 200 clock pulses with pin RST LOW are not taken into account) and before the first n_{max} clock pulses with pin RST in HIGH state. These two features are re-initialized at each toggling of pin RST. n_{max} = 384 for TDA8029HL/C1; n_{max} = 368 for TDA8029HL/C2. |
| 3 | PE | Parity Error. In protocol T = 0, bit PE = 1 if the UART has detected a number of received characters with parity errors equal to the number written in bits PEC[2:0] or if a transmitted character has been NAKed by the card a number of times equal to the value programmed in bits PEC[2:0]. It is set at 10.5 ETU in the reception mode and at 11.5 ETU in the transmission mode. A character received with a parity error is not stored in register FIFO in protocol T = 0; the card should repeat this character. In protocol T = 1, a character with a parity error is stored in the FIFO and the parity error counter is not active. |

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| BIT | SYMBOL | DESCRIPTION |
|-----|---------|--|
| 2 | OVR | Overrun. OVR = 1 if the UART has received a new character whilst URR was full. In this case, at least one character has been lost. |
| 1 | FER | Framing Error. FER = 1 when I/O was not in high-impedance state at 10.25 ETU after a start-bit. It is reset when USR has been read. |
| 0 | TBE/RBF | <p>Transmit Buffer Empty/Receive Buffer Full. TBE and RBF share the same bit within register USR: when in transmission mode the relevant bit is TBE; when in reception mode it is RBF.</p> <p>TBE = 1 when the UART is in transmission mode and when the microcontroller may write the next character to transmit in register UTR. It is reset when the microcontroller has written data in the transmit register or when bit T/R in register UCR1 has been reset either automatically or by software. After detection of a parity error in transmission, it is necessary to wait 13.5 ETU before rewriting the character which has been NAKed by the card (manual mode, see Table 51).</p> <p>RBF = 1 when register FIFO is full. The microcontroller may read some of the characters in register URR, which clears bit RBF.</p> |

8.10.3 CARD REGISTERS

When working with a card, the following registers are used for programming some specific parameters.

8.10.3.1 Programmable Divider Register (PDR)

This register is used for counting the card clock cycles forming the ETU. It is an auto-reload 8 bits counter counting from the programmed value down to 0.

Table 54 Programmable divider register, address 2h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Symbol | PD7 | PD6 | PD5 | PD4 | PD3 | PD2 | PD1 | PD0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 55 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|---------|------------------------------------|
| 7 to 0 | PD[7:0] | Programmable divider value. |

8.10.3.2 UART Configuration Register 2 (UCR2)

Table 56 UART configuration register 2, address 3h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|--------|----------------|---|------|-----|----------|-----|-----|
| Symbol | ENINT1 | DISTBE/ RBF | – | ENRX | SAN | AUTOCONV | CKU | PSC |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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Table 57 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|------------|--|
| 7 | ENINT1 | Enable INT1. If ENINT1 = 1, a HIGH to LOW transition on pin INT1_N will wake-up the TDA8029 from the Power-down mode. Note that in case of reception of a character when in Power-down mode, the start of the frame will be lost. When not in Power-down mode ENINT1 has no effect. For details on Power-down mode see Section 8.15. |
| 6 | DISTBE/RBF | Disable TBE/RBF interrupts. If DISTBE/RBF is set, then reception or transmission of a character will not generate an interrupt. This feature is useful for increasing communication speed with the card; in this case, the copy of TBE/RBF bit within MSR must be polled, and not the original, in order not to loose priority interrupts which can occur in USR. |
| 5 | – | Not used. |
| 4 | ENRX | Enable RX. If ENRX = 1, a HIGH to LOW transition on pin RX will wake-up the TDA8029 from the Power-down mode. Note that in case of reception of a character when in Power-down mode, the start of the frame will be lost. When not in Power-down mode ENRX has no effect. For details on Power-down mode see Section 8.15. |
| 3 | SAN | Synchronous/Asynchronous. SAN is set by software if a synchronous card is expected. The UART is then bypassed and only bit 0 in registers URR and UTR is connected to pin I/O. In this case the clock is controlled by bit SC in register CCR. |
| 2 | AUTOCONV | Automatic set convention. If AUTOCONV = 1, then the convention is set by software using bit CONV in register UCR1. If AUTOCONV = 0, then the configuration is automatically detected on the first received character whilst the start session (bit SS) is set. $\overline{\text{AUTOCONV}}$ must not be changed during a card session. |
| 1 | CKU | Clock Unit. For baud rates other than those given in Table 58, there is the possibility to set bit CKU = 1. In this case, the ETU will last half the number of card clock cycles equal to prescaler PDR. Note that bit CKU = 1 has no effect if $f_{\text{CLK}} = f_{\text{XTAL}}$. This means, for example, that 76800 baud is not possible when the card is clocked with the frequency on pin XTAL1. |
| 0 | PSC | Prescaler value. If PSC = 1, then the prescaler value is 32; if PSC = 0, then the prescaler value is 31. One ETU will last a number of card clock cycles equal to prescaler \times PDR. All baud rates specified in ISO 7816 norm are achievable with this configuration. See Fig.10 and Table 58. |

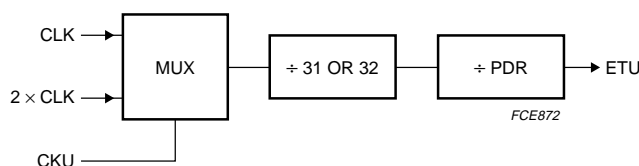


Fig.10 ETU generation.

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Table 58 Baud rate selection using values F and D; card clock frequency $f_{CLK} = 3.58$ MHz for PSC = 31 and $f_{CLK} = 4.92$ MHz for PSC = 32 (example: in this table 31;12 means prescaler set to 31 and PDR set to 12)

| D | F | | | | | | | | | | | |
|---|----------------|----------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|----------------|----------------|---------------|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 10 | 11 | 12 | 13 |
| 1 | 31;12 9600 | 31;12 9600 | 31;18 6400 | 31;24 4800 | 31;36 3200 | 31;48 2400 | 31;60 1920 | 32;16 9600 | 32;24 6400 | 32;32 4800 | 32;48 3200 | 32;64 2400 |
| 2 | 31;6 19200 | 31;6 19200 | 31;9 12800 | 31;12 9600 | 31;18 6400 | 31;24 4800 | 31;30 3840 | 32;8 19200 | 32;12 12800 | 32;16 9600 | 32;24 6400 | 32;32 4800 |
| 3 | 31;3 38400 | 31;3 38400 | – | 31;6 19200 | 31;9 12800 | 31;12 9600 | 31;15 7680 | 32;4 38400 | 32;6 25600 | 32;8 19200 | 32;12 12800 | 32;16 9600 |
| 4 | – | – | – | 31;3 38400 | – | 31;6 19200 | – | 32;2 76800 | 32;3 51300 | 32;4 38400 | 32;6 25600 | 32;8 19200 |
| 5 | – | – | – | – | – | 31;3 38400 | – | 32;1 153600 | – | 32;2 76800 | 32;3 51300 | 32;4 38400 |
| 6 | – | – | – | – | – | – | – | – | – | 32;1 153600 | – | 32;2 76800 |
| 8 | 31;1 115200 | 31;1 115200 | – | 31;2 57600 | 31;3 38400 | 31;4 28800 | 31;5 23040 | – | 32;2 76800 | – | 32;4 38400 | – |
| 9 | – | – | – | – | – | – | 31;3 38400 | – | – | – | – | – |

8.10.3.3 Guard Time Register (GTR)

The guard time register is used for storing the number of guard ETUs given by the card during ATR. In transmission mode, the UART will wait this number of ETUs before transmitting the character stored in register UTR.

