DP8570A

DP8570A Timer Clock Peripheral (TCP)

Literature Number: SNAS557

National Semiconductor

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DP8570A Timer Clock Peripheral (TCP)

General Description

The DP8570A is intended for use in microprocessor based systems where information is required for multi-tasking, data logging or general time of day/date information. This device is implemented in low voltage silicon gate microCMOS technology to provide low standby power in battery back-up environments. The circuit's architecture is such that it looks like a contiguous block of memory or I/O ports. The address space is organized as 2 software selectable pages of 32 bytes. This includes the Control Registers, the Clock Counters, the Alarm Compare RAM, the Timers and their data RAM, and the Time Save RAM. Any of the RAM locations that are not being used for their intended purpose may be used as general purpose CMOS RAM.

Time and date are maintained from 1/100 of a second to year and leap year in a BCD format, 12 or 24 hour modes. Day of week, day of month and day of year counters are provided. Time is controlled by an on-chip crystal oscillator requiring only the addition of the crystal and two capacitors. The choice of crystal frequency is program selectable.

Two independent multifunction 10 MHz 16-bit timers are provided. These timers operate in four modes. Each has its own prescaler and can select any of 8 possible clock inputs. Thus, by programming the input clocks and the timer counter values a very wide range of timing durations can be achieved. The range is from about 400 ns (4.915 MHz oscillator) to 65,535 seconds (18 hrs., 12 min.).

Power failure logic and control functions have been integrated on chip. This logic is used by the TCP to issue a power fail interrupt, and lock out the μp interface. The time power fails may be logged into RAM automatically when $V_{BB} > V_{CC}$. Additionally, two supply pins are provided. When $V_{BB} > V_{CC}$, internal circuitry will automatically switch from the main supply to the battery supply. Status bits are provided to indicate initial application of battery power, system power, and low battery detect. (Continued)

Features

- Full function real time clock/calendar
  - — 12/24 hour mode timekeeping
  - — Day of week and day of years counters
  - — Four selectable oscillator frequencies
  - — Parallel Resonant Oscillator
- Two 16-bit timers
  - — 10 MHz external clock frequency
  - — Programmable multi-function output
  - — Flexible re-trigger facilities
- Power fail features
  - — Internal power supply switch to external battery
  - — Power Supply Bus glitch protection
  - — Automatic log of time into RAM at power failure
- On-chip interrupt structure
  - — Periodic, alarm, timer and power fail interrupts
- Up to 44 bytes of CMOS RAM
- INTR/MFO/T1 pins programmable High/Low and push-pull or open drain

Block Diagram

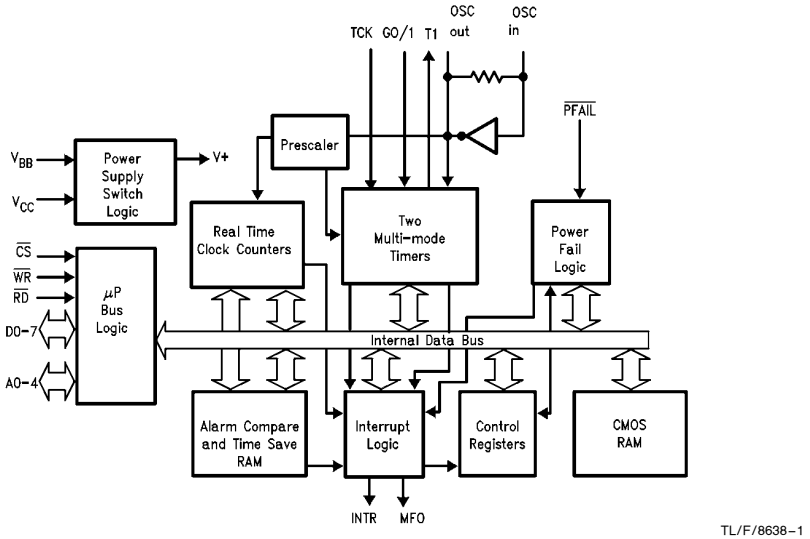

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FIGURE 1

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Absolute Maximum Ratings (Notes 1 & 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (V_{CC})	−0.5V to +7.0V
DC Input Voltage (V_{IN})	−0.5V to V_{CC} +0.5V
DC Output Voltage (V_{OUT})	−0.5V to V_{CC} + 0.5V
Storage Temperature Range	−65°C to +150°C
Power Dissipation (PD)	500 mW
Lead Temperature (Soldering, 10 sec.)	260°C

Operation Conditions

	Min	Max	Unit
Supply Voltage (V_{CC}) (Note 3)	4.5	5.5	V
Supply Voltage (V_{BB}) (Note 3)	2.2	V_{CC} −0.4	V
DC Input or Output Voltage (V_{IN}, V_{OUT})	0.0	V_{CC}	V
Operation Temperature (T_A)	−40	+85	°C
Electr-Static Discharge Rating TBD		1	kV
Transistor Count		15,200	
Typical Values			
θ_{JA} DIP		Board = 45°C/W Socket = 50°C/W	
θ_{JA} PLCC		Board = 77°C/W Socket = 85°C/W	

DC Electrical Characteristics

V_{CC} = 5V ±10%, V_{BB} = 3V, $V_{\overline{PFAIL}} > V_{IH}$, C_L = 100 pF (unless otherwise specified)

Symbol	Parameter	Conditions	Min	Max	Units
V_{IH}	High Level Input Voltage (Note 4)	Any Inputs Except OSC IN, OSC IN with External Clock	2.0 V_{BB} −0.1		V V
V_{IL}	Low Level Input Voltage	All Inputs Except OSC IN OSC IN with External Clock		0.8 0.1	V V
V_{OH}	High Level Output Voltage (Excluding OSC OUT)	I_{OUT} = −20 μA I_{OUT} = −4.0 mA	V_{CC} −0.1 3.5		V V
V_{OL}	Low Level Output Voltage (Excluding OSC OUT)	I_{OUT} = 20 μA I_{OUT} = 4.0 mA		0.1 0.25	V V
I_{IN}	Input Current (Except OSC IN)	V_{IN} = V_{CC} or GND		±1.0	μA
I_{OZ}	Output TRI-STATE® Current	V_{OUT} = V_{CC} or GND		±5.0	μA
I_{LKG}	Output High Leakage Current T1, MFO, INTR Pins	V_{OUT} = V_{CC} or GND Outputs Open Drain		±5.0	μA
I_{CC}	Quiescent Supply Current (Note 7)	F_{OSC} = 32.768 kHz V_{IN} = V_{CC} or GND (Note 5) V_{IN} = V_{CC} or GND (Note 6) V_{IN} = V_{IH} or V_{IL} (Note 6)		260 1.0 12.0	μA mA mA
		F_{OSC} = 4.194304 MHz or 4.9152 MHz V_{IN} = V_{CC} or GND (Note 6) V_{IN} = V_{IH} or V_{IL} (Note 6)		8 20	mA mA
I_{CC}	Quiescent Supply Current (Single Supply Mode) (Note 7)	V_{BB} = GND V_{IN} = V_{CC} or GND F_{OSC} = 32.768 kHz F_{OSC} = 4.9152 MHz or 4.194304 MHz		80 7.5	μA mA
I_{BB}	Standby Mode Battery Supply Current (Note 8)	V_{CC} = GND OSC OUT = Open Circuit, Other Pins = GND F_{OSC} = 32.768 kHz F_{OSC} = 4.9152 MHz or 4.194304 MHz		10 400	μA μA
I_{BLK}	Battery Supply Leakage	2.2V ≤ V_{BB} ≤ 4.0V Other Pins at GND V_{CC} = GND, V_{BB} = 4.0V V_{CC} = 5.5V, V_{BB} = 2.2V	 −5	 1.5	 μA μA

Note 1: Absolute Maximum Ratings are those values beyond which damage to the device may occur.

Note 2: Unless otherwise specified all voltages are referenced to ground.

Note 3: For F_{OSC} = 4.194304 or 4.9152 MHz, V_{BB} minimum = 2.8V. In battery backed mode, V_{BB} ≤ V_{CC} −0.4V.
Single Supply Mode: Data retention voltage is 2.2V min.
In single Supply Mode (Power connected to V_{CC} pin) 4.5V ≤ V_{CC} ≤ 5.5V.

Note 4: This parameter (V_{IH}) is not tested on all pins at the same time.

Note 5: This specification tests I_{CC} with all power fail circuitry disabled, by setting D7 of Interrupt Control Register 1 to 0.

Note 6: This specification tests I_{CC} with all power fail circuitry enabled, by setting D7 of Interrupt Control Register 1 to 1.

Note 7: This specification is tested with both the timers and OSC IN driven by a signal generator. Contents of the Test Register = 00(H), the MFO pin is not configured as buffered oscillator out and MFO, T1, INTR, are configured as open drain.

Note 8: This specification is tested with both the timers off, and only OSC IN is driven by a signal generator. Contents of the Test Register = 00(H) and the MFO pin is not configured as buffered oscillator out.

AC Electrical Characteristics

V_{CC} = 5V ±10%, V_{BB} = 3V, $V_{\overline{PFAIL}} > V_{IH}$, C_L = 100 pF (unless otherwise specified)

Symbol	Parameter	Min	Max	Units
READ TIMING				
t_{AR}	Address Valid Prior to Read Strobe	20		ns
t_{RW}	Read Strobe Width (Note 9)	80		ns
t_{CD}	Chip Select to Data Valid Time		80	ns
t_{RAH}	Address Hold after Read (Note 10)	3		ns
t_{RD}	Read Strobe to Valid Data		70	ns
t_{DZ}	Read or Chip Select to TRI-STATE		60	ns
t_{RCH}	Chip Select Hold after Read Strobe	0		ns
t_{DS}	Minimum Inactive Time between Read or Write Accesses	50		ns
WRITE TIMING				
t_{AW}	Address Valid before Write Strobe	20		ns
t_{WAH}	Address Hold after Write Strobe (Note 10)	3		ns
t_{CW}	Chip Select to End of Write Strobe	90		ns
t_{WW}	Write Strobe Width (Note 11)	80		ns
t_{DW}	Data Valid to End of Write Strobe	50		ns
t_{WDH}	Data Hold after Write Strobe (Note 10)	3		ns
t_{WCH}	Chip Select Hold after Write Strobe	0		ns
TIMER 0/TIMER 1 TIMING				
F_{TCK}	Input Frequency Range	DC	10	MHz
t_{CK}	Propagation Delay Clock to Output ⎍		120	ns
t_{GO}	Propagation Delay G0 to G1 to Timer Output (Note 12) ⎎		100	ns
t_{PGW}	Pulse Width G0 or G1 ⎍ (Note 12)	25		ns
t_{GS}	Setup Time, G0, G1 to TCK (Note 13)	100		ns
INTERRUPT TIMING				
t_{ROLL}	Clock Rollover to INTR Out is Typically 16.5 μs			

Note 9: Read Strobe width as used in the read timing table is defined as the period when both chip select and read inputs are low. Hence read commences when both signals are low and terminates when either signal returns high.

Note 10: Hold time is guaranteed by design but not production tested. This limit is not used to calculate outgoing quality levels.

Note 11: Write Strobe width as used in the write timing table is defined as the period when both chip select and write inputs are low. Hence write commences when both signals are low and terminates when either signal returns high.

Note 12: Timers in Mode 3.

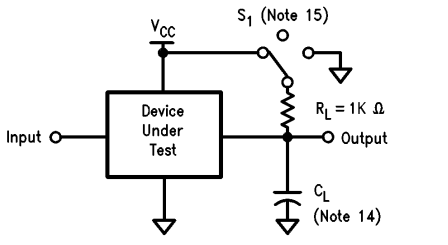
Note 13: Guaranteed by design, not production tested. This limit is not used to calculate outgoing quality levels.

AC Test Conditions

Input Pulse Levels	GND to 3.0V
Input Rise and Fall Times	6 ns (10%–90%)
Input and Output Reference Levels	1.3V
TRI-STATE Reference Levels (Note 15)	Active High +0.5V Active Low −0.5V

Note 14: C_L = 100 pF, includes jig and scope capacitance.

Note 15: S1 = V_{CC} for active low to high impedance measurements.
S1 = GND for active high to high impedance measurements.
S1 = open for all other timing measurements.



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Capacitance (T_A = 25°C, f = 1 MHz)

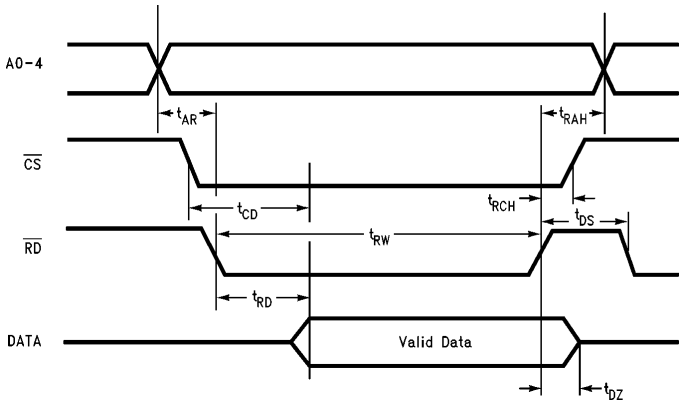
Symbol	Parameter (Note 16)	Typ	Units
C_{IN}	Input Capacitance	5	pF
C_{OUT}	Output Capacitance	7	pF

Note 16: This parameter is not 100% tested.

