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What is "Embedded - Microcontrollers"?

"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Obsolete
Core Processor	ACE1502
Core Size	8-Bit
Speed	25MHz
Connectivity	-
Peripherals	Brown-out Detect/Reset, LVD, POR, PWM, WDT
Number of I/O	8
Program Memory Size	2KB (2K x 8)
Program Memory Type	EEPROM
EEPROM Size	64 x 8
RAM Size	64 x 8
Voltage - Supply (Vcc/Vdd)	1.8V ~ 3.6V
Data Converters	-
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	14-SOIC (0.154", 3.90mm Width)
Supplier Device Package	14-SOIC
Purchase URL	https://www.e-xfl.com/pro/item?MUrl=&PartUrl=ace1502emx

2. Electrical Characteristics

Absolute Maximum Ratings

Ambient Storage Temperature	-65 °C to +150 °C
Input Voltage	-0.3V to V_{CC} + 0.3V
Lead Temperature (10s max)	+300°C
Electrostatic Discharge on all pins	2000V min

Operating Conditions

Relative Humidity (non-condensing)	95%
EEPROM write limits	See DC Electrical Characteristics

Part Number	Operating Voltage	Ambient Operating Temperature
ACE1502E	1.8 to 3.6V	-40°C to +85°C
ACE1502V	1.8 to 3.6V	-40°C to +125°C

ACE1502 DC Electrical Characteristics, V_{CC} = 1.8 to 3.6V

All measurements are valid for ambient operating temperature unless otherwise stated.

Symbol	Parameter	Conditions	MIN	TYP	MAX	Units
Icc^3	Suppy Current - no data EEPROM write in progress	1.8V 2.2V 2.7V 3.6V		0.4 0.4 0.5 0.6	0.6 0.6 0.7 1.0	mA mA mA mA
Icc_H	HALT Mode current	2.7V @ 25°C 2.7V @ -40°C to +85°C		 100	400 5000	nA nA
		3.6V @ 25°C 3.6V @ -40°C to +85°C		 0.25	1000 10	nA µA
$Icc_L{}^4$	IDLE Mode current	1.8V 3.6V		210 250	 400	µA µA
Vcc_W	EEPROM write voltage	Code EEPROM in Programming Mode Data EEPROM in Operating Mode	3.0 1.8	3.3	3.6 3.6	V V
S_{Vcc}	Power Supply Slope		1µs/V		10ms/V	
V_{IL}	Input Low with Schmitt Trigger buffer	Vcc = 2.2 - 3.6V			0.2Vcc	V
		Vcc < 2.2V			0.15Vcc	V
V_{IH}	Input High with Schmitt Trigger buffer	Vcc = 1.8 - 3.6V	0.8Vcc			V
I_{IP}	Input Pull-up Current	Vcc = 3.6V, V_{IN} = 0V	30	65	350	µA
I_{TL}	Tri-State Leakage	Vcc = 3.6V		2	200	nA
V_{OL}	Output Low Voltage: G0, G1, G2, G3, G4, G5, G6, G7	Vcc = 1.8 - 2.7V 2 mA sink			0.2Vcc	V
	Output Low Voltage: G0, G1, G2, G3, G4, G5, G6, G7	Vcc = 3.3 - 3.6V 7.0 mA sink			0.2Vcc	V
V_{OH}	Output High Voltage: G0, G1, G2, G3, G4, G5, G6, G7	Vcc = 2.2 - 2.7V 2 mA source	0.8Vcc			V
	Output High Voltage: G0, G1, G2, G3, G4, G5, G6, G7	Vcc = 3.3 - 3.6V 7 mA source	0.8Vcc			V

3. Icc active current is dependant on the program code.

4. Based on a continuous IDLE looping program.

ACE1502 AC Electrical Characteristics, Vcc = 1.8 to 3.6V

All measurements are valid for ambient operating temperature unless otherwise stated.

Parameter	Conditions	MIN	TYP	MAX	Units
Instruction cycle time from internal clock - setpoint	3.3V at +25°C	0.98	1.0	1.02	µs
Internal clock frequency variation	1.8V to 3.6V at constant temperature		1.2		%
	1.8V to 3.6V at full temperature range (Note 6)			6	%
Crystal oscillator frequency	(Note 5)			25	MHz
External clock frequency	(Note 5)			8	MHz
EEPROM write time			5.5	10	ms
Internal clock start up time	(Note 6)			2	ms
Oscillator start up time	(Note 6)			2400	cycles

5. The maximum permissible frequency is guaranteed by design but is not 100% tested
6. The parameter is characterized but is not 100% tested, contact Fairchild for additional characterization data.

ACE1502 Electrical Characteristics for programming

All data valid at ambient temperature between 3.0V and 3.6V. The following characteristics are guaranteed by design but are not 100% tested. See “EEPROM write time” in the AC Electrical Characteristics for definition of the programming ready time.