Table 59 Guard time register, address 5h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Symbol | GT7 | GT6 | GT5 | GT4 | GT3 | GT2 | GT1 | GT0 |
| Reset value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 60 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|---------|---|
| 7 to 0 | GT[7:0] | <p>Guard time value. When GT[7:0] = FFh:</p> <ul style="list-style-type: none"> • In protocol T = 1 <ul style="list-style-type: none"> – TDA8029HL/C1 operates at 11 ETU – TDA8029HL/C2 operates at 10.8 ETU. • In protocol T = 0. <ul style="list-style-type: none"> – TDA8029HL/C1 operates at 12 ETU – TDA8029HL/C2 operates at 11.8 ETU. |

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8.10.3.4 UART Configuration Register 1 (UCR1)

This register is used for setting the parameters of the ISO UART.

Table 61 UART configuration register 1, address 6h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|-----|----|------|-----|-----|----|------|
| Symbol | – | FIP | FC | PROT | T/R | LCT | SS | CONV |
| Reset value | – | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 62 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|-----|--------|---|
| 7 | – | Not used. |
| 6 | FIP | Force Inverse Parity. If FIP = 1, then the UART will NAK a correct received character, and will transmit characters with wrong parity bit. |
| 5 | FC | Test bit. FC must be left to logic 0. |
| 4 | PROT | Protocol. If PROT = 1, then protocol type is asynchronous T = 1; if PROT = 0, the protocol is T = 0. |
| 3 | T/R | Transmit/Receive. This bit is set by software for transmission mode. A change from logic 0 to logic 1 will set bit TBE in register USR. T/R is automatically reset by hardware if LCT has been used before transmitting the last character. |
| 2 | LCT | Last Character to Transmit. This bit is set by software before writing the last character to be transmitted in register UTR. It allows automatic change to reception mode. It is reset by hardware at the end of a successful transmission. When LCT is being reset, the bit T/R is also reset and the ISO 7816 UART is ready for receiving a character. |
| 1 | SS | Start Session. This bit is set by software before ATR for automatic convention detection and early answer detection. It is automatically reset by hardware at 10.5 ETU after reception of the initial character. |
| 0 | CONV | Convention. This bit is set if the convention is direct. Bit CONV is either automatically written by hardware according to the convention detected during ATR, or by software if bit $\overline{\text{AUTOCONV}}$ in register UCR2 is set. |

8.10.3.5 Clock Configuration Register (CCR)

This register defines the clock to the card and the clock to the ISO UART. Note that if bit CKU in the prescaler register of the selected card (register UCR2) is set, then the ISO UART is clocked at twice the frequency to the card, which allows to reach baud rates not foreseen in ISO 7816 norm.

Table 63 Clock configuration register, address 1h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|-----|-----|----|-----|-----|-----|
| Symbol | – | – | SHL | CST | SC | AC2 | AC1 | AC0 |
| Reset value | – | – | 0 | 0 | 0 | 0 | 0 | 0 |

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Table 64 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|---------|---------|---|
| 7 and 6 | – | Not used. |
| 5 | SHL | Select HIGH Level. This bit determines how the clock is stopped when bit CST = 1. If SHL = 0, then the clock is stopped at LOW level, if SHL = 1 at HIGH level. |
| 4 | CST | Clock Stop. In case of an asynchronous card, bit CST defines whether the clock to the card is stopped or not. If CST = 1, then the clock is stopped. If CST = 0, then the clock is determined by bits AC[2:0] according to Table 65. All frequency changes are synchronous, ensuring that no spike or unwanted pulse width occurs during changes |
| 3 | SC | Synchronous Clock. In the event of a synchronous card, then pin CLK is the copy of the value of bit SC. In reception mode, the data from the card is available to bit UR0 after a read operation of register URR. In transmission mode, the data is written on the I/O line of the card when register UTR has been written to. |
| 2 to 0 | AC[2:0] | <p>Asynchronous card clock. When CST = 0, the clock is determined by the state of these bits according to Table 65.</p> <p>f_{int} is the frequency delivered by the internal oscillator clock circuitry.</p> <p>For switching from $1/nf_{XTAL}$ to $1/2f_{int}$ and reverse, only the bit AC2 must be changed (AC1 and AC0 must remain the same). For switching from $1/nf_{XTAL}$ or $1/2f_{int}$ to stopped clock and reverse, only bits CST and SHL must be changed.</p> <p>When switching from $1/nf_{XTAL}$ to $1/2f_{int}$ and reverse, a delay can occur between the command and the effective frequency change on pin CLK. The fastest switch is from $1/2f_{XTAL}$ to $1/2f_{int}$ and reverse, the best regarding duty cycle is from $1/8f_{XTAL}$ to $1/2f_{int}$ and reverse. The bit CLKSW in register MSR tells the effective switch moment.</p> <p>In case of $f_{CLK} = f_{XTAL}$, the duty cycle must be ensured by the incoming clock signal on pin XTAL1.</p> |

Table 65 Clock value for an asynchronous card

| AC2 | AC1 | AC0 | CLOCK |
|-----|-----|-----|---------------|
| 0 | 0 | 0 | f_{XTAL} |
| 0 | 0 | 1 | $1/2f_{XTAL}$ |
| 0 | 1 | 0 | $1/4f_{XTAL}$ |
| 0 | 1 | 1 | $1/8f_{XTAL}$ |
| 1 | 0 | 0 | $1/2f_{int}$ |
| 1 | 0 | 1 | $1/2f_{int}$ |
| 1 | 1 | 0 | $1/2f_{int}$ |
| 1 | 1 | 1 | $1/2f_{int}$ |

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8.10.3.6 Power Control Register (PCR)

This register is used for starting or stopping card sessions.

Table 66 Power control register, address 7h, read and write

| BIT | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------|---|---|---|---|-----|-------|-------|-------|
| Symbol | – | – | – | – | 1V8 | RSTIN | 3V/5V | START |
| Reset value | – | – | 0 | 0 | 0 | 0 | 0 | 0 |

Table 67 Description of register bits

| BIT | SYMBOL | DESCRIPTION |
|--------|--------|---|
| 7 to 4 | – | Not used. |
| 3 | 1V8 | Select 1.8 V. If 1V8 = 1, then $V_{CC} = 1.8$ V. It should be noted that specifications are not guaranteed at this voltage when the supply voltage V_{DD} is less than 3 V. |
| 2 | RSTIN | Card reset. When the card is activated, pin RST is the copy of the value written in RSTIN. |
| 1 | 3V/5V | Select 3 V or 5 V. If 3V/5V = 1, then $V_{CC} = 3$ V. If 3V/5V = 0, then $V_{CC} = 5$ V. |
| 0 | START | Activate and deactivate card. If START = 1 is written by the controller, then the card is activated (see description of activation sequence in Section 8.16). If the controller writes START = 0, then the card is deactivated (see description of deactivation sequence in Section 8.17). START is automatically reset in case of emergency deactivation. For deactivating the card, only bit START should be reset. |