Note 17: Output rise and fall times 25 ns max (10%–90%) with 100 pF load.

Timing Waveforms

Read Timing Diagram



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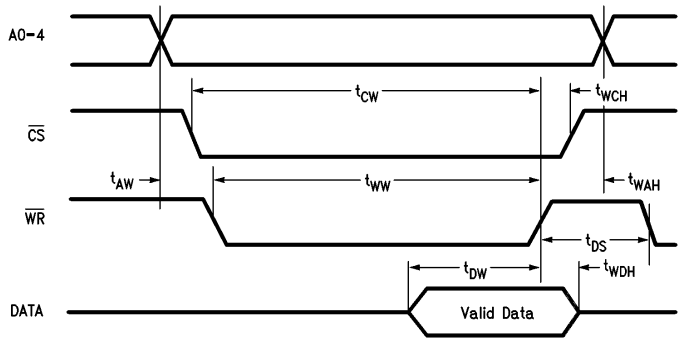
Write Timing Diagram



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General Description (Continued)

The DP8570A's interrupt structure provides four basic types of interrupts: Periodic, Alarm/Compare, Timer, and Power Fail. Interrupt mask and status registers enable the masking and easy determination of each interrupt.

One dedicated general purpose interrupt output is provided. A second interrupt output is available on the Multiple Function Output (MFO) pin. Each of these may be selected to generate an interrupt from any source. Additionally, the MFO pin may be programmed to be either as oscillator output or Timer 0's output.

Pin Description

$\overline{CS}$, $\overline{RD}$, $\overline{WR}$ (Inputs): These pins interface to μP control lines. The $\overline{CS}$ pin is an active low enable for the read and write operations. Read and Write pins are also active low and enable reading or writing to the TCP. All three pins are disabled when power failure is detected. However, if a read or write is in progress at this time, it will be allowed to complete its cycle.

A0–A4 (Inputs): These 5 pins are for register selection. They individually control which location is to be accessed. These inputs are disabled when power failure is detected.

OSC IN (Input): OSC OUT (Output): These two pins are used to connect the crystal to the internal parallel resonant oscillator. The oscillator is always running when power is applied to V_{BB} and V_{CC}, and the correct crystal select bits in the Real Time Mode Register have been set.

MFO (Output): The multi-function output can be used as a second interrupt output for interrupting the μP. This pin can also provide an output for the oscillator or the internal Timer 0. The MFO output can be programmed active high or low, open drain or push-pull. If in battery backed mode and a pull-up resistor is attached, it should be connected to a voltage no greater than V_{BB}. This pin is configured open drain during battery operation ($V_{BB} > V_{CC}$).

INTR (Output): The interrupt output is used to interrupt the processor when a timing event or power fail has occurred and the respective interrupt has been enabled. The INTR output can be programmed active high or low, push-pull or open drain. If in battery backed mode and a pull-up resistor is attached, it should be connected to a voltage no greater than V_{BB}. This pin is configured open drain during battery operation ($V_{BB} > V_{CC}$). The output is a DC voltage level. To clear the INTR, write a 1 to the appropriate bit(s) in the Main Status Register.

D0–D7 (Input/Output): These 8 bidirectional pins connect to the host μP's data bus and are used to read from and write to the TCP. When the $\overline{PFAIL}$ pin goes low and a write is not in progress, these pins are at TRI-STATE.

$\overline{PFAIL}$ (Input): In battery backed mode, this pin can have a digital signal applied to it via some external power detection logic. When $\overline{PFAIL}$ = logic 0 the TCP goes into a lockout mode, in a minimum of 30 μs or a maximum of 63 μs unless lockout delay is programmed. In the single power supply mode, this pin is not useable as an input and should be tied to V_{CC}. Refer to section on Power Fail Functional Description.

V_{BB} (Battery Power Pin): This pin is connected to a back-up power supply. This power supply is switched to the internal circuitry when the V_{CC} becomes lower than V_{BB}. Utilizing this pin eliminates the need for external logic to switch in and out the back-up power supply. If this feature is not to be used then this pin must be tied to ground, the TCP programmed for single power supply only, and power applied to the V_{CC} pin.

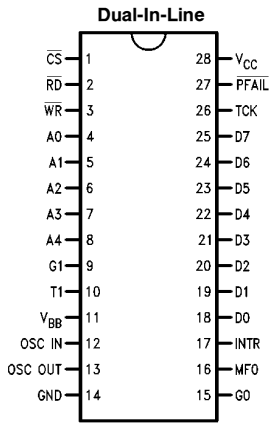
TCK, G1, G0, (Inputs), T1 (Output): TCK is the clock input to both timers when they have an external clock selected. In modes 0, 1, and 2, G0 and G1 are active low enable inputs for timers 0 and 1 respectively. In mode 3, G0 and G1 are positive edge triggers to the timers. T1 is dedicated to the timer 1 output. The T1 output can be programmed active high or low, push-pull or open drain. Timer 0 output is available through MFO pin if desired. If in battery backed mode and a pull-up resistor is attached to T1, it should be connected to a voltage no greater than V_{BB}. The T1 pin is configured open drain during battery operation ($V_{BB} > V_{CC}$).

V_{CC}: This is the main system power pin.

GND: This is the common ground power pin for both V_{BB} and V_{CC}.

Connection Diagrams

Dual-In-Line



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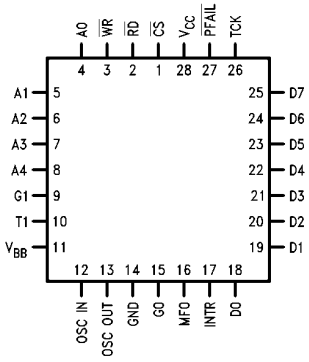
Top View

Order Number DP8570AN
See NS Package Number N28B

Plastic Chip Carrier



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Top View

Order Number DP8570AV
See NS Package Number V28A

Functional Description

The DP8570A contains a fast access real time clock, two 10 MHz 16-bit timers, interrupt control logic, power fail detect logic, and CMOS RAM. All functions of the TCP are controlled by a set of nine registers. A simplified block diagram that shows the major functional blocks is given in *Figure 1*.

The blocks are described in the following sections:

1. Real Time Clock
2. Oscillator Prescaler
3. Interrupt Logic
4. Power Failure Logic
5. Additional Supply Management
6. Timers

The memory map of the TCP is shown in the memory addressing table. The memory map consists of two 31 byte pages with a main status register that is common to both pages. A control bit in the Main Status Register is used to select either page. *Figure 2* shows the basic concept. Page 0 contains all the clock timer functions, while page 1 has scratch pad RAM. The control registers are split into two separate blocks to allow page 1 to be used entirely as scratch pad RAM. Again a control bit in the Main Status Register is used to select either control register block.

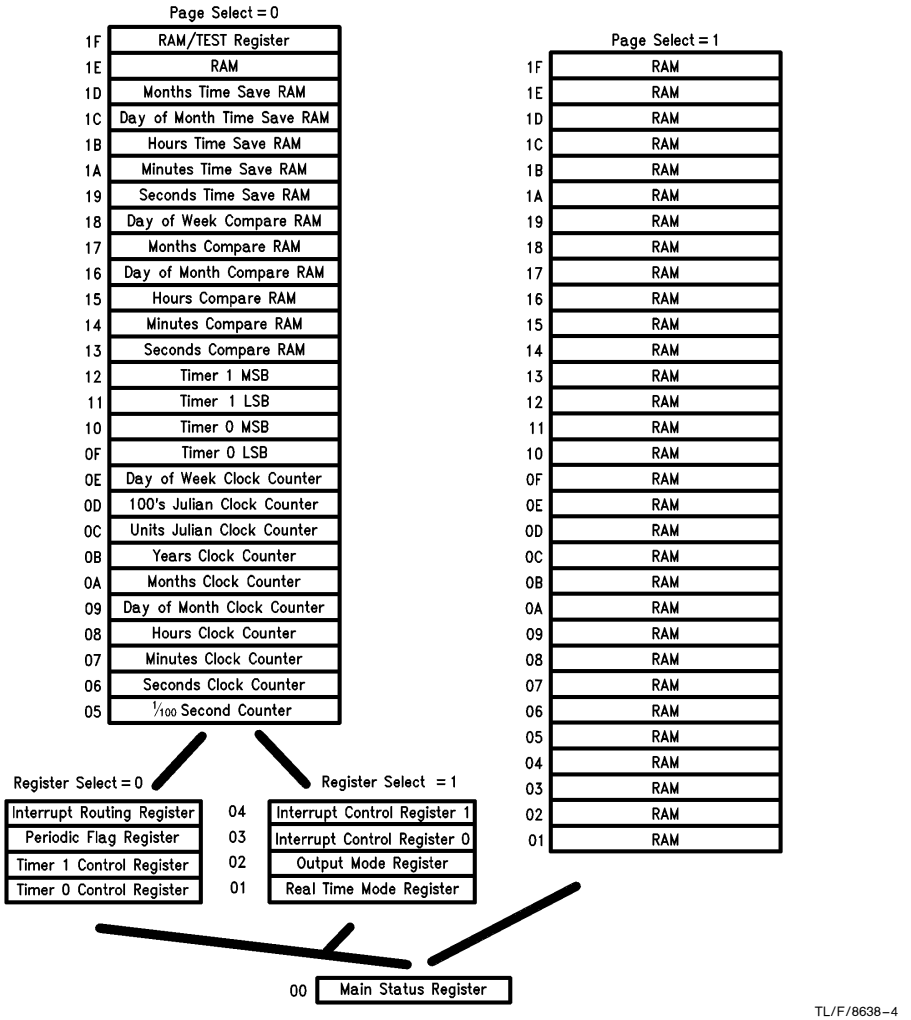

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FIGURE 2. DP8570A Internal Memory Map

Functional Description (Continued)

INITIAL POWER-ON of BOTH V_{BB} and V_{CC}

V_{BB} and V_{CC} may be applied in any sequence. In order for the power fail circuitry to function correctly, whenever power is off, the V_{CC} pin must see a path to ground through a maximum of 1 MΩ. The user should be aware that the control registers will contain random data. The first task to be carried out in an initialization routine is to start the oscillator by writing to the crystal select bits in the Real Time Mode Register. If the DP8570A is configured for single supply mode, an extra 50 μA may be consumed until the crystal select bits are programmed. The user should also ensure that the TCP is not in test mode (see register descriptions).

REAL TIME CLOCK FUNCTIONAL DESCRIPTION

As shown in *Figure 2*, the clock has 10 bytes of counters, which count from 1/100 of a second to years. Each counter counts in BCD and is synchronously clocked. The count sequence of the individual byte counters within the clock is shown later in Table VII. Note that the day of week, day of month, day of year, and month counters all roll over to 1. The hours counter in 12 hour mode rolls over to 1 and the AM/PM bit toggles when the hours rolls over to 12 (AM = 0, PM = 1). The AM/PM bit is bit D7 in the hours counter.

All other counters roll over to 0. Also note that the day of year counter is 12 bits long and occupies two addresses. Upon initial application of power the counters will contain random information.

READING THE CLOCK: VALIDATED READ

Since clocking of the counter occurs asynchronously to reading of the counter, it is possible to read the counter while it is being incremented (rollover). This may result in an incorrect time reading. Thus to ensure a correct reading of the entire contents of the clock (or that part of interest), it must be read without a clock rollover occurring. In general this can be done by checking a rollover bit. On this chip the periodic interrupt status bits can serve this function. The following program steps can be used to accomplish this.

1. Initialize program for reading clock.
2. Dummy read of periodic status bit to clear it.
3. Read counter bytes and store.
4. Read rollover bit, and test it.
5. If rollover occured go to 3.
6. If no rollover, done.

To detect the rollover, individual periodic status bits can be polled. The periodic bit chosen should be equal to the highest frequency counter register to be read. That is if only SECONDS through HOURS counters are read, then the SECONDS periodic bit should be used.

READING THE CLOCK: INTERRUPT DRIVEN

Enabling the periodic interrupt mask bits cause interrupts just as the clock rolls over. Enabling the desired update rate and providing an interrupt service routine that executes in less than 10 ms enables clock reading without checking for a rollover.