Parameter	Description	MIN	MAX	Units
t_{HI}	CLOCK high time	500	DC	ns
t_{LO}	CLOCK low time	500	DC	ns
t_{DIS}	SHIFT_IN setup time	100		ns
t_{DIH}	SHIFT_IN hold time	100		ns
t_{DOS}	SHIFT_OUT setup time	100		ns
t_{DOH}	SHIFT_OUT hold time	900		ns
T_{RESET}	Power On Reset time	3.2	4.5	ms
t_{LOAD1}, t_{LOAD2}, t_{LOAD3}, t_{LOAD4}	LOAD timing	5		µs

ACE1502 Low Battery Detect (LBD) Characteristics, Vcc = 1.8 to 3.6V

Parameter	Conditions	MIN	TYP	MAX	Units
LBD voltage threshold variation	-40°C to +85°C	-5		+5	%

ACE1502 Brown-out Reset (BOR) Characteristics, Vcc = 1.8 to 3.6V

Parameter	Conditions	MIN	TYP	MAX	Units
BOR voltage threshold variation	-40°C to +85°C	1.72	1.83	1.92	V

AC & DC Electrical Characteristic Graphs

The graphs in this section are for design guidance and are based on preliminary test data.

Figure 6. Internal Oscillator Frequency

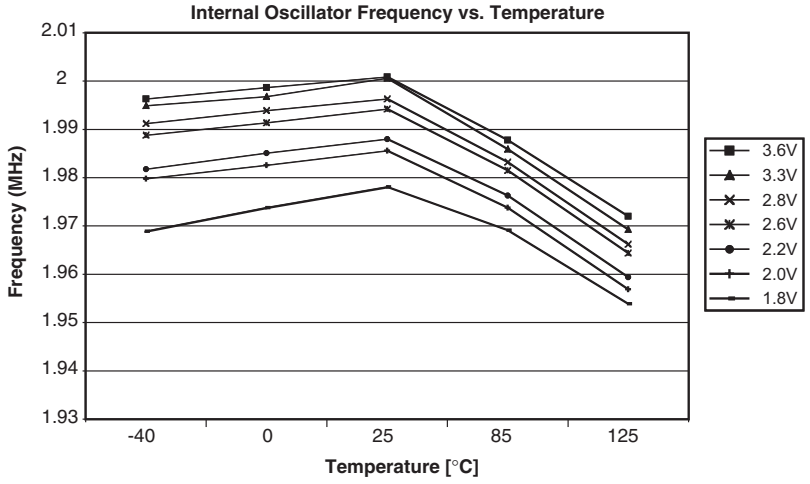
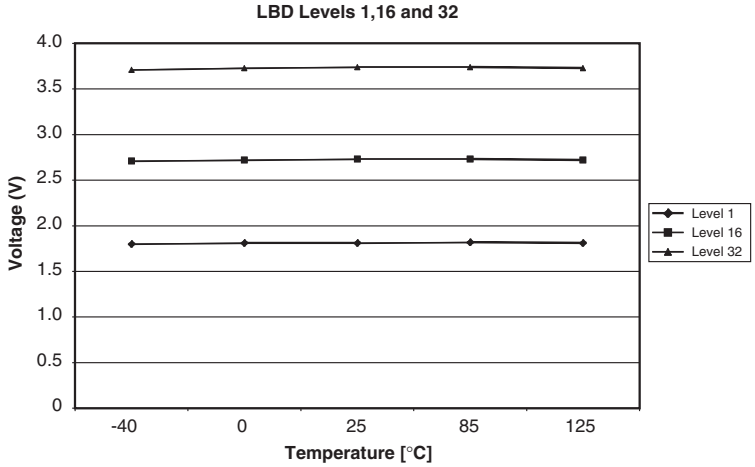