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8.10.4 REGISTER SUMMARY

Table 68 Register summary

| NAME | ADDR (HEX) | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | VALUE AT RESET ⁽¹⁾ | VALUE WHEN RIU = 0 ⁽¹⁾ |
|------|------------|-----|--------|------------|-------|-------|-------|-------|-------|---------|-------------------------------|-----------------------------------|
| CSR | 00 | R/W | – | – | – | – | RIU | – | – | – | XXXX 0XXX | XXXX 0XXX |
| CCR | 01 | R/W | – | – | SHL | CST | SC | AC2 | AC1 | AC0 | XX00 0000 | XXuu uuuu |
| PDR | 02 | R/W | PD7 | PD6 | PD5 | PD4 | PD3 | PD2 | PD1 | PD0 | 0000 0000 | uuuu uuuu |
| UCR2 | 03 | R/W | ENINT1 | DISTBE/RBF | – | ENRX | SAN | AUTO | CKU | PSC | 00X0 0000 | uuuu uuuu |
| GTR | 05 | R/W | GT7 | GT6 | GT5 | GT4 | GT3 | GT2 | GT1 | GT0 | 0000 0000 | uuuu uuuu |
| UCR1 | 06 | R/W | – | FIP | FC | PROT | T/R | LCT | SS | CONV | X000 0000 | Xuuu 00uu |
| PCR | 07 | R/W | – | – | – | – | 1V8 | RSTIN | 3V/5V | START | XXXX 0000 | XXXX uuuu |
| TOC | 08 | R/W | TOC7 | TOC6 | TOC5 | TOC4 | TOC3 | TOC2 | TOC1 | TOC0 | 0000 0000 | 0000 0000 |
| TOR1 | 09 | W | TOL7 | TOL6 | TOL5 | TOL4 | TOL3 | TOL2 | TOL1 | TOL0 | 0000 0000 | uuuu uuuu |
| TOR2 | 0A | W | TOL15 | TOL14 | TOL13 | TOL12 | TOL11 | TOL10 | TOL9 | TOL8 | 0000 0000 | uuuu uuuu |
| TOR3 | 0B | W | TOL23 | TOL22 | TOL21 | TOL20 | TOL19 | TOL18 | TOL17 | TOL16 | 0000 0000 | uuuu uuuu |
| FCR | 0C | W | – | PEC2 | PEC1 | PEC0 | – | FL2 | FL1 | FL0 | X000 X000 | Xuuu Xuuu |
| MSR | 0C | R | CLKSW | FE | BGT | – | – | PR1 | – | TBE/RBF | 010X XXX0 | u10X XuX0 |
| URR | 0D | R | UR7 | UR6 | UR5 | UR4 | UR3 | UR2 | UR1 | UR0 | 0000 0000 | 0000 0000 |
| UTR | 0D | W | UT7 | UT6 | UT5 | UT4 | UT3 | UT2 | UT1 | UT0 | 0000 0000 | 0000 0000 |
| USR | 0E | R | TO3 | TO2 | TO1 | EA | PE | OVR | FER | TBE/RBF | 0X00 0000 | 0000 0000 |
| HSR | 0F | R | SDWN | – | PRTL1 | SUPL | – | PRL1 | – | PTL | XX01 X0X0 | uXuX XuXu |

Note

1. X = undefined, u = no change.

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8.11 Supply

The circuit operates within a supply voltage range of 2.7 to 6 V. The supply pins are V_{DD} , DCIN, GND and PGND. Pins DCIN and PGND supply the analog drivers to the cards and have to be externally decoupled because of the large current spikes the card and the step-up converter can create. V_{DD} and GND supply the rest of the chip. An integrated spike killer ensures the contacts to the card to remain inactive during power-up or -down. An internal voltage reference is generated which is used within the step-up converter, the voltage supervisor, and the V_{CC} generators.

V_{DCIN} may be higher than V_{DD} .

The voltage supervisor generates an alarm pulse, whose length is defined by an external capacitor connected to the CDEL pin, when V_{DD} is too low to ensure proper operation (1 ms per 2 nF typical). This pulse is used as a Power-on reset pulse, and also to block either any spurious signals on card contacts during controllers reset or to force an automatic deactivation of the contacts in the event of supply drop-out (see Sections 8.16 and 8.17).

After power-on or after a voltage drop, the bit SUPL is set within the Hardware Status Register (HSR) and remains set until HSR is read when the alarm pulse is inactive. As long as the Power-on reset is active, INT0_N is LOW.

The same occurs when leaving shut-down mode or when the RESET pin has been set active.

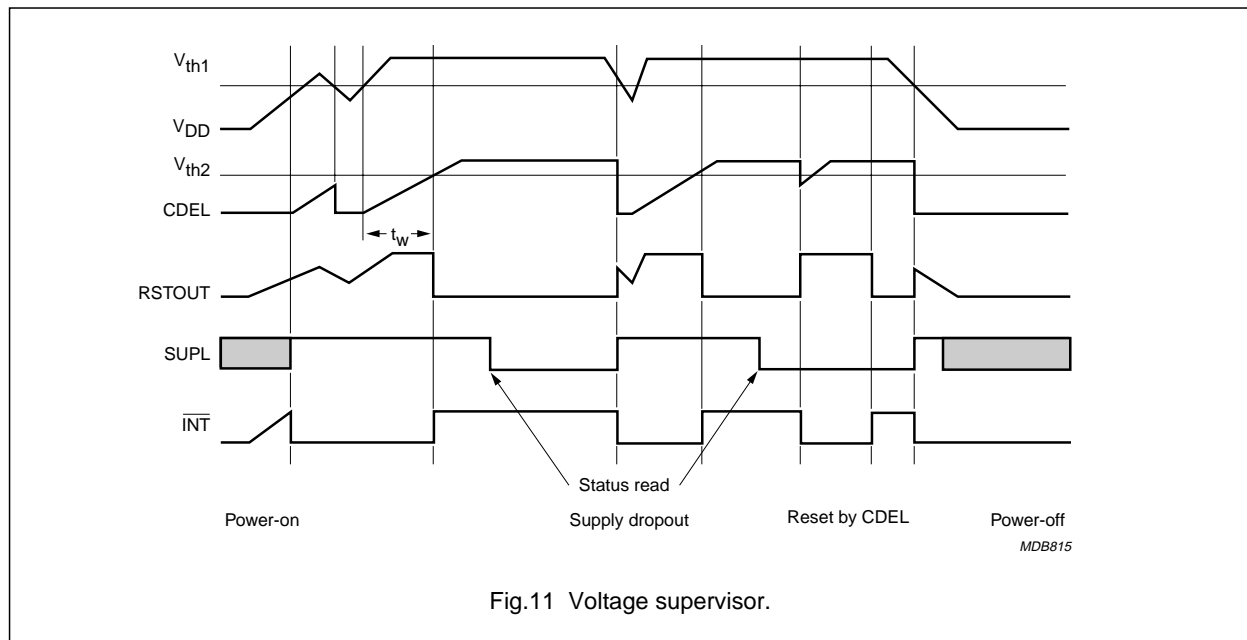


Fig.11 Voltage supervisor.

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8.12 DC/DC converter

Except for V_{CC} generator, and the other card contacts buffers, the whole circuit is powered by V_{DD} and DCIN. If the supply voltage is 2.7 V, then a higher voltage is needed for the ISO contacts supply. When a card session is requested by the controller, the sequencer first starts the DC/DC converter, which is a switched capacitors type, clocked by an internal oscillator at a frequency of approximately 2.5 MHz.

There are several possible situations:

- $V_{DCIN} = 3\text{ V}$ and $V_{CC} = 3\text{ V}$: In this case the DC/DC converter is acting as a doubler with a regulation of about 4.0 V
- $V_{DCIN} = 3\text{ V}$ and $V_{CC} = 5\text{ V}$: In this case the DC/DC converter is acting as a tripler with a regulation of about 5.5 V
- $V_{DCIN} = 5\text{ V}$ and $V_{CC} = 3\text{ V}$: In this case, the DC/DC converter is acting as a follower, V_{DD} is applied on VUP
- $V_{DCIN} = 5\text{ V}$ and $V_{CC} = 5\text{ V}$. In this case, the DC/DC converter is acting as a doubler with a regulation of about 5.5 V
- $V_{CC} = 1.8\text{ V}$. In this case, whatever value of V_{DCIN} , the DC/DC converter is acting as a follower, V_{DD} is applied on VUP.