READING THE CLOCK: LATCHED READ

Another method to read the clock that does not require checking the rollover bit is to write a one into the Time Save Enable bit (D7) of the Interrupt Routing Register, and then to write a zero. Writing a one into this bit will enable the clock contents to be duplicated in the Time Save RAM. Changing the bit from a one to a zero will freeze and store the contents of the clock in Time Save RAM. The time then can be read without concern for clock rollover, since internal logic takes care of synchronization of the clock. Because only the bits used by the clock counters will be latched, the Time Save RAM should be cleared prior to use to ensure that random data stored in the unused bits do not confuse the host microprocessor. This bit can also provide time save at power failure, see the Additional Supply Management Functions section. With the Time Save Enable bit at a logical 0, the Time Save RAM may be used as RAM if the latched read function is not necessary.

INITIALIZING AND WRITING TO THE CALENDAR-CLOCK

Upon initial application of power to the TCP or when making time corrections, the time must be written into the clock. To correctly write the time to the counters, the clock would normally be stopped by writing the Start/$\overline{\text{Stop}}$ bit in the Real Time Mode Register to a zero. This stops the clock from counting and disables the carry circuitry. When initializing the clock's Real Time Mode Register, it is recommended that first the various mode bits be written while maintaining the Start/$\overline{\text{Stop}}$ bit reset, and then writing to the register a second time with the Start/$\overline{\text{Stop}}$ bit set.

The above method is useful when the entire clock is being corrected. If one location is being updated the clock need not be stopped since this will reset the prescaler, and time will be lost. An ideal example of this is correcting the hours for daylight savings time. To write to the clock "on the fly" the best method is to wait for the 1/100 of a second periodic interrupt. Then wait an additional 16 μs, and then write the data to the clock.

PRESCALER/OSCILLATOR FUNCTIONAL DESCRIPTION

Feeding the counter chain is a programmable prescaler which divides the crystal oscillator frequency to 32 kHz and further to 100 Hz for the counter chain (see *Figure 3*). The crystal frequency that can be selected are: 32 kHz, 32.768 kHz, 4.9152 MHz, and 4.194304 MHz.

Once 32 kHz is generated it feeds both timers and the clock. The clock and timer prescalers can be independently enabled by controlling the timer or clock Start/$\overline{\text{Stop}}$ bits.

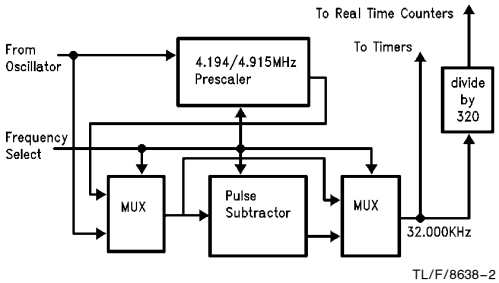

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FIGURE 3. Programmable Clock Prescaler Block

Functional Description (Continued)

The oscillator is programmed via the Real Time Mode Register to operate at various frequencies. The crystal oscillator is designed to offer optimum performance at each frequency. Thus, at 32.768 kHz the oscillator is configured as a low frequency and low power oscillator. At the higher frequencies the oscillator inverter is reconfigured. In addition to the inverter, the oscillator feedback bias resistor is included on chip, as shown in *Figure 4*. The oscillator input may be driven from an external source if desired. Refer to test mode application note for details. The oscillator stability is enhanced through the use of an on chip regulated power supply.

The typical range of trimmer capacitor (as shown in Oscillator Circuit Diagram *Figure 4*, and in the typical application) at the oscillator input pin is suggested only to allow accurate tuning of the oscillator. This range is based on a typical printed circuit board layout and may have to be changed depending on the parasitic capacitance of the printed circuit board or fixture being used. In all cases, the **load capacitance** specified by the crystal manufacturer (nominal value 11 pF for the 32.768 crystal) is what determines proper oscillation. This load capcitance is the series combination of capacitance on each side of the crystal (with respect to ground).

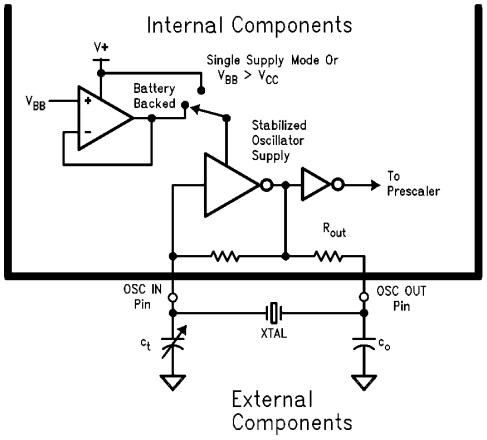

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FIGURE 4. Oscillator Circuit Diagram

XTAL	C_o	C_t	R_{OUT} (Switched Internally)
32/32.768 kHz	47 pF	2 pF–22 pF	150 kΩ to 350 kΩ
4.194304 MHz	68 pF	0 pF–80 pF	500Ω to 900Ω
4.9152 MHz	68 pF	29 pF–49 pF	500Ω to 900Ω

INTERRUPT LOGIC FUNCTIONAL DESCRIPTION

The TCP has the ability to coordinate processor timing activities. To enhance this, an interrupt structure has been implemented which enables several types of events to cause interrupts. Interrupts are controlled via two Control Registers in block 1 and two Status Registers in block 0. (See Register Description for notes on paging and also *Figure 5* and Table I.)

The interrupts are enabled by writing a one to the appropriate bits in Interrupt Control Register 0 and/or 1. Any of the interrupts can be routed to either the INTR pin or the MFO pin, depending on how the Interrupt Routing register is programmed. This, for example, enables the user to dedicate the MFO as a non-maskable interrupt pin to the CPU for power failure detection and enable all other interrupts to appear on the INTR pin. The polarity for the active interrupt can be programmed in the Output Mode Register for either active high or low, and open drain or push pull outputs.

TABLE I. Registers that are Applicable to Interrupt Control

Register Name	Register Select	Page Select	Address
Main Status Register	X	X	00H
Periodic Flag Register	0	0	03H
Interrupt Routing Register	0	0	04H
Interrupt Control Register 0	1	0	03H
Interrupt Control Register 1	1	0	04H
Output Mode Register	1	0	02H

The Interrupt Status Flag D0, in the Main Status Register, indicates the state of INTR and MFO outputs. It is set when either output becomes active and is cleared when all TCP interrupts have been cleared and no further interrupts are pending (i.e., both INTR and MFO are returned to their inactive state). This flag enables the TCP to be rapidly polled by the μP to determine the source of an interrupt in a wired—OR interrupt system.

Note that the Interrupt Status Flag will only monitor the state of the MFO output if it has been configured as an interrupt output (see Output Mode Register description). This is true, regardless of the state of the Interrupt Routing Register. Thus the Interrupt Status Flag provides a true reflection of all conditions routed to the external pins.

Status for the interrupts are provided by the Main Status Register and the Periodic Flag Register. Bits D1–D5 of the Main Status Register are the main interrupt bits.

These register bits will be set when their associated timing events occur. Enabled Alarm or Timer interrupts that occur will set its Main Status Register bit to a one. However, an external interrupt will only be generated if the appropriate Alarm or Timer interrupt enable bits are set (see *Figure 5*).

Disabling the periodic bits will mask the Main Status Register periodic bit, but not the Periodic Flag Register bits. The Power Fail Interrupt bit is set when the interrupt is enabled and a power fail event has occurred, and is not reset until the power is restored. If all interrupt enable bits are 0 no interrupt will be asserted. However, status still can be read from the Main Status Register in a polled fashion (see *Figure 5*).

To clear a flag in bits D2–D5 of the Main Status Register a 1 must be written back into the bit location that is to be cleared. For the Periodic Flag Register reading the status will reset all the periodic flags.

Functional Description (Continued)

Interrupts Fall Into Four Categories:

1. The Timer Interrupts: For description see Timer Section.
2. The Alarm Compare Interrupt: Issued when the value in the time compared RAM equals the counter.
3. The Periodic Interrupts: These are issued at every increment of the specific clock counter signal. Thus, an interrupt is issued every minute, second, etc. Each of these interrupts occurs at the roll-over of the specific counter.
4. The Power Fail Interrupt: Issued upon recognition of a power fail condition by the internal sensing logic. The power failed condition is determined by the signal on the $\overline{\text{PFAIL}}$ pin. The internal power fail signal is gated with the chip select signal to ensure that the power fail interrupt does not lock the chip out during a read or write.

ALARM COMPARE INTERRUPT DESCRIPTON

The alarm/time comparison interrupt is a special interrupt similar to an alarm clock wake up buzzer. This interrupt is generated when the clock time is equal to a value programmed into the alarm compare registers. Up to six bytes can be enabled to perform alarm time comparisons on the counter chain. These six bytes, or some subset thereof, would be loaded with the future time at which the interrupt will occur. Next, the appropriate bits in the Interrupt Control Register 1 are enabled or disabled (refer to detailed description of Interrupt Control Register 1). The TCP then compares these bytes with the clock time. When all the enabled compare registers equal the clock time an alarm interrupt is issued, but only if the alarm compare interrupt is enabled can the interrupt be generated externally. Each alarm compare bit in the Control Register will enable a specific byte for comparison to the clock. Disabling a compare byte is the same as setting its associated counter comparator to an ''always equal'' state. For example, to generate an interrupt at 3:15 AM of every day, load the hours compare with 0 3 (BCD), the minutes compare with 1 5 (BCD) and the faster counters with 0 0 (BCD), and then disable all other compare registers. So every day when the time rolls over from 3:14:59.99, an interrupt is issued. This bit may be reset by writing a one to bit D3 in the Main Status Register at any time after the alarm has been generated.

If time comparison for an individual byte counter is disabled, that corresponding RAM location can then be used as general purpose storage.

PERIODIC INTERRUPTS DESCRIPTION

The Periodic Flag Register contains six flags which are set by real-time generated ''ticks'' at various time intervals, see *Figure 5*. These flags constantly sense the periodic signals and may be used whether or not interrupts are enabled. These flags are cleared by any read or write operation performed on this register.

To generate periodic interrupts at the desired rate, the associated Periodic Interrupt Enable bit in Interrupt Control Register 0 must be set. Any combination of periodic interrupts may be enabled to operate simultaneously. Enabled periodic interrupts will now affect the Periodic Interrupt Flag in the Main Status Register. The Periodic Route bit in the Interrupt Routing Register is used to route the periodic interrupt events to either the INTR output or the MFO output.

When a periodic event occurs, the Periodic Interrupt Flag in the Main Status Register is set, causing an interrupt to be generated. The μP clears both flag and interrupt by writing a ''1'' to the Periodic Interrupt Flag. The individual flags in the periodic Interrupt Flag Register do not require clearing to cancel the interrupt.

If all periodic interrupts are disabled and a periodic interrupt is left pending (i.e., the Periodic Interrupt Flag is still set), the Periodic Interrupt Flag will still be required to be cleared to cancel the pending interrupt.

POWER FAIL INTERRUPTS DESCRIPTION

The Power Fail Status Flag in the Main Status Register monitors the state of the internal power fail signal. This flag may be interrogated by the μP, but it cannot be cleared; it is cleared automatically by the TCP when system power is restored. To generate an interrupt when the power fails, the Power Fail Interrupt Enable bit in Interrupt Control Register 1 is set.

The Power Fail Route bit determines which output the interrupt will appear on. Although this interrupt may not be cleared, it may be masked by clearing the Power Fail Interrupt Enable bit.

POWER FAILURE CIRCUITRY FUNCTIONAL DESCRIPTION

Since the clock must be operated from a battery when the main system supply has been turned off, the DP8570A provides circuitry to simplify design in battery backed systems. This circuitry switches over to the back up supply, and isolates the DP8570A from the host system. *Figure 6* shows a simplified block diagram of this circuitry, which consists of three major sections; 1) power loss logic: 2) battery switch over logic: and 3) isolation logic.

Detection of power loss occurs when $\overline{\text{PFAIL}}$ is low. Debounce logic provides a 30 μs–63 μs debounce time, which will prevent noise on the $\overline{\text{PFAIL}}$ pin from being interpreted as a system failure. After 30 μs–63 μs the debounce logic times out and a signal is generated indicating that system power is marginal and is failing. The Power Fail Interrupt will then be generated.

Functional Description (Continued)

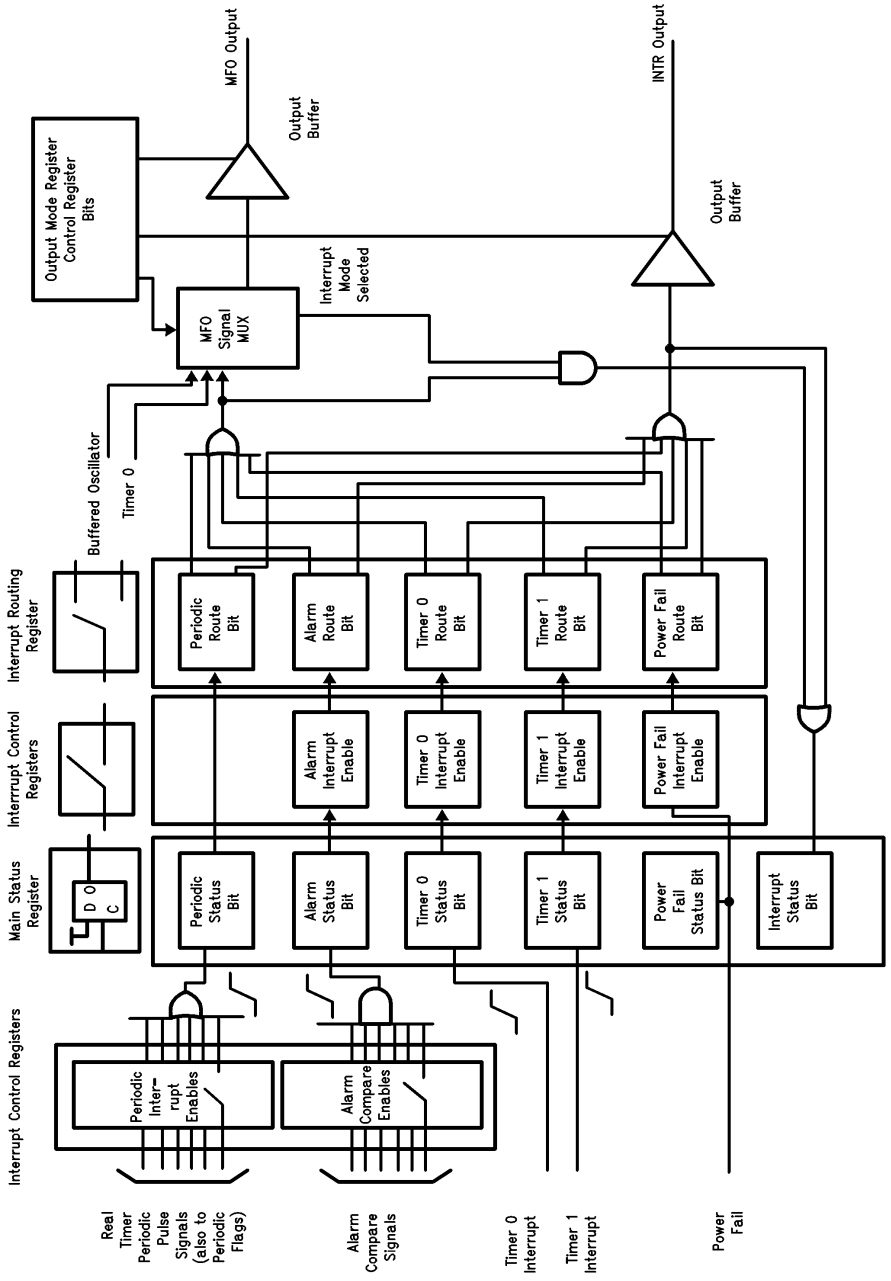

FIGURE 5. Interrupt Control Logic Overview

Functional Description (Continued)

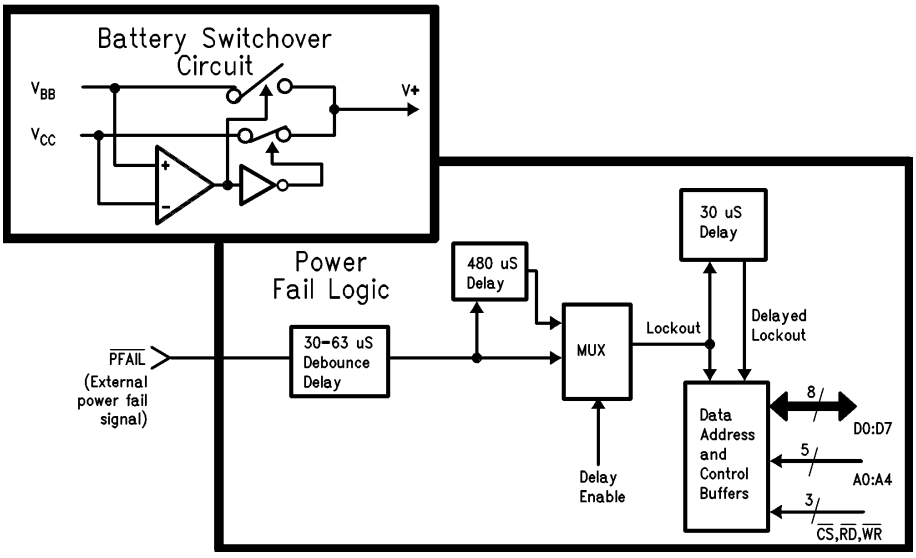

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FIGURE 6. System-Battery Switchover (Upper Left), Power Fail and Lock-Out Circuits (Lower Right)

The user may choose to have this power failed signal lock-out the TCP's data bus within 30 μs min/63 μs max or to delay the lock-out to enable μP access after power failure is detected. This delay is enabled by setting the delay enable bit in the Routing Register. Also, if the lock-out delay was not enabled the TCP will disconnect itself from the bus within 30 μs min $\rightarrow$ 63 μs max. If chip select is low when a power failure is detected, a safety circuit will ensure that if a read or write is held active continuously for greater than 30 μs after the power fail signal is asserted, the lock-out will be forced. If a lock-out delay is enabled, the DP8570A will remain active for 480 μs after power fail is detected. This will enable the μP to perform last minute bookkeeping before total system collapse. When the host CPU is finished accessing the TCP it may force the bus lock-out before 480 μs has elapsed by resetting the delay enable bit.

The battery switch over circuitry is completely independent of the $\overline{\text{PFAIL}}$ pin. A separate circuit compares V_{CC} to the V_{BB} voltage. As the main supply fails, the TCP will continue to operate from the V_{CC} pin until V_{CC} falls below the V_{BB} voltage. At this time, the battery supply is switched in, V_{CC} is disconnected, and the device is now in the standby mode. If indeterminate operation of the battery switch over circuit is to be avoided, then the voltage at the V_{CC} pin must not be allowed to equal the voltage at the V_{BB} pin.

After the generation of a lock-out signal, and eventual switch in of the battery supply, the pins of the TCP will be configured as shown in Table II. Outputs that have a pull-up resistor should be connected to a voltage no greater than V_{BB}.

TABLE II. Pin Isolation during a Power Failure

Pin	$\overline{\text{PFAIL}}$ = Logic 0	Standby Mode $V_{BB} > V_{CC}$
$\overline{\text{CS}}$, $\overline{\text{RD}}$, $\overline{\text{WR}}$	Locked Out	Locked Out
A0–A4	Locked Out	Locked Out
D0–D7	Locked Out	Locked Out
Oscillator	Not Isolated	Not Isolated
TCK, G0, G1	Not Isolated	Locked Out
$\overline{\text{PFAIL}}$	Not Isolated	Not Isolated
INTR, MFO T1	Not Isolated	Open Drain

The Timer and Interrupt Power Fail Operation bits in the Real-Time Mode Register determine whether or not the timers and interrupts will continue to function after a power fail event.

As power returns to the system, the battery switch over circuit will switch back to V_{CC} power as soon as it becomes greater than the battery voltage. The chip will remain in the locked out state as long as $\overline{\text{PFAIL}} = 0$. When $\overline{\text{PFAIL}} = 1$

Functional Description (Continued)

the chip is unlocked, but only after another 30 μs min → 63 μs max debounce time. The system designer must ensure that his system is stable when power has returned.

The power fail circuitry contains active linear circuitry that draws supply current from V_{CC}. In some cases this may be undesirable, so this circuit can be disabled by masking the power fail interrupt. The power fail input can perform all lock-out functions previously mentioned, except that no external interrupt will be issued. Note that the linear power fail circuitry is switched off automatically when using V_{BB} in standby mode.

LOW BATTERY, INITIAL POWER ON DETECT, AND POWER FAIL TIME SAVE

There are three other functions provided on the DP8570A to ease power supply control. These are an initial Power On detect circuit, which also can be used as a time keeping failure detect, a low battery detect circuit, and a time save on power failure.

On initial power up the Oscillator Fail Flag will be set to a one and the real time clock start bit reset to a zero. This indicates that an oscillator fail event has occurred, and time keeping has failed.

The Oscillator Fail flag will not be reset until the real-time clock is started. This allows the system to discriminate between an initial power-up and recovery from a power failure. If the battery backed mode is selected, then bit D6 of the Periodic Flag Register must be written low. This will not affect the contents of the Oscillator Fail Flag.

Another status bit is the low battery detect. This bit is set only when the clock is operating under the V_{CC} pin, and when the battery voltage is determined to be less than 2.1V (typical). When the power fail interrupt enable bit is low, it disables the power fail circuit and will also shut off the low battery voltage detection circuit as well.

To relieve CPU overhead for saving time upon power failure, the Time Save Enable bit is provided to do this automatically. (See also Reading the Clock: Latched Read.) The Time Save Enable bit, when set, causes the Time Save RAM to follow the contents of the clock. This bit can be reset by software, but if set before a power failure occurs, it will automatically be reset when the clock switches to the battery supply (not when a power failure is detected by the $\overline{PFAIL}$ pin). Thus, writing a one to the Time Save bit enables both a software write or power fail write.

SINGLE POWER SUPPLY APPLICATIONS

The DP8570A can be used in a single power supply application. To achieve this, the V_{BB} pin must be connected to ground, and the power connected to V_{CC} and $\overline{PFAIL}$ pins. The Oscillator Failed/Single Supply bit in the Periodic Flag Register should be set to a logic 1, which will disable the oscillator battery reference circuit. The power fail interrupt should also be disabled. This will turn off the linear power fail detection circuits, and will eliminate any quiescent power drawn through these circuits. Until the crystal select bits are initialized, the DP8570A may consume about 50 μA due to arbitrary oscillator selection at power on.

(This extra 50 μA is not consumed if the battery backed mode is selected).

TIMER FUNCTIONAL DESCRIPTION

The DP8570A contains 2 independent multi-mode timers. Each timer is composed of a 16-bit negative edge triggered binary down counter and associated control. The operation is similar to existing μP peripheral timers except that several features have been enhanced. The timers can operate in four modes, and in addition, the input clock frequency can be selected from a prescaler over a wide range of frequencies. Furthermore, these timers are capable of generating interrupts as well as hardware output signals, and both the interrupt and timer outputs are fully programmable active high, or low, open drain, or push-pull.

Figure 7 shows the functional block diagram of one of the timers. The timer consists of a 16-bit counter, two 8-bit input registers, two 8-bit output registers, clock prescaler, mode control logic, and output control logic. The timer and the data registers are organized as two bytes for each timer. Under normal operations a read/write to the timer locations will read or write to the data input register. The timer contents can be read by setting the counter Read bit (RD) in the timer control register.

TIMER INITIALIZATION

The timer's operation is controlled by a set of registers, as listed in Table III. These consist of 2 data input registers and one control register per timer. The data input registers contain the timers count down value. The Timer Control Register is used to set up the mode of operation and the input clock rate. The timer related interrupts can be controlled by programming the Interrupt Routing Register and Interrupt Control Register 0. The timer outputs are configured by the Output Mode Register.

TABLE III. Timer Associated Registers

Register Name	Register Select	Page Select	Address
Timer 0 Data MSB	X	0	10H
Timer 0 Data LSB	X	0	0FH
Timer 0 Control Register	0	0	01H
Timer 1 Data MSB	X	0	12H
Timer 1 Data LSB	X	0	11H
Timer 1 Control Register	0	0	02H
Interrupt Routing Register	0	0	04H
Interrupt Control Reg. 0	1	0	03H
Output Mode Register	1	0	02H

All these registers must be initialized prior to starting the timer(s). The Timer Control Register should first be set to select the timer mode with the timer start/$\overline{stop}$ bit reset. Then when the timer is to be started the control register should be rewritten identically but with the start/$\overline{stop}$ bit set.

TIMER OPERATION

Each timer is capable of operation in one of four modes. As mentioned, these modes are programmed in each timer's Control Register which is described later. All four modes operate in a similar manner. They operate on the two 8-bit data words stored into the Data Input Register. At the beginning of a counting cycle the 2 bytes are loaded into the timer and the timer commences counting down towards zero. The exact action taken when zero is reached depends on the mode selected, but in general, the timer output will change state, and an interrupt will be generated if the timer interrupts are unmasked.

Functional Description (Continued)

INPUT CLOCK SELECTION

The input frequency to the timers may be selected. Each timer has a prescaler that gives a wide selection of clocking rates. In addition, the DP8570A has a single external clock input pin that can be selected for either of the timers. Table IV shows the range of programmable clocks available and the corresponding setting in the Timer Control Register.

TABLE IV. Programmable Timer Input Clocks

C2	C1	C0	Selected Clock
0	0	0	External
0	0	1	Crystal Oscillator
0	1	0	(Crystal Oscillator)/4
0	1	1	93.5 μs (10.7 kHz)
1	0	0	1 ms (1 kHz)
1	0	1	10 ms (100 Hz)
1	1	0	1/10 Second (10 Hz)
1	1	1	1 Second (1 Hz)

Note that the second and third selections are not fixed frequencies, but depend on the crystal oscillator frequency chosen.