The switch between different modes of the DC/DC converter is done by the TDA8029 at about $V_{DCIN} = 3.5\text{ V}$.

The output voltage is fed to the V_{CC} generator. V_{CC} and GND are used as a reference for all other card contacts.

8.13 ISO 7816 security

The correct sequence during activation and deactivation of the card is ensured through a specific sequencer, clocked by a division ratio of the internal oscillator.

Activation (bit START = 1 in register PCR) is only possible if the card is present (pin PRES is HIGH) and if the supply voltage is correct (supervisor not active).

The presence of the card is signalled to the controller by the HSR.

Bit PR1 in register MSR is set if the card is present. Bit PRL1 in register HSR is set if PR1 has toggled.

During a session, the sequencer performs an automatic emergency deactivation on the card in the event of card take-off, short-circuit, supply dropout or overheating. The card is also automatically deactivated in case of supply voltage drop or overheating. The HSR register is updated and the INTO_N line falls down, so the system controller is aware of what happened.

8.14 Protections and limitations

The TDA8029 features the following protections and limitations:

- I_{CC} limited to 100 mA, and deactivation when this limit is reached
- Current to or from pin RST limited to 20 mA, and deactivation when this limit is reached
- Deactivation when the temperature of the die exceeds 150 °C
- Current to or from pin I/O limited to 10 mA
- Current to or from pin CLK limited to 70 mA
- ESD protection on all cards contacts and pin PRES at minimum 6 kV, thus no need of extra components for protecting against ESD flash caused by a charged card being introduced in the slot
- Short circuit between any card contacts can have any duration without any damage.

8.15 Power reduction modes

On top of the standard controller power reduction features described in the microcontroller section, the TDA8029 has several power reduction modes that allow its use in portable equipment, and help protecting the environment:

- Shut-down mode: when SDWN_N pin is LOW, then the bit SDWN within HSR will be set, causing an interrupt on INTO_N. The TDA8029 will read the status, deactivate the card if it was active, set all ports to logic 1 and enter Power-down mode by setting bit PD in the controller's PCON register. In this mode, it will consume less than 20 μA , because the internal oscillator is stopped, and all biasing currents are cut.

When SDWN_N returns to HIGH, a Power-on reset operation is performed, so the chip is in the same state than at power-on.

- Power-down mode: the microcontroller is in Power-down mode, and the card is deactivated. The bias currents in the chip and the frequency of the internal oscillator are reduced. In this mode, the consumption is less than 100 μA .
- Sleep mode: the microcontroller is in Power-down mode, the card is activated, but with the clock stopped HIGH or LOW. In this case, the card is supposed not to draw more than 2 mA from V_{CC} . The bias currents and the frequency of the internal oscillator are also reduced. With a current of 100 μA drawn by the card, the consumption is less than 500 μA in tripler mode, 400 μA in doubler mode, or 300 μA in follower mode.

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When in Power-down or Sleep mode, card extraction or insertion, overcurrent on V_{CC} , or HIGH level on pins RST or RESET will wake up the chip.

The same occurs in case of a falling edge on RX if bit ENRX is set, or on INT1_N if bit ENINT1 is set and if INT1_N is enabled within the controller.

If only INT1_N should wake up the TDA8029, then INT1_N must be enabled in the controller, and ENINT1 only should be set.

If RX should wake up the TDA8029, then INT1_N must be enabled in the controller, and ENRX and ENINT1 should be set.

In case of wake up by RX, then the first received characters may be lost, depending on the baud rate on the serial link. (The controller waits for 1536 clock cycles before leaving Power-down mode).

For more details about the use of these modes, please refer to the application notes "AN00069" and "AN01005".

8.16 Activation sequence

When the card is inactive, V_{CC} , CLK, RST and I/O are LOW, with low impedance with respect to GNDC. The DC/DC converter is stopped.

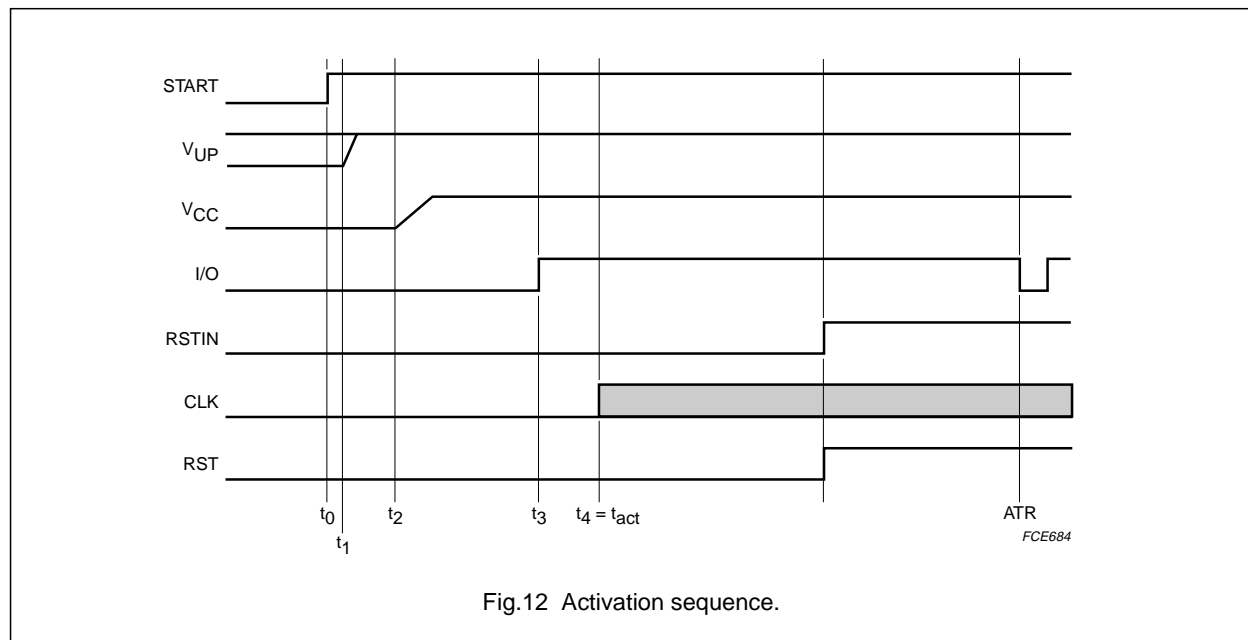
When everything is satisfactory (voltage supply, card present and no hardware problems), the system controller may initiate an activation sequence of the card. Figure 12 shows the activation sequence.

After leaving the UART reset mode, and then configuring the necessary parameters for the UART, it may set the bit START in register PCR (t_0). The following sequence will take place:

- The DC/DC converter is started (t_1)
- V_{CC} starts rising from 0 to 5 V or 3 V with a controlled rise time of 0.17 V/ μ s typically (t_2)
- I/O rises to V_{CC} (t_3), (Integrated 14 k Ω pull-up to V_{CC})
- CLK is sent to the card and RST is enabled (t_4).

After a number of clock pulses that can be counted with the time out counter, bit RSTIN may be set by software, then pin RST rises to V_{CC} .

The sequencer is clocked by $1/64f_{int}$ which leads to a time interval T of 25 μ s typical. Thus $t_1 = 0$ to $3/64T$, $t_2 = t_1 + 3/2T$, $t_3 = t_1 + 7/2T$, and $t_4 = t_1 + 4T$.