Since the input clock frequencies are usually running asynchronously to the timer Start/$\overline{\text{Stop}}$ control bit, a 1 clock cycle error may result. This error results when the Start/Stop occurs just after the clock edge (max error). To minimize this error on all clocks an independent prescaler is used for each timer and is designed so that its Start/Stop error is less than 1 clock cycle.

The count hold/gate bit in the Timer Control Register and the external enable pins, G0/G1, can be used to suspend the timer operation in modes 0, 1, and 2 (in mode 3 it is the trigger input). The external pin and the register bit are OR'ed together, so that when either is high the timers are suspended. Suspending the timer causes the same synchronization error that starting the timer does. The range of errors is specified in Table V.

TABLE V. Maximum Synchronization Errors

Clock Selected	Error
External	+ Ext. Clock Period
Crystal	+ 1 Crystal Clock Period
Crystal/4	+ 1 Crystal Clock Period
10.7 kHz	+ 32 μs
1 kHz	+ 32 μs
100 Hz	+ 32 μs
10 Hz	+ 32 μs
1 Hz	+ 32 μs

MODES OF OPERATION

Bits M0 and M1 in the Timer Control Registers are used to specify the modes of operation. The mode selection is described in Table VI.

TABLE VI. Programmable Timer Modes of Operation

M1	M0	Function	Modes
0	0	Single Pulse Generator	Mode 0
0	1	Rate Generator, Pulse Output	Mode 1
1	0	Square Wave Output	Mode 2
1	1	Retriggerable One Shot	Mode 3

MODE 0: SINGLE PULSE GENERATOR

When the timer is in this mode the output will be initially low if the Timer Start/$\overline{\text{Stop}}$ bit is low (stopped). When this mode is initiated the timer output will go high on the next falling edge of the prescaler's input clock, the contents

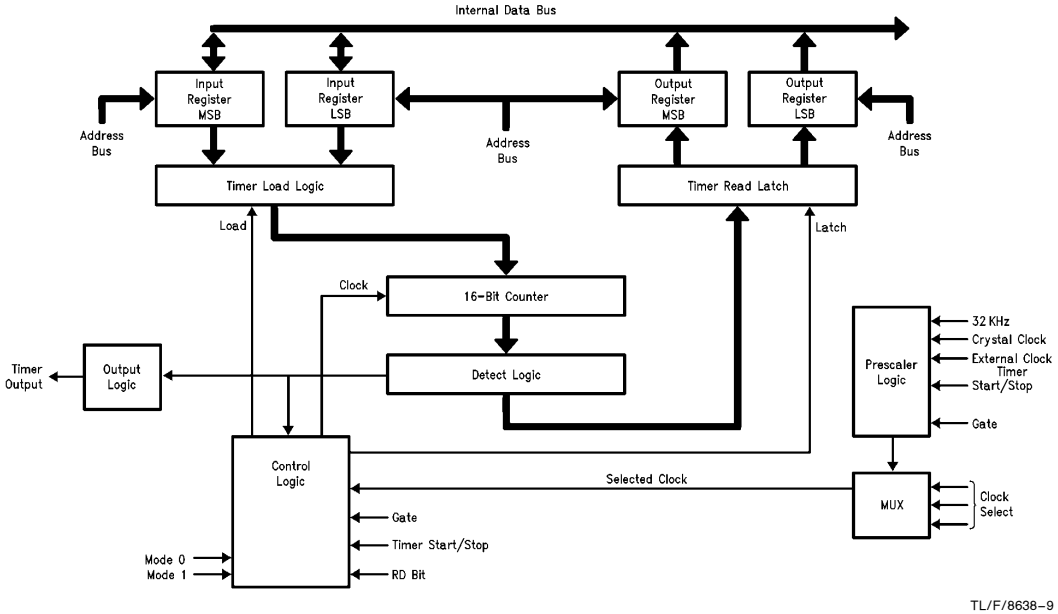

FIGURE 7. DP8570A Timer Block Diagram

Functional Description (Continued)

of the input data registers are loaded into the timer. The output will stay high until the counter reaches zero. At zero the output is reset. The result is an output pulse whose duration is equal to the input clock period times the count value (N) loaded into the input data register. This is shown in *Figure 8*.

Pulse Width = Clock Period × N

An interrupt is generated when the zero count is reached. This can be used for one-time interrupts that are set to occur a certain amount of time in the future. In this mode the Timer Start/$\overline{\text{Stop}}$ bit (TSS) is automatically reset upon zero detection. This removes the need to reset TSS before starting another operation.

The count down operation may be temporarily suspended either under software control by setting the Count Hold/Gate bit in the timer register high, or in hardware by setting the G0 or G1 pin high.

The above discussion assumes that the timer outputs were programmed to be non-inverting outputs (active high). If the polarity of the output waveform is wrong for the application the polarity can be reversed by configuring the Output Mode Register. The drive configuration can also be programmed to be push pull or open drain.

MODE 1: RATE GENERATOR

When operating in this mode the timer will operate continuously. Before the timer is started its output is low. When the timer is started the input data register contents are loaded into the counter on the negative clock edge and the output is set high (again assuming the Output Mode Register is programmed active high). The timer will then count down to zero. Once the zero count is reached the output goes low for one clock period of the timer clock. Then on the next clock the counter is reloaded automatically and the countdown repeats itself. The output, shown in *Figure 9*, is a waveform whose pulse width and period is determined by N, the input register value, and the input clock period:

Period = (N + 1) (Clock Period)

Pulse Width = Clock Period

The G0 or G1 pin and the count hold/gate bit can be used to suspend the appropriate timer countdown when either is high. Again, the output polarity is controllable as in mode 0. If enabled, an interrupt is generated whenever the zero count is reached. This can be used to generate a periodic interrupt.

MODE 2: SQUARE WAVE GENERATOR

This mode is also cyclic but in this case a square wave rather than a pulse is generated. The output square wave period is determined by the value loaded into the timer input register. This period and the duty cycle are:

Period = 2(N + 1) (Clock Period) Duty Cycle = 0.5

When the timer is stopped the output will be low, and when the Start/$\overline{\text{Stop}}$ bit is set high the timer's counter will be loaded on the next clock falling transition and the output will be set high.

The output will be toggled after the zero count is detected and the counter will then be reloaded, and the cycle will continue. Thus, every N + 1 counts the output gets toggled, as shown in *Figure 10*. Like the other modes the timer operation can be suspended either by software setting the count hold/gate bit (CHG) in the Timer Control Register or by using the gate pins. An interrupt will be generated every falling edge of the timer output, if enabled.

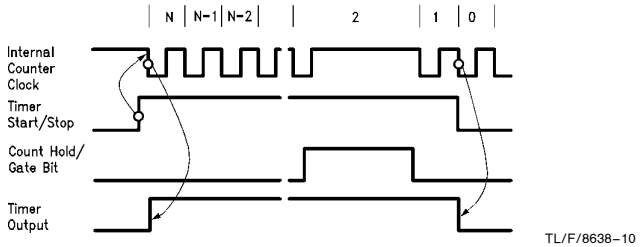

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FIGURE 8. Typical Waveforms for Timer Mode 0 (Timer Output Programmed Active High)

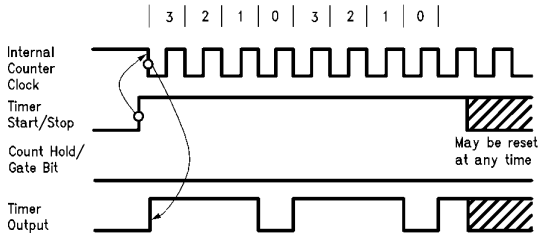

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FIGURE 9. Timing Waveforms for Timer Mode 1 (Timer Output Programmed Active High)

Functional Description (Continued)

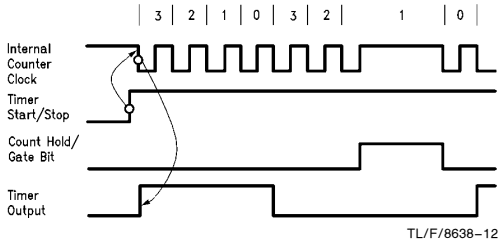


FIGURE 10. Timing Waveforms for Timer Mode 2 (Timer Output Programmed Active High)

MODE 3: RETRIGGERABLE ONE SHOT

This mode is different from the previous three modes in that this is the only mode which uses the external gate to trigger the output. Once the timer Start/$\overline{\text{Stop}}$ bit is set the output stays inactive, and nothing happens until a positive transition is received on the G1 or G0 pins, or the Count Hold/ Gate (CHG) bit is set in the timer control register. When a transition ocurs the one shot output is set active immediately; the counter is loaded with the value in the input register on the next transition of the input clock and the countdown begins. If a retrigger occurs, regardless of the current counter value, the counters will be reloaded with the value in the input register and the counter will be restarted without changing the output state. See *Figure 11*. A trigger count can occur at any time during the count cycle and can be a hardware or software signal (G0, G1 or CHG). In this mode the timer will output a single pulse whose width is determined by the value in the input data register (N) and the input clock period.

Pulse Width = Clock Period $\times$ N

Before entering mode 3, if a spurious edge has occurred on G0/G1 or the CHG bit is set to logic 1, then a pulse will appear at MFO or T1 or INTR output pin when the timer is started. To ensure this does not happen, do the following steps before entering mode 3: Configure the timer for mode 0, load a count of zero, then start the timer.

The timer will generate an interrupt only when it reaches a count of zero. This timer mode is useful for continuous ''watch dog'' timing, line frequency power failure detection, etc.

READING THE TIMERS

National has discovered that some users may encounter unacceptable error rates for their applications when reading the timers on the fly asynchronously. When doing asynchronous reads of the timers, an error may occur. The error is that a successive read may be larger than the previous read. Experimental results indicate that the typical error rate Is approximately one per 29,000 under the following conditions:

Timer clock frequency of 5 MHz.

Computer: 386/33 MHz PC/AT

Program: Microsoft ''C'' 6.0, reading and saving timer contents in a continuous loop.

Those users who find the error rate unacceptable may reduce the problem effectively to zero by employing a hardware work-around that synchronizes the writing of the read bit to the timer control register with respect to the decrementing clock. Refer to *Figure 1* in Appendix A, for a suggested hardware work-around.

A software work-around can reduce the errors but not as substantial as a hardware work-around. Software work-arounds are based on observations that the read following a bad read appeared to be valid.

This problem concerns statistical probability and is similar to metastability issues. For more information on metastability, refer to 1991 IEEE transactions on Custom Integrated Circuits Conference. paper by T.J. Gabara of AT&T Bell Laboratories, page 29.4.1.

Normally reading the timer data register addresses, 0FH and 10H for Timer 0 and 11H and 12H for Timer 1 will result in reading the input data register which contains the preset value for the timers.

To read the contents of a timer, the μP first sets the timer read bit in the appropriate Timer Control Register high. This will cause the counters contents to be latched to 2-bit–8-bit output registers, and will enable these registers to be read if the μP reads the timers input data register addresses. On reading the LSB byte the timer read bit is internally reset and subsequent reads of the timer locations will return the input register values.

DETAILED REGISTER DESCRIPTION

There are 5 external address bits: Thus, the host microprocessor has access to 32 locations at one time. An internal switching scheme provides a total of 67 locations.

This complete address space is organized into two pages. Page 0 contains two blocks of control registers, timers, real time clock counters, and special purpose RAM, while page 1 contains general purpose RAM. Using two blocks enables the 9 control registers to be mapped into 5 locations. The only register that does not get switched is the Main Status Register. It contains the page select bit and the register select bit as well as status information.

A memory map is shown in *Figure 2* and register addressing in Table VII. They show the name, address and page locations for the DP8570A.

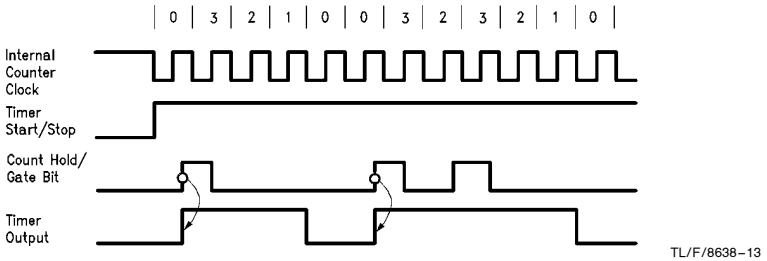


FIGURE 11. Timing Waveforms for Timer Mode 3, Output Programmed Active High

Functional Description (Continued)

TABLE VII. Register/Counter/RAM Addressing for DP8570A

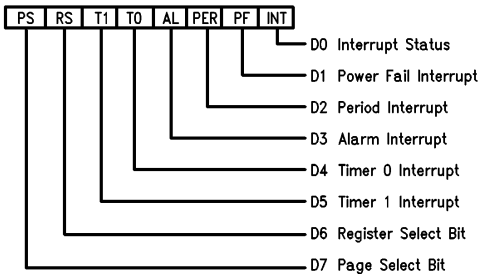
A0-4	PS (Note 1)	RS (Note 2)	Description
CONTROL REGISTERS			
00	X	X	Main Status Register
01	0	0	Timer 0 Control Register
02	0	0	Timer 1 Control Register
03	0	0	Periodic Flag Register
04	0	0	Interrupt Routing Register
01	0	1	Real Time Mode Register
02	0	1	Output Mode Register
03	0	1	Interrupt Control Register 0
04	0	1	Interrupt Control Register 1
COUNTERS (CLOCK CALENDAR)			
05	0	X	1/100, 1/10 Seconds (0–99)
06	0	X	Seconds (0–59)
07	0	X	Minutes (0–59)
08	0	X	Hours (1–12, 0–23)
09	0	X	Days of Month (1–28/29/30/31)
0A	0	X	Months (1–12)
0B	0	X	Years (0–99)
0C	0	X	Julian Date (LSB) (0–99) (Note 3)
0D	0	X	Julian Date (0–3)
0E	0	X	Day of Week (1–7)
TIMER DATA REGISTERS			
0F	0	X	Timer 0 LSB
10	0	X	Timer 0 MSB
11	0	X	Timer 1 LSB
12	0	X	Timer 1 MSB
TIME COMPARE RAM			
13	0	X	Sec Compare RAM (0–59)
14	0	X	Min Compare RAM (0–59)
15	0	X	Hours Compare RAM (1–12, 0–23)
16	0	X	DOM Compare RAM (1–28/29/30/31)
17	0	X	Months Compare RAM (1–12)
18	0	X	DOW Compare RAM (1–7)
TIME SAVE RAM			
19	0	X	Seconds Time Save RAM
1A	0	X	Minutes Time Save RAM
1B	0	X	Hours Time Save RAM
1C	0	X	Day of Month Time Save RAM
1D	0	X	Months Time Save RAM
1E	0	1	RAM
1F	0	X	RAM/Test Mode Register
01–1F	1	X	2nd Page General Purpose RAM

Note 1: PS—Page Select (Bit D7 of Main Status Register)

Note 2: RS—Register Select (Bit D6 of Main Status Register)

Note 3: The LSB counters count 0–99 until the hundreds of days counter reaches 3. Then the LSB counters count to 65 or 66 (if a leap year). The rollover is from 365/366 to 1.

MAIN STATUS REGISTER



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The Main Status Register is always located at address 0 regardless of the register block or the page selected.

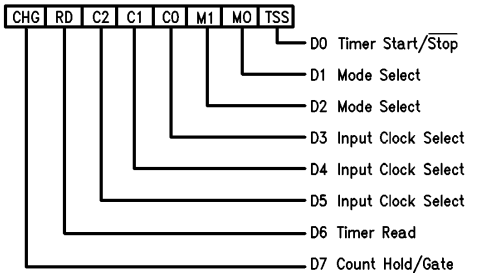
D0: This read only bit is a general interrupt status bit that is taken directly from the interrupt pins. The bit is a one when an interrupt is pending on either the INTR pin or the MFO pin (when configured as an interrupt). This is unlike D3–D5 which can be set by an internal event but may not cause an interrupt. This bit is reset when the interrupt status bits in the Main Status Register are cleared.

D1–D5: These five bits of the Main Status Register are the main interrupt status bits. Any bit may be a one when any of the interrupts are pending. Once an interrupt is asserted the μP will read this register to determine the cause. These interrupt status bits are not reset when read. Except for D1, to reset an interrupt a one is written back to the corresponding bit that is being tested. D1 is reset whenever the $\overline{\text{PFAIL}}$ pin = logic 1. This prevents loss of interrupt status when reading the register in a polled mode. D1, D3–D5 are set regardless of whether these interrupts are masked or not by bits D6 and D7 of Interrupt Control Registers 0 and 1.

D6 and D7: These bits are Read/Write bits that control which register block or RAM page is to be selected. Bit D6 controls the register block to be accessed (see memory map). The memory map of the clock is further divided into two memory pages. One page is the registers, clock and timers, and the second page contains 31 bytes of general purpose RAM. The page selection is determined by bit D7.

Functional Description (Continued)

TIMER 0 AND 1 CONTROL REGISTER



TL/F/8638–15

These registers control the operation of the timers. Each timer has its own register.

D0: This bit will Start (1) or Stop (0) the timer. When the timer is stopped the timer's prescaler and counter are reset, and the timer will restart from the beginning when started again. In mode 0 on time out the TSS bit is internally reset.

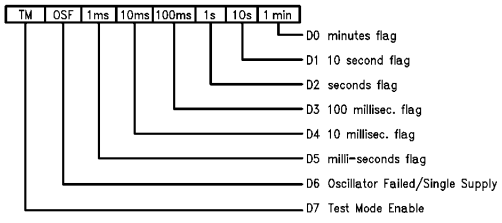
D1 and D2: These control the count mode of the timers. See Table VI.

D3–D5: These bits control which clock signal is applied to the timer's counter input. There is one external clock input pin (TCK) and either (or both) timer(s) can be selected to run off this pin: refer to Table IV for details.

D6: This is the read bit. If a one is written into this location it will cause the contents of the timer to be latched into a holding register, which can be read by the μP at any time. Reading the least significant byte of the timer will reset the RD bit. The timer read cycle can be aborted by writing RD to zero.

D7: The CHG bit has two mode dependent functions. In modes 0 through 2 writing a one to this bit will suspend the timer operation (without resetting the timer prescaler). However, in mode 3 this bit is used to trigger or re-trigger the count sequence as with the gate pins. If retriggering is desired using the CHG bit, it is not necessary to write a zero to this location prior to the re-trigger. The action of further writing a one to this bit will re-trigger the count.

PERIODIC FLAG REGISTER



TL/F/8638–16

The Periodic Flag Register has the same bit for bit correspondence as Interrupt Control Register 0 except for D6 and D7. For normal operation (i.e., not a single supply application) this register must be written to on initial power up or after an oscillator fail event. D0–D5 are read only bits, D6 and D7 are read/write.

D0–D5: These bits are set by the real time rollover events: (Time Change = 1). The bits are reset when the register is read and can be used as selective data change flags.

D6: This bit performs a dual function. When this bit is read, a one indicates that an oscillator failure has occurred and the time information may have been lost. Some of the ways an oscillator failure may be caused are: failure of the crystal; shorting OSC IN or OSC OUT to GND or V_{CC}; removal of crystal; removal of battery when in the battery backed mode (when a '0' is written to D6); lowering the voltage at the V_{BB} pin to a value less than 2.2V when in the battery backed mode. Bit D6 is automatically set to 1 on initial power-up or an oscillator fail event. The oscillator fail flag is reset by writing a one to the clock start/$\overline{\text{stop}}$ bit in the Real Time Mode Register, with the crystal oscillating.

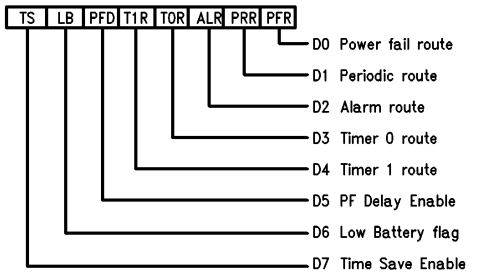
When D6 is written to, it defines whether the TCP is being used in battery backed (normal) or in a single supply mode application. When set to a one this bit configures the TCP for single power supply applications. This bit is automatically set on initial power-up or an oscillator fail event. When set, D6 disables the oscillator reference circuit. The result is that the oscillator is referenced to V_{CC}. When a zero is written to D6 the oscillator reference is enabled, thus the oscillator is referenced to V_{BB}. This allows operation in standard battery standby applications.

At initial power on, if the DP8570A is going to be programmed for battery backed mode, the V_{BB} pin should be connected to a potential in the range of 2.2V to V_{CC} − 0.4V.

For single supply mode operation, the V_{BB} pin should be connected to GND and the $\overline{\text{PFAIL}}$ pin connected to V_{CC}.

D7: Writing a one to this bit enables the test mode register at location 1F (see Table VII). This bit should be forced to zero during initialization for normal operation. If the test mode has been entered, clear the test mode register before leaving test mode. (See separate test mode application note for further details.)

INTERRUPT ROUTING REGISTER



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D0–D4: The lower 5 bits of this register are associated with the main interrupt sources created by this chip. The purpose of this register is to route the interrupts to either the MFO (multi-function pin), or to the main interrupt pin. When any bit is set the associated interrupt signal will be sent to the MFO pin, and when zero it will be sent to the INTR pin.

Functional Description (Continued)

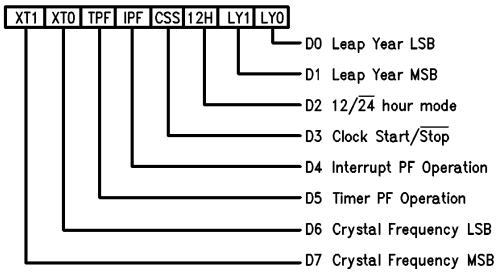
D5: The Delay Enable bit is used when a power fail occurs. If this bit is set, a 480 μs delay is generated internally before the μP interface is locked out. This will enable the μP to access the registers for up to 480 μs after it receives a power fail interrupt. After a power failure is detected but prior to the 480 μs delay timing out, the host μP may force immediate lock out by resetting the Delay Enable bit. Note if this bit is a 0 when power fails then after a delay of 30 μs min/63 μs max the μP cannot read the chip.

D6: This read only bit is set and reset by the voltage at the V_{BB} pin. It can be used by the μP to determine whether the battery voltage at the V_{BB} pin is getting too low. A comparator monitors the battery and when the voltage is lower than 2.1V (typical) this bit is set. The power fail interrupt must be enabled to check for a low battery voltage.

D7: Time Save Enable bit controls the loading of real-time-clock data into the Time Save RAM. When a one is written to this bit the Time Save RAM will follow the corresponding clock registers, and when a zero is written to this bit the time in the Time Save RAM is frozen. This eliminates any synchronization problems when reading the clock, thus negating the need to check for a counter rollover during a read cycle.

This bit must be set to a one prior to power failing to enable the Time Save feature. When the power fails this bit is automatically reset and the time is saved in the Time Save RAM.

REAL TIME MODE REGISTER



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D0–D1: These are the leap year counter bits. These bits are written to set the number of years from the previous leap year. The leap year counter increments on December 31st and it internally enables the February 29th counter state. This method of setting the leap year allows leap year to occur whenever the user wishes to, thus providing flexibility in implementing Japanese leap year function.

LY1	LY0	Leap Year Counter
0	0	Leap Year Current Year
0	1	Leap Year Last Year
1	0	Leap Year 2 Years Ago
1	1	Leap Year 3 Years Ago

D2: The count mode for the hours counter can be set to either 24 hour mode or 12 hour mode with AM/PM indicator. A one will place the clock in 12 hour mode.

D3: This bit is the master Start/$\overline{\text{Stop}}$ bit for the clock. When a one is written to this bit the real time counter's prescaler and counter chain are enabled. When this bit is reset to zero the contents of the real time counter is stopped and the prescaler is cleared. When the TCP is initially powered up this bit will be held at a logic 0 until the oscillator starts functioning correctly after which this bit may be modified. If an oscillator fail event occurs, this bit will be reset to logic 0.

D4: This bit controls the operation of the interrupt output in standby mode. If set to a one it allows Alarm, Periodic, and Power Fail interrupts to be functional in standby mode. Timer interrupts will also be functional provided that bit D5 is also set. Note that the MFO and INTR pins are configured as open drain in standby mode.

If bit D4 is set to a zero then interrupt control register 0 and bits D6 and D7 of interrupt control register 1 will be reset when the TCP enters the standby mode ($V_{BB} > V_{CC}$). They will have to be re-configured when system (V_{CC}) power is restored.

D5: This bit controls the operation of the timers in standby mode. If set to a one the timers will continue to function when the TCP is in standby mode. The input pins TCK, G0, G1 are locked out in standby mode, and cannot be used.

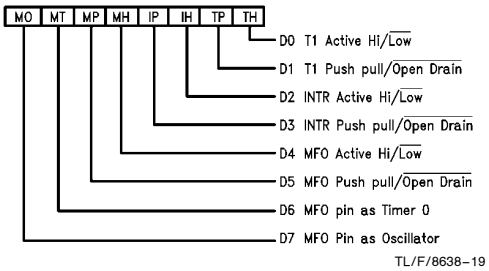
Therefore external control of the timers is not possible in standby mode. Note also that MFO and T1 pins are automatically reconfigured open drain during standby.