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8.17 Deactivation sequence

When the session is completed, the microcontroller resets bit START (t_{10}). The circuit then executes an automatic deactivation sequence shown in Fig.13:

- Card reset (pin RST falls LOW) (t_{11})
- Clock (pin CLK) is stopped LOW (t_{12})
- Pin I/O falls to 0 V (t_{13})
- V_{CC} falls to 0 V with typical 0.17 V/ μ s slew rate (t_{14})
- The DC/DC converter is stopped and CLK, RST, V_{CC} and I/O become low impedance to GNDC (t_{15}).

$$t_{11} = t_{10} + \frac{3}{64}T, \quad t_{12} = t_{11} + \frac{1}{2}T, \quad t_{13} = t_{11} + T,$$

$$t_{14} = t_{11} + \frac{3}{2}T, \quad t_{15} = t_{11} + \frac{7}{2}T.$$

t_{de} is the time that V_{CC} needs for going down to less than 0.4 V.

Automatic emergency deactivation is performed in the following cases:

- Withdrawal of the card (PRES LOW)
- Overcurrent detection on V_{CC} (bit PRTL1 set)
- Overcurrent detection on RST (bit PRTL1 set)
- Overheating (bit PTL set)
- Supply too low (bit SUPL set)
- RESET pin active HIGH.

If the reason of the deactivation is a card take off, an overcurrent or an overheating, then INTO_N is LOW. The corresponding bit in the hardware status register is set. Bit START is automatically reset.

If the reason is a supply dropout, then the deactivation sequence occurs, and a complete reset of the chip is performed. When the supply will be OK again, then the bit SUPL will be set in HSR.

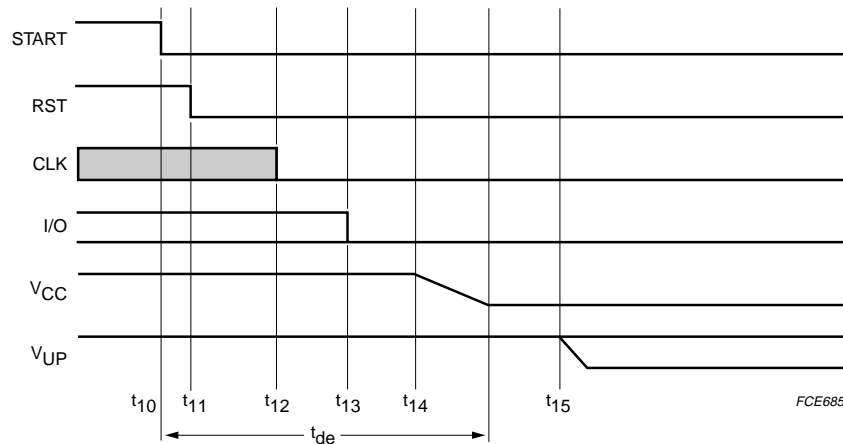


Fig.13 Deactivation sequence.

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9 LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134).

| SYMBOL | PARAMETER | CONDITIONS | MIN. | MAX. | UNIT |
|------------|---|-----------------------------|----------------------|-----------------------|----------------------|
| V_{DCIN} | input voltage for the DC/DC converter | | -0.5 | +6.5 | V |
| V_{DD} | supply voltage | | -0.5 | +6.5 | V |
| V_n | voltage limit on pins SAM, SBM, SAP, SBP and VUP on all other pins | | -0.5 -0.5 | 7.5 $V_{DD} + 0.5$ | V V |
| P_{tot} | continuous total power dissipation | $T_{amb} = -40$ to $+90$ °C | - | 500 | mW |
| T_{stg} | storage temperature | | -55 | +150 | °C |
| T_j | junction temperature | | - | 125 | °C |
| V_{esd} | electrostatic discharge voltage on pins I/O, V_{CC} , RST, CLK and GNDC on pin PRES on pins SAM and SBM on other pins | human body model; note 1 | -6 -3 -1 -2 | +6 +3 +1 +2 | kV kV kV kV |

Note

- Human body model as defined in JEDEC Standard JESD22-A114-B, dated June 2000.

10 HANDLING

Inputs and outputs are protected against electrostatic discharge voltages during normal handling. However, to be totally safe, it is desirable to take normal precautions appropriate to handling MOS devices.

11 THERMAL CHARACTERISTICS

| SYMBOL | PARAMETER | CONDITIONS | VALUE | UNIT |
|---------------|---|-------------|-------|------|
| $R_{th(j-a)}$ | thermal resistance from junction to ambient | in free air | 80 | K/W |

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12 CHARACTERISTICS

$V_{DD} = V_{DCIN} = 3.3\text{ V}$; $T_{amb} = 25\text{ °C}$; unless otherwise specified.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|---|-------------|------|----------------|---------------|
| Supply | | | | | | |
| V_{DD} | supply voltage | | 2.7 | – | 6.0 | V |
| V_{DCIN} | input voltage for the DC/DC converter | | V_{DD} | – | 6.0 | V |
| $I_{DD(sd)}$ | supply current in shut-down mode | $V_{DD} = 3.3\text{ V}$ | – | – | 20 | μA |
| $I_{DD(pd)}$ | supply current in Power-down mode | $V_{DD} = 3.3\text{ V}$; card inactive; microcontroller in Power-down mode | – | – | 110 | μA |
| $I_{DD(sl)}$ | supply current in Sleep mode | $V_{DD} = 3.3\text{ V}$; card active at $V_{CC} = 5\text{ V}$; clock stopped; microcontroller in Power-down mode; $I_{CC} = 0\text{ }\mu\text{A}$ | – | – | 675 | μA |
| $I_{DD(om)}$ | supply current in operating mode | $I_{CC} = 65\text{ mA}$; $f_{XTAL} = 20\text{ MHz}$; $f_{CLK} = 10\text{ MHz}$; 5 V card; $V_{DD} = 2.7\text{ V}$ | – | – | 250 | mA |
| | | $I_{CC} = 50\text{ mA}$; $f_{XTAL} = 20\text{ MHz}$; $f_{CLK} = 10\text{ MHz}$; 3 V card; $V_{DD} = 2.7\text{ V}$ | – | – | 125 | mA |
| | | $I_{CC} = 50\text{ mA}$; $f_{XTAL} = 20\text{ MHz}$; $f_{CLK} = 10\text{ MHz}$; 3 V card; $V_{DD} = 5\text{ V}$ | – | – | 65 | mA |
| V_{th1} | threshold voltage on V_{DD} (falling) | | 2.15 | – | 2.45 | V |
| V_{hys1} | hysteresis on V_{th1} | | 50 | – | 170 | mV |
| V_{th2} | threshold voltage on pin CDEL | | – | 1.25 | – | V |
| V_{CDEL} | voltage on pin CDEL | | – | – | $V_{DD} + 0.3$ | V |
| I_{CDEL} | output current at pin CDEL | charge: pin grounded | – | –2 | – | μA |
| | | discharge: $V_{CDEL} = V_{DD}$ | – | 2 | – | mA |
| C_{CDEL} | capacitance value | | 1 | – | – | nF |
| $t_{W(alarm)}$ | alarm pulse width | $C_{CDEL} = 22\text{ nF}$ | – | 10 | – | ms |
| Crystal oscillator: pins XTAL1 and XTAL2 | | | | | | |
| f_{XTAL} | crystal frequency | $V_{DD} = 5\text{ V}$ | 4 | – | 27 | MHz |
| | | $V_{DD} < 3\text{ V}$ | 4 | – | 16 | MHz |
| f_{ext} | external frequency applied on XTAL1 | | 0 | – | 25 | MHz |
| V_{IH} | HIGH level input voltage on XTAL1 | | $0.8V_{DD}$ | – | $V_{DD} + 0.2$ | V |
| V_{IL} | LOW level input voltage on XTAL1 | | –0.3 | – | $0.2V_{DD}$ | V |