D6 and D7: These two bits select the crystal clock frequency as per the following table:

XT1	XT0	Crystal Frequency
0	0	32.768 kHz
0	1	4.194304 MHz
1	0	4.9152 MHz
1	1	32.000 kHz

All bits are Read/Write, and any mode written into this register can be determined by reading the register. On initial power up these bits are random.

OUTPUT MODE REGISTER



TL/F/8638–19

Functional Description (Continued)

D0: This bit, when set to a one makes the T1 (timer 1) output pin active high, and when set to a zero, it makes this pin active low.

D1: This bit controls whether the T1 pin is an open drain or push-pull output. A one indicates push pull.

D2: This bit, when set to a one makes the INTR output pin active high, and when set to a zero, it makes this pin active low.

D3: This bit controls whether the INTR pin is an open drain or push-pull output. A one indicates push-pull.

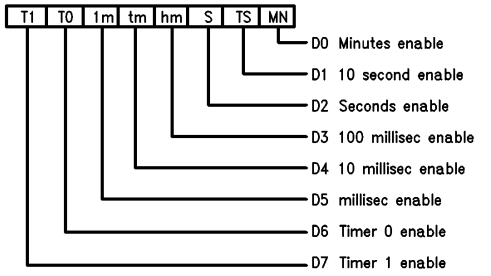
D4: This bit, when set to a one makes the MFO output pin active high, and when set to a zero, it makes this pin active low.

D5: This bit controls whether the MFO pin is an open drain or push-pull output. A one indicates push-pull.

D6 and D7: These bits are used to program the signal appearing at the MFO output, as follows:

D7	D6	MFO Output Signal
0	0	2nd Interrupt
0	1	Timer 0 Waveform
1	X	Buffered Crystal Oscillator

INTERRUPT CONTROL REGISTER 0



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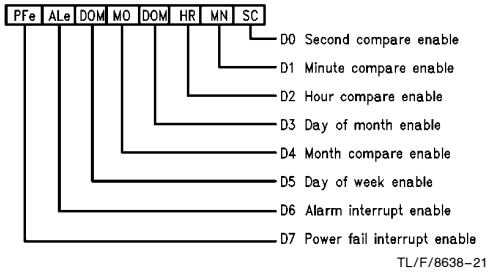
If battery backed mode is selected and the DP8570A is in standby ($V_{BB} > V_{CC}$), then all bits are controlled by D4 of the Real Time Mode Register.

D0–D5: These bits are used to enable one of the selected periodic interrupts by writing a one into the appropriate bit. These interrupts are issued at the rollover of the clock. For example, the minutes interrupt will be issued whenever the minutes counter increments. In all likelihood the interrupt will be enabled asynchronously with the real time change. Therefore, the very first interrupt will occur in less than the periodic time chosen, but after the first interrupt all subsequent interrupts will be spaced correctly. These interrupts are useful when minute, second, real time reading, or task switching is required. When all six bits are written to a 0 this disables periodic interrupts from the Main Status Register and the interrupt pin.

D6 and D7: These are individual timer enable bits. A one written to these bits enable the timers to generate interrupts to the μP.

INTERRUPT CONTROL REGISTER 1



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D0–D5: Each of these bits are enable bits which will enable a comparison between an individual clock counter and its associated compare RAM. If any bit is a zero then that clock-RAM comparator is set to the ''always equal'' state and the associated TIME COMPARE RAM byte can be used as general purpose RAM. However, to ensure that an alarm interrupt is not generated at bit D3 of the Main Status Register, all bits must be written to a logic zero.

D6: In order to generate an external alarm compare interrupt to the μP from bit D3 of the Main Status Register, this bit must be written to a logic 1. If battery backed mode is selected and the DP8570A is in standby ($V_{BB} > V_{CC}$), then this bit is controlled by D4 of the Real Time Mode Register.

D7: The MSB of this register is the enable bit for the Power Fail Interrupt. When this bit is set to a one an interrupt will be generated to the μP when $\overline{PFAIL} = 0$. If battery backed mode is selected and the DP8570A is in standby ($V_{BB} > V_{CC}$), then this bit is controlled by D4 of the Real Time Mode Register.

This bit also enables the low battery detection analog circuitry.

If the user wishes to mask the power fail interrupt, but utilize the analog circuitry, this bit should be enabled, and the Routing Register can be used to route the interrupt to the MFO pin. The MFO pin can then be left open or configured as the Timer 0 or buffered oscillator output.

Control and Status Register Address Bit Map

Main Status Register PS = 0 RS = 0 ADDRESS = 00H

D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W[1]	R/W[1]	R/W[1]	R/W[1]	R[2]	R[3]
Page Select	Register Select	Timer 1 Interrupt	Timer 0 Interrupt	Alarm Interrupt	Periodic Interrupt	Power Fail Interrupt	Interrupt Status

1. Reset by writing 1 to bit.
2. Set/reset by voltage at $\overline{PFAIL}$ pin.
3. Reset when all pending interrupts are removed.

Timer 0 Control Register PS = 0 RS = 0 Address = 01H

Count Hold Gate	Timer Read	Input Clock Select C2	Input Clock Select C1	Input Clock Select C0	Mode Select M1	Mode Select M0	Timer Start/$\overline{Stop}$

All Bits R/W

Timer 1 Control Register PS = 0 RS = 0 Address = 02H

Count Hold Gate	Timer Read	Input Clock Select C2	Input Clock Select C1	Input Clock Select C0	Mode Select M1	Mode Select M0	Timer Start/$\overline{Stop}$

All Bits R/W

Periodic Flag Register PS = 0 RS = 0 Address = 03H

R/W	R/W[4]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]
Test Mode	Osc. Fail/ Single Supply	1 ms Flag	10 ms Flag	100 ms Flag	Seconds Flag	10 Second Flag	Minute Flag

4. Read Osc fail Write 0 Batt-Backed Mode Write 1 Single Supply Mode
5. Reset by positive edge of read.

Interrupt Routing Register PS = 0 RS = 0 Address = 04H

R/W	R[6]	R/W	R/W	R/W	R/W	R/W	R/W
Time Save Enable	Low Battery Flag	Power Fail Delay Enable	Timer 1 Int. Route MFO/$\overline{INT}$	Timer 0 Int. Route MFO/$\overline{INT}$	Alarm Int. Route MFO/$\overline{INT}$	Periodic Int. Route MFO/$\overline{INT}$	Power Fail Int. Route MFO/$\overline{INT}$

6. Set and reset by V_{BB} voltage.

Real Time Mode Register PS = 0 RS = 1 Address = 01H

Crystal Freq. XT1	Crystal Freq. XT0	Timers EN on Back-Up	Interrupt EN on Back-Up	Clock Start/$\overline{Stop}$	12/$\overline{24}$ Hr. Mode	Leap Year MSB	Leap Year LSB

All Bits R/W

Output Mode Register PS = 0 RS = 1 Address = 02H

MFO as Crystal	MFO as Timer 0	MFO PP/$\overline{OD}$	MFO Active HI/$\overline{LO}$	INTR PP/$\overline{OD}$	INTR Active HI/$\overline{LO}$	T1 PP/$\overline{OD}$	T1 Active HI/$\overline{LO}$

All Bits R/W

Interrupt Control Register 0 PS = 0 RS = 1 Address = 03H

Timer 1 Interrupt Enable	Timer 0 Interrupt Enable	1 ms Interrupt Enable	10 ms Interrupt Enable	100 ms Interrupt Enable	Seconds Interrupt Enable	10 Second Interrupt Enable	Minute Interrupt Enable

All Bits R/W

Interrupt Control Register 1 PS = 0 RS = 1 Address = 04H

Power Fail Interrupt Enable	Alarm Interrupt Enable	DOW Interrupt Enable	Month Interrupt Enable	DOM Interrupt Enable	Hours Interrupt Enable	Minute Interrupt Enable	Second Interrupt Enable

All Bits R/W

Application Hints

Suggested Initialization Procedure for DP8570A in battery backed applications that use the V_{BB} pin

1. Enter the test mode by writing a 1 to bit D7 in the Periodic Flag Register.
2. Write zero to the RAM/TEST mode Register located in page 0, address HEX 1F.
3. Leave the test mode by writing a 0 to bit D7 in the Periodic Flag Register. Steps 1, 2, 3 guarantee that if the test mode had been entered during power on (due to random pulses from the system), all test mode conditions are cleared. Most important is that the OSC Fail Disable bit is cleared. Refer to AN-589 for more information on test mode operation.
4. After power on (V_{CC} and V_{BB} powered), select the correct crystal frequency bits (D7, D6 in the Real Time Mode Register) as shown in Table I.

TABLE I

Frequency	D7	D6
32.768 kHz	0	0
4.194304 MHz	0	1
4.9152 MHz	1	0
32.0 kHz	1	1

5. Enter a software loop that does the following:

   Set a 3 second (approx.) software counter. The crystal oscillator may take 1 second to start.

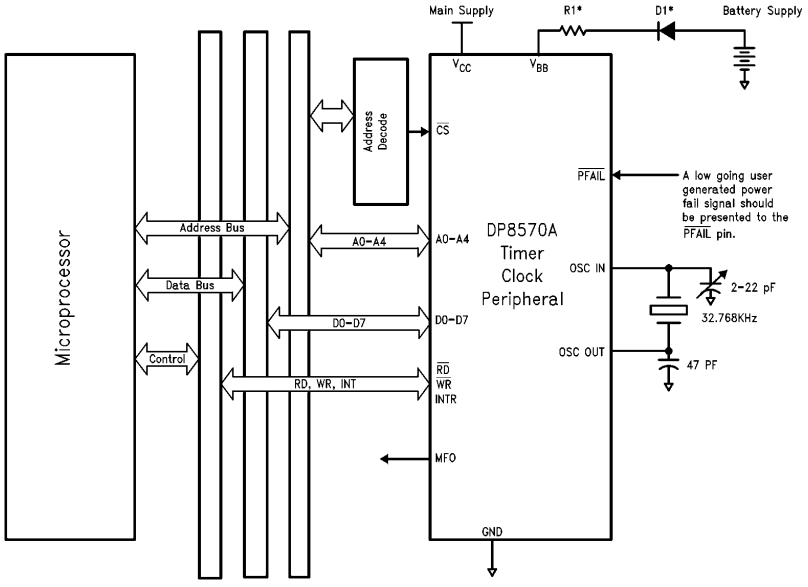
   5.1 Write a 1 to bit D3 in the Real Time Mode Register (try to start the clock). Make sure the crystal select bits remain the same as in step 1. Under normal operation, this bit can be set only if the oscillator is running. During the software loop, RAM, real time counters, output configuration, interrupt control and timer functions may be initialized.
6. Test bit D6 in the Periodic Flag Register:

   IF a 1, go to 5.1. If this bit remains a 1 after 3 seconds, then abort and check hardware. The crystal may be defective or not installed. There may be a short at OSC IN or OSC OUT to V_{CC} or GND, or to some impedance that is less than 10 MΩ.

   IF a 0, then the oscillator is running, go to step 7.
7. Write a 0 to bit D6 in the Periodic Flag Register. This action puts the clock chip in the battery backed mode. This mode can be entered only if the osc fail flag (bit D6 of the Periodic Flag Register) is a 0. Reminder, Bit D6 is a dual function bit. When read, D6 returns oscillator status. When written, D6 causes either the Battery Backed Mode, or the Single Supply Mode of operation.

   The only method to ensure the chip is in the battery backed mode is to measure the waveform at the OSC OUT pin. If the battery backed mode was selected successfully, then the peak to peak waveform at OSC OUT is referenced to the battery voltage. If not in battery backed mode, the waveform is referenced to V_{CC}. The measurement should be made with a high impedance low capacitance probe (10 MΩ, 10 pF oscilloscope probe or better). Typical peak to peak swings are within 0.6V of V_{CC} and ground respectively.
8. Write a 1 to bit D7 of Interrupt Control Register 1. This action enables the $\overline{PFAIL}$ pin and associated circuitry.
9. Write a 1 to bit D4 of the Real Time Mode Register. This action ensures that bit D7 of Interrupt Control Register 1 remains a 1 when $V_{BB} > V_{CC}$ (Standby Mode).
10. Initialize the rest of the chip as needed.