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|---|---|--|--------------------|------|-----------------|---------------|
| DC/DC converter | | | | | | |
| f_{int} | oscillation frequency | | 2 | 2.6 | 3.2 | MHz |
| V_{VUP} | voltage on pin VUP | 5 V card | – | 5.7 | – | V |
| | | 3 V card | – | 4.1 | – | V |
| V_{det} | detection voltage for doubler/tripler selection | | 3.4 | 3.5 | 3.6 | V |
| Reset output to the card: pin RST | | | | | | |
| $V_{\text{O(inactive)}}$ | output voltage in inactive mode | no load | 0 | – | 0.1 | V |
| | | $I_{\text{O(inactive)}} = 1 \text{ mA}$ | 0 | – | 0.3 | V |
| $I_{\text{O(inactive)}}$ | current from RST when inactive and pin grounded | | 0 | – | –1 | mA |
| V_{OL} | LOW level output voltage | $I_{\text{OL}} = 200 \mu\text{A}$ | 0 | – | 0.3 | V |
| V_{OH} | HIGH level output voltage | $I_{\text{OH}} = -200 \mu\text{A}$ | $0.9V_{\text{CC}}$ | – | V_{CC} | V |
| t_{r} | rise time | $C_{\text{L}} = 250 \text{ pF}$ | – | – | 0.1 | μs |
| t_{f} | fall time | $C_{\text{L}} = 250 \text{ pF}$ | – | – | 0.1 | μs |
| Clock output to the card: pin CLK | | | | | | |
| $V_{\text{O(inactive)}}$ | output voltage in inactive mode | no load | 0 | – | 0.1 | V |
| | | $I_{\text{O(inactive)}} = 1 \text{ mA}$ | 0 | – | 0.3 | V |
| $I_{\text{O(inactive)}}$ | current from pin CLK | inactive and pin grounded | 0 | – | –1 | mA |
| V_{OL} | LOW level output voltage | $I_{\text{OL}} = 200 \mu\text{A}$ | 0 | – | 0.3 | V |
| V_{OH} | HIGH level output voltage | $I_{\text{OH}} = -200 \mu\text{A}$ | $0.9V_{\text{CC}}$ | – | V_{CC} | V |
| t_{r} | rise time | $C_{\text{L}} = 35 \text{ pF}$, $V_{\text{CC}} = 5 \text{ or } 3 \text{ V}$ | – | – | 10 | ns |
| t_{f} | fall time | $C_{\text{L}} = 35 \text{ pF}$, $V_{\text{CC}} = 5 \text{ or } 3 \text{ V}$ | – | – | 10 | ns |
| f_{clk} | clock frequency | 1 MHz idle configuration | 1 | – | 1.5 | MHz |
| | | operational | 0 | – | 20 | MHz |
| δ | duty cycle | except for XTAL; $C_{\text{L}} = 35 \text{ pF}$ | 45 | – | 55 | % |
| SR_{r} , SR_{f} | slew rate, rise and fall | $C_{\text{L}} = 35 \text{ pF}$ | 0.2 | – | – | V/ns |
| Card supply voltage: pin V_{CC}; 2 ceramic multilayer capacitances with low ESR of minimum 100 nF should be used in order to meet these specifications | | | | | | |
| $V_{\text{O(inactive)}}$ | output voltage inactive | no load | 0 | – | 0.1 | V |
| | | $I_{\text{O(inactive)}} = 1 \text{ mA}$ | 0 | – | 0.3 | V |
| $I_{\text{O(inactive)}}$ | current from pin I/O | inactive and pin grounded | – | – | –1 | mA |

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|--|--|---------------------|------|------------------------|------|
| V _{CC} | card supply voltage | active mode including static loads; I _{CC} < 65 mA; 5 V card | 4.75 | 5.0 | 5.25 | V |
| | | active mode; current pulses of 40 nAs with I < 200 mA, t < 400 ns, f < 20 MHz; 5 V card | 4.6 | – | 5.4 | V |
| | | active mode including static loads; I _{CC} < 65 mA; V _{DD} > 3.0 V; 3 V card | 2.78 | 3 | 3.22 | V |
| | | active mode; current pulses of 24 nAs with I < 200 mA, t < 400 ns, f < 20 MHz; 3 V card | 2.75 | – | 3.25 | V |
| | | active mode including static loads; I _{CC} < 30 mA; 1.8 V card | 1.62 | 1.8 | 1.98 | V |
| | | active mode; current pulses of 12 nAs with I < 200 mA, t < 400 ns, f < 20 MHz; 1.8 V card | 1.62 | – | 1.98 | V |
| I _{CC} | card supply current | 5 V card; V _{CC} = 0 to 5 V | – | – | 65 | mA |
| | | 3 V card; V _{CC} = 0 to 3 V; V _{DD} > 3.0 V | – | – | 65 | mA |
| | | 1.8 V card; V _{CC} = 0 to 1.8 V | – | – | 30 | mA |
| | | V _{CC} shorted to ground | – | – | 120 | mA |
| SR _r , SR _f | rise and fall slew rate on V _{CC} | maximum load capacitor 300 nF | 0.05 | 0.16 | 0.22 | V/μs |
| V _{ripple(p-p)} | ripple voltage on V _{CC} (peak to peak value) | 20 kHz < f < 200 MHz | – | – | 350 | mV |
| Data line: pin I/O, with an integrated 14 kΩ pull-up resistor to V_{CC} | | | | | | |
| V _{O(inactive)} | output voltage inactive | no load | 0 | – | 0.1 | V |
| | | I _{O(inactive)} = 1 mA | – | – | 0.3 | V |
| I _{O(inactive)} | current from I/O when inactive and pin grounded | | – | – | –1 | mA |
| V _{OL} | LOW level output voltage | I/O configured as output; I _{OL} = 1 mA | 0 | – | 0.3 | V |
| V _{OH} | HIGH level output voltage | I/O configured as output; V _{CC} = 5 or 3 V | | | | |
| | | I _{OH} < –40 μA | 0.75V _{CC} | – | V _{CC} + 0.25 | V |
| | | I _{OH} < –20 μA | 0.8V _{CC} | – | V _{CC} + 0.25 | V |
| V _{IL} | LOW level input voltage | I/O configured as input | –0.3 | – | 0.8 | V |
| V _{IH} | HIGH level input voltage | I/O configured as input | 1.5 | – | V _{CC} | V |
| I _{IL} | input current LOW | V _{IL} = 0 | – | – | 500 | μA |
| I _{LI(H)} | input leakage current HIGH | V _{IH} = V _{CC} | – | – | 10 | μA |

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|--|---|-------------------|------|----------------|--------------|
| $t_{i(r)}, t_{i(f)}$ | input rise and fall times | $C_L \leq 60$ pF | – | – | 1 | μ s |
| $t_{o(r)}, t_{o(f)}$ | output rise and fall times | $C_L \leq 60$ pF | – | – | 0.1 | μ s |
| R_{pu} | internal pull-up resistance between I/O and V_{CC} | | 11 | 14 | 17 | k Ω |
| t_{edge} | width of active pull-up pulse | I/O configured as output, rising from LOW to HIGH | $1/2f_{XTAL1}$ | – | $1/3f_{XTAL1}$ | ns |
| I_{edge} | current from I/O when active pull-up | $V_{OH} = 0.9 V_{CC}$; $C = 60$ pF | –1 | – | – | mA |
| Timings | | | | | | |
| t_{act} | activation sequence duration | | – | – | 130 | μ s |
| t_{de} | deactivation sequence duration | | – | – | 100 | μ s |
| Protections and limitations | | | | | | |
| $I_{CC(sd)}$ | shut-down and limitation current at V_{CC} | | – | –100 | – | mA |
| $I_{I/O(lim)}$ | limitation current on I/O | | –15 | – | +15 | mA |
| $I_{CLK(lim)}$ | limitation current on CLK | | –70 | – | +70 | mA |
| $I_{RST(sd)}$ | shut-down current on RST | | – | –20 | – | mA |
| $I_{RST(lim)}$ | limitation current on RST | | –20 | – | +20 | mA |
| T_{sd} | shut-down temperature | | – | 150 | – | $^{\circ}$ C |
| Card presence input: pin PRES | | | | | | |
| V_{IL} | LOW level input voltage | | – | – | $0.3V_{DD}$ | V |
| V_{IH} | HIGH level input voltage | | $0.7V_{DD}$ | – | – | V |
| $I_{LI(L)}$ | input leakage current LOW | $V_I = 0$ | –20 | – | +20 | μ A |
| $I_{LI(H)}$ | input leakage current HIGH | $V_I = V_{DD}$ | –20 | – | +20 | μ A |
| Shut-down input: pin SDWN_N | | | | | | |
| V_{IL} | LOW level input voltage | | – | – | $0.3V_{DD}$ | V |
| V_{IH} | HIGH level input voltage | | $0.7V_{DD}$ | – | – | V |
| $I_{LI(L)}$ | input leakage current LOW | $V_I = 0$ | –20 | – | +20 | μ A |
| $I_{LI(H)}$ | input leakage current HIGH | $V_I = V_{DD}$ | –20 | – | +20 | μ A |
| General purpose I/O: pins P16, P17, P26, P27, INT1_N, RX and TX | | | | | | |
| V_{IL} | LOW level input voltage | | – | – | $0.2V_{DD}$ | V |
| V_{IH} | HIGH level input voltage | | $0.2V_{DD} + 0.9$ | – | – | V |
| V_{OL} | output voltage LOW | $I_{OL} = 1.6$ mA | – | – | 0.4 | V |
| V_{OH} | output voltage HIGH | $I_{OH} = -30$ μ A | $V_{DD} - 0.7$ | – | – | V |
| I_{IL} | input current LOW | $V_I = 0.4$ V | –1 | – | –50 | μ A |
| I_{THL} | HIGH to LOW transition current | $V_I = 2$ V | – | – | –650 | μ A |

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| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNIT |
|--|--------------------------|------------|--------------------|------|--------------------|------|
| Reset input: pin RESET, active HIGH | | | | | | |
| V _{IL} | LOW level input voltage | | – | – | 0.2V _{DD} | V |
| V _{IH} | HIGH level input voltage | | 0.7V _{DD} | – | – | V |

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13 APPLICATION INFORMATION

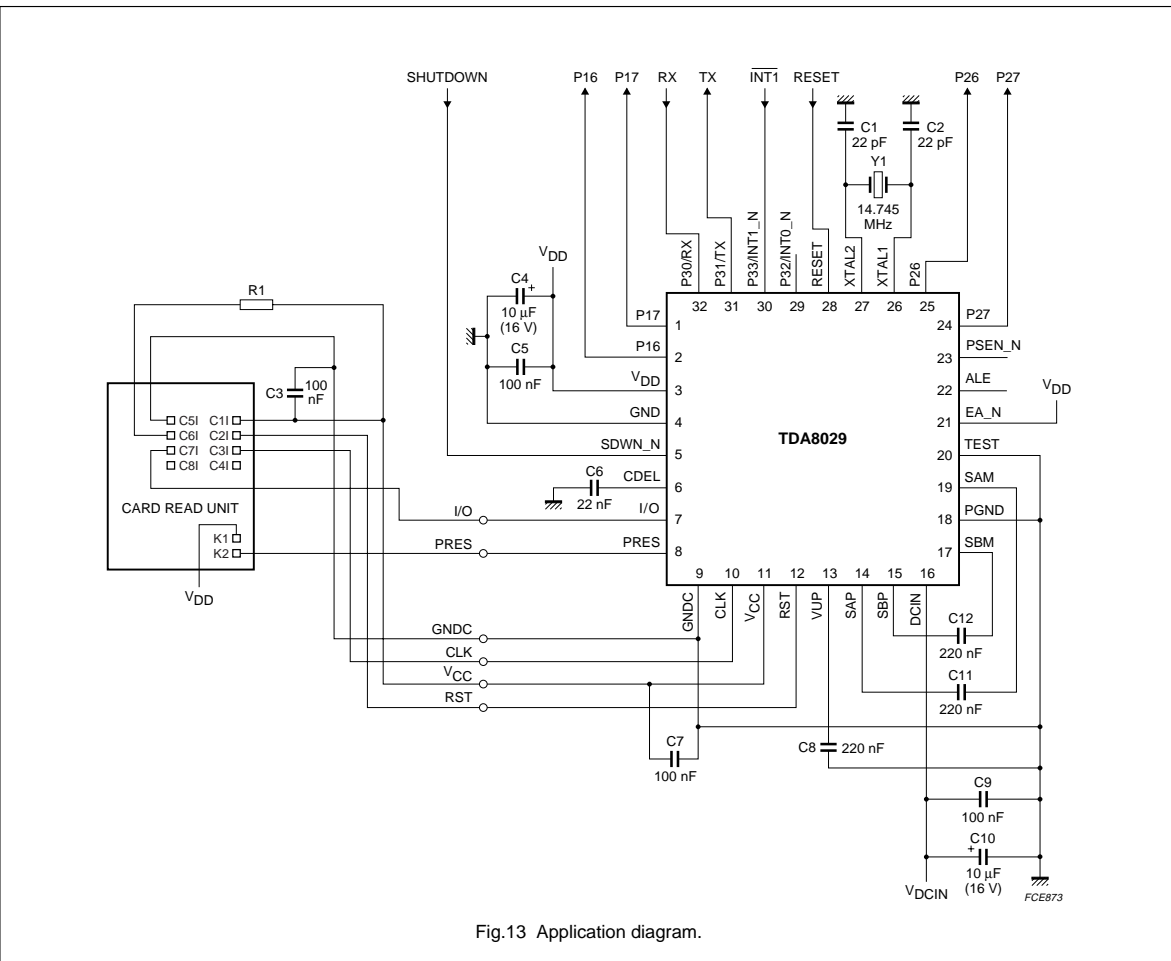


Fig.13 Application diagram.