Typical Application



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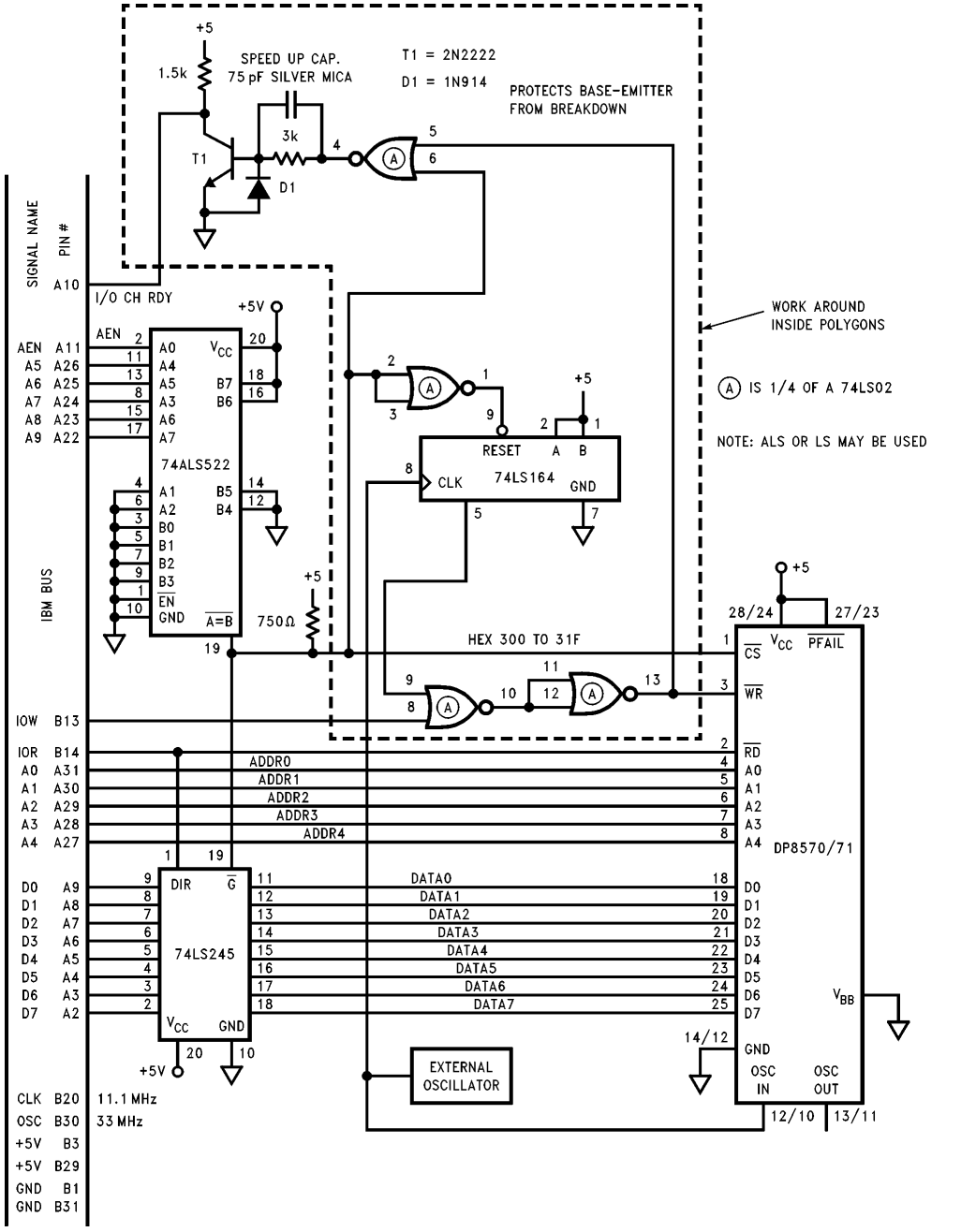
*These components may be necessary to meet UL requirements for lithium batteries. Consult battery manufacturer.

Appendix A

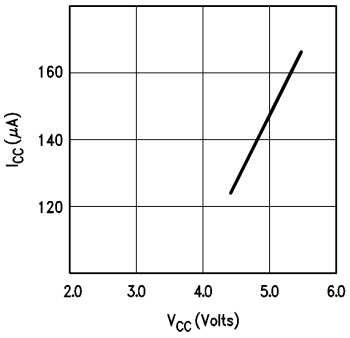


TL/F/8638–30

FIGURE A1. Typical Interface Where the "Write Strobe" is Synchronized to the Decrementing Clock of the Timer

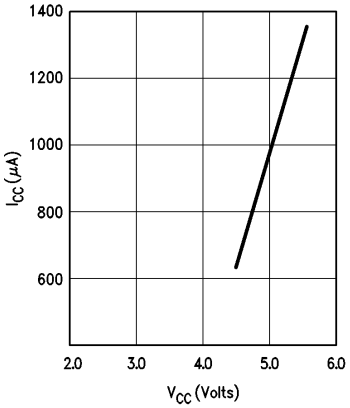
Typical Performance Characteristics

Operating Current vs Supply Voltage (Single Supply Mode F_{OSC} = 32.768 kHz)



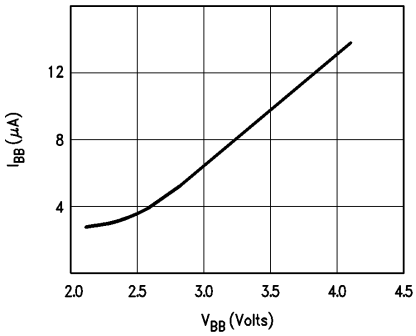
TL/F/8638–26

Operating Current vs Supply Voltage (Battery Backed Mode F_{OSC} = 32.768 kHz)



TL/F/8638–27

Standby Current vs Power Supply Voltage (F_{OSC} = 32.768 kHz)



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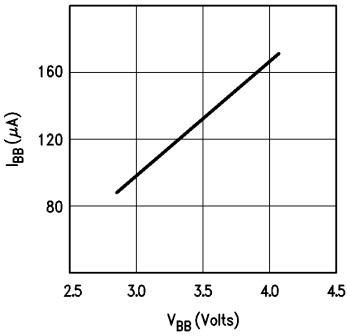
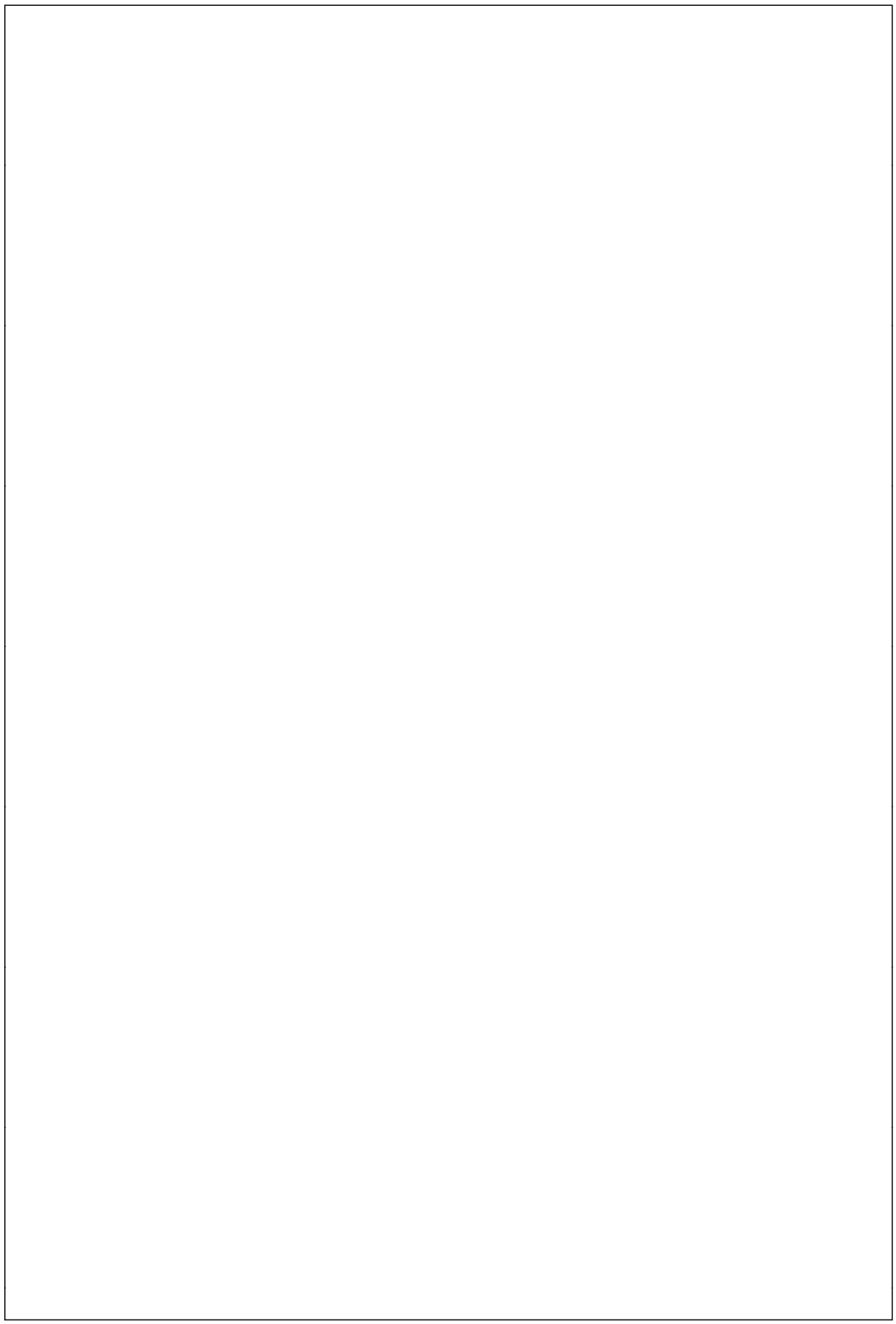
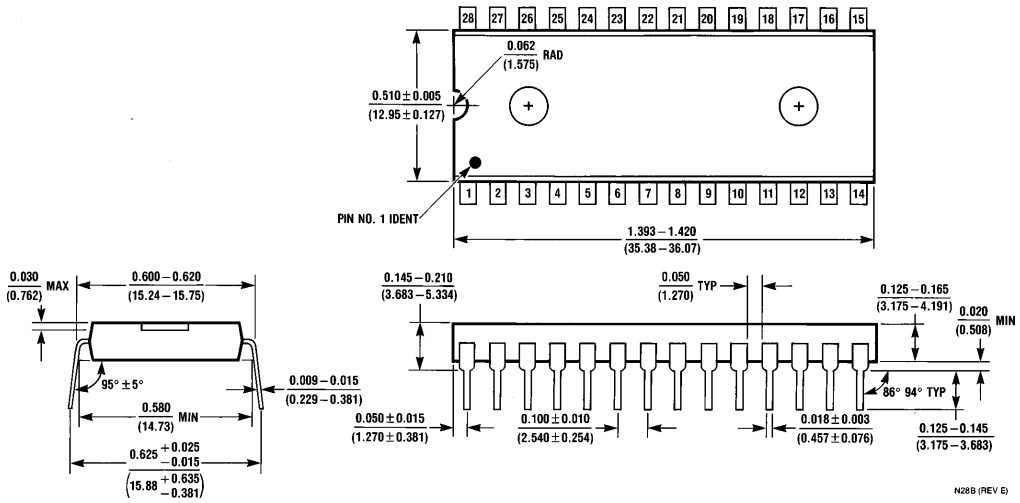
Standby Current vs Power Supply Voltage F_{OSC} = 4.194304 MHz



TL/F/8638–29

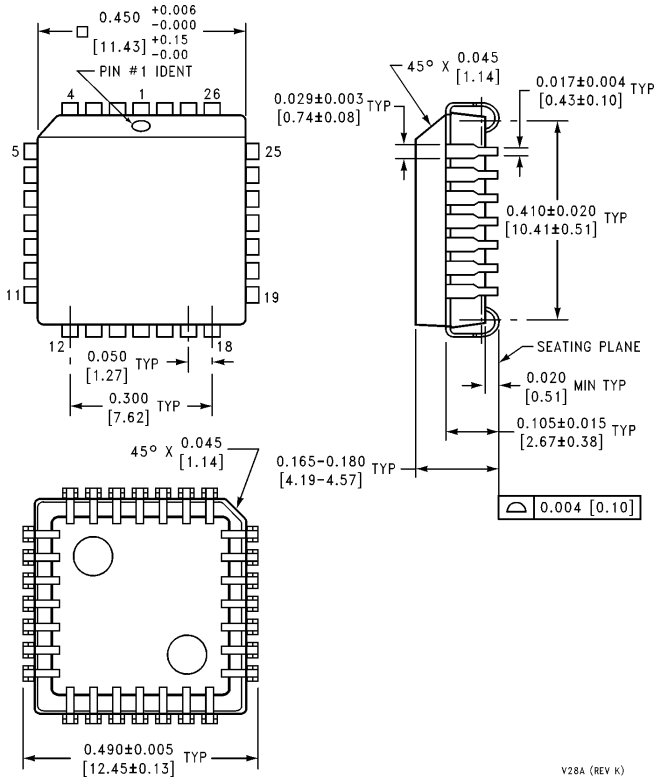


Physical Dimensions inches (millimeters)



Molded Dual-In-Line Package (N)
Order Number DP8570AN
NS Package Number N28B

Physical Dimensions inches (millimeters) (Continued)



Plastic Chip Carrier Package (V)
Order Number DP8570AV
NS Package Number V28A

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