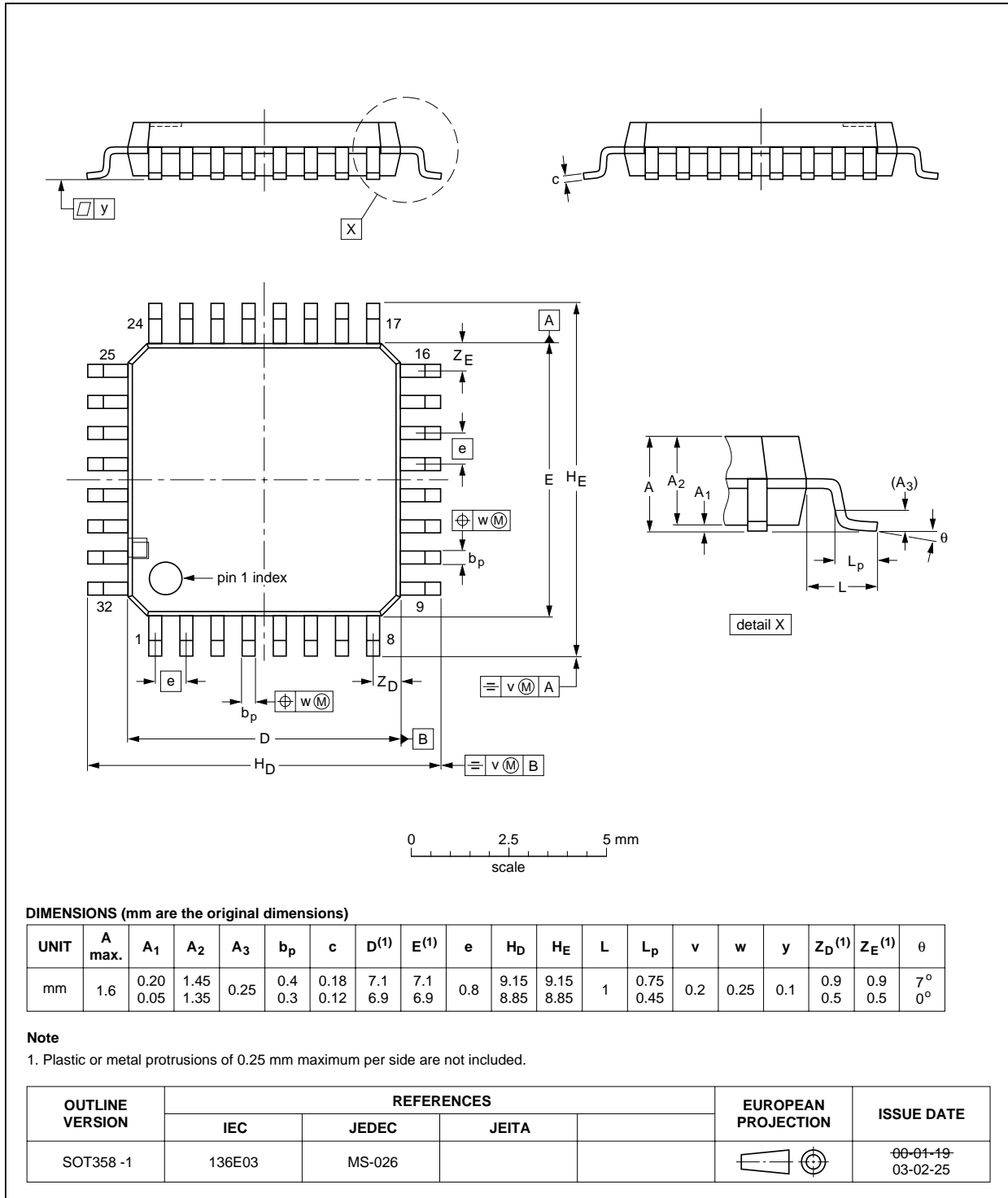
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14 PACKAGE OUTLINE

LQFP32: plastic low profile quad flat package; 32 leads; body 7 x 7 x 1.4 mm

SOT358-1



DIMENSIONS (mm are the original dimensions)

| UNIT | A max. | A ₁ | A ₂ | A ₃ | b _p | c | D ⁽¹⁾ | E ⁽¹⁾ | e | H _D | H _E | L | L _p | v | w | y | Z _D ⁽¹⁾ | Z _E ⁽¹⁾ | θ |
|------|--------|----------------|----------------|----------------|----------------|--------------|------------------|------------------|-----|----------------|----------------|---|----------------|-----|------|-----|-------------------------------|-------------------------------|----------|
| mm | 1.6 | 0.20 0.05 | 1.45 1.35 | 0.25 | 0.4 0.3 | 0.18 0.12 | 7.1 6.9 | 7.1 6.9 | 0.8 | 9.15 8.85 | 9.15 8.85 | 1 | 0.75 0.45 | 0.2 | 0.25 | 0.1 | 0.9 0.5 | 0.9 0.5 | 7° 0° |

Note

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

| OUTLINE VERSION | REFERENCES | | | EUROPEAN PROJECTION | ISSUE DATE |
|-----------------|------------|--------|-------|---------------------|----------------------|
| | IEC | JEDEC | JEITA | | |
| SOT358-1 | 136E03 | MS-026 | | | 00-01-19 03-02-25 |

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15 SOLDERING

15.1 Introduction to soldering surface mount packages

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"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering can still be used for certain surface mount ICs, but it is not suitable for fine pitch SMDs. In these situations reflow soldering is recommended.

15.2 Reflow soldering

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. Driven by legislation and environmental forces the worldwide use of lead-free solder pastes is increasing.

Several methods exist for reflowing; for example, convection or convection/infrared heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 270 °C depending on solder paste material. The top-surface temperature of the packages should preferably be kept:

- below 220 °C (SnPb process) or below 245 °C (Pb-free process)
 - for all BGA and SSOP-T packages
 - for packages with a thickness ≥ 2.5 mm
 - for packages with a thickness < 2.5 mm and a volume ≥ 350 mm³ so called thick/large packages.
- below 235 °C (SnPb process) or below 260 °C (Pb-free process) for packages with a thickness < 2.5 mm and a volume < 350 mm³ so called small/thin packages.

Moisture sensitivity precautions, as indicated on packing, must be respected at all times.

15.3 Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
 - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
 - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

The footprint must incorporate solder thieves at the downstream end.

- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

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.

Typical dwell time of the leads in the wave ranges from 3 to 4 seconds at 250 °C or 265 °C, depending on solder material applied, SnPb or Pb-free respectively.

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

15.4 Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron 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.

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15.5 Suitability of surface mount IC packages for wave and reflow soldering methods

| PACKAGE ⁽¹⁾ | SOLDERING METHOD | |
|--|-----------------------------------|-----------------------|
| | WAVE | REFLOW ⁽²⁾ |
| BGA, LBGA, LFBGA, SQFP, SSOP-T ⁽³⁾ , TFBGA, VFBGA | not suitable | suitable |
| DHVQFN, HBCC, HBGA, HLQFP, HSQFP, HSOP, HTQFP, HTSSOP, HVQFN, HVSON, SMS | not suitable ⁽⁴⁾ | suitable |
| PLCC ⁽⁵⁾ , SO, SOJ | suitable | suitable |
| LQFP, QFP, TQFP | not recommended ⁽⁵⁾⁽⁶⁾ | suitable |
| SSOP, TSSOP, VSO, VSSOP | not recommended ⁽⁷⁾ | suitable |
| PMFP ⁽⁸⁾ | not suitable | not suitable |

Notes

- For more detailed information on the BGA packages refer to the "*(LF)BGA Application Note*" (AN01026); order a copy from your Philips Semiconductors sales office.
- All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the "*Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods*".
- These transparent plastic packages are extremely sensitive to reflow soldering conditions and must on no account be processed through more than one soldering cycle or subjected to infrared reflow soldering with peak temperature exceeding $217\text{ °C} \pm 10\text{ °C}$ measured in the atmosphere of the reflow oven. The package body peak temperature must be kept as low as possible.
- These packages are not suitable for wave soldering. On versions with the heatsink on the bottom side, the solder cannot penetrate between the printed-circuit board and the heatsink. On versions with the heatsink on the top side, the solder might be deposited on the heatsink surface.
- If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
- Wave soldering is suitable for LQFP, TQFP and QFP packages with a pitch (e) larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
- Wave soldering is suitable for SSOP, TSSOP, VSO and VSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.
- Hot bar or manual soldering is suitable for PMFP packages.

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16 DATA SHEET STATUS

| LEVEL | DATA SHEET STATUS ⁽¹⁾ | PRODUCT STATUS ⁽²⁾⁽³⁾ | DEFINITION |
|-------|----------------------------------|----------------------------------|--|
| I | Objective data | Development | This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice. |
| II | Preliminary data | Qualification | This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product. |
| III | Product data | Production | This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN). |

Notes

1. Please consult the most recently issued data sheet before initiating or completing a design.
2. The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.
3. For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

17 DEFINITIONS

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). 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.

Application information — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

18 DISCLAIMERS

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Contact information

For additional information please visit <http://www.semiconductors.philips.com>. Fax: **+31 40 27 24825**

For sales offices addresses send e-mail to: sales.addresses@www.semiconductors.philips.com.

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