Figure 7. LBD and BOR Threshold Levels



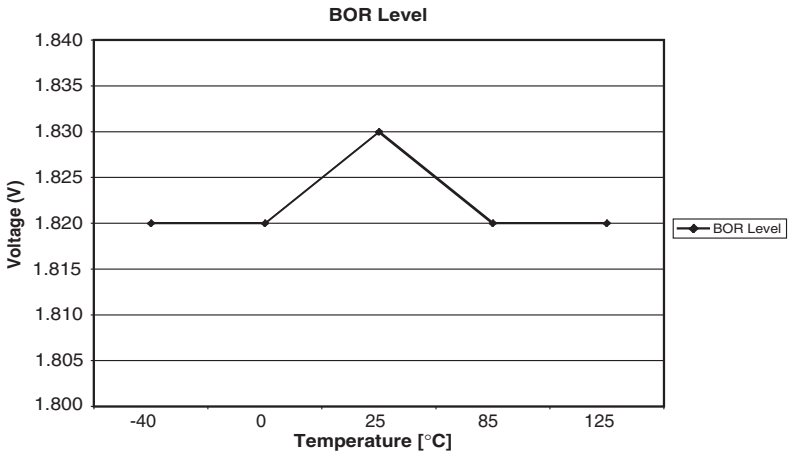


Figure 10. IDLE Mode Currents

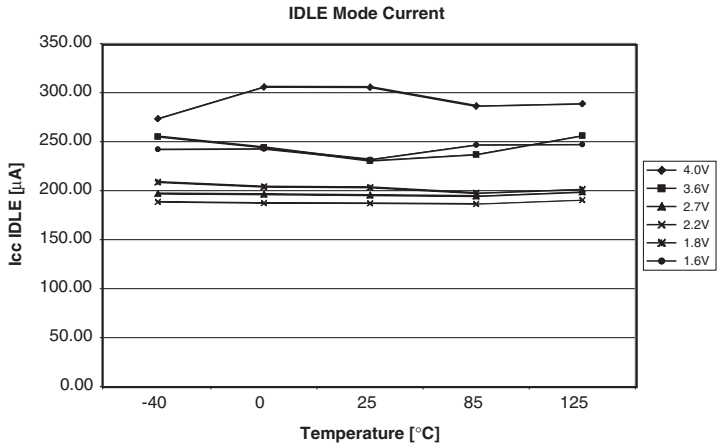
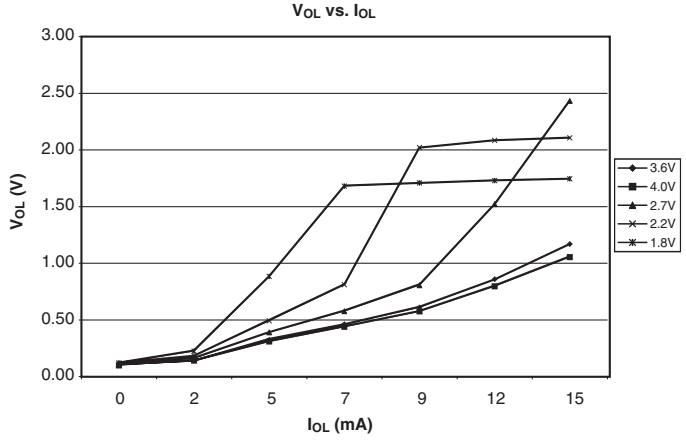
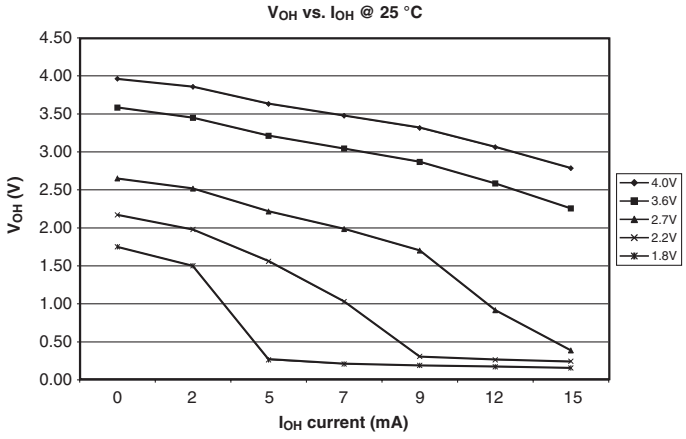


Figure 11. V_{OL}/V_{OH} vs. Current





subroutine is finished, a return from subroutine (RET) instruction is executed. The RET instruction pulls the previously stacked return address from the stack and loads it into the program counter. Execution then continues at the recovered return address.

3.1.5 Status Register (SR)

The 8-bit Status register (SR) contains four condition code indicators (C, H, Z, and N), one interrupt masking bit (G), and an EEPROM write flag (R.) The condition codes are automatically updated by most instructions. (See Table 9.)

Carry/Borrow (C)

The carry flag is set if the arithmetic logic unit (ALU) performs a carry or borrow during an arithmetic operation and by its dedicated instructions. The rotate instruction operates with and through the carry bit to facilitate multiple-word shift operations. The LDC and INVC instructions facilitate direct bit manipulation using the carry flag.

Half Carry (H)

The half carry flag indicates whether an overflow has taken place on the boundary between the two nibbles in the accumulator. It is primarily used for Binary Coded Decimal (BCD) arithmetic calculation.

Zero (Z)

The zero flag is set if the result of an arithmetic, logic, or data manipulation operation is zero. Otherwise, it is cleared.

Negative (N)

The negative flag is set if the MSB of the result from an arithmetic, logic, or data manipulation operation is set to one. Otherwise, the flag is cleared. A result is said to be negative if its MSB is a one.

Interrupt Mask (G)

The interrupt request mask (G) is a global mask that disables all maskable interrupt sources. If the G Bit is cleared, interrupts can become pending, but the operation of the core continues uninterrupted. However, if the G Bit is set an interrupt is recognized. After any reset, the G bit is cleared by default and can only be set by a software instruction. When an interrupt is recognized, the G bit is cleared after the PC is stacked and the interrupt vector is fetched. Once the interrupt is serviced, a return from interrupt instruction is normally executed to restore the PC to the value that was present before the interrupt occurred. The G bit is the reset to one after a return from interrupt is executed. Although the G bit can be set within an interrupt service routine, “nesting” interrupts in this way should only be done when there is a clear understanding of latency and of the arbitration mechanism.

3.2 Interrupt handling

When an interrupt is recognized, the current instruction completes its execution. The return address (the current value in the program counter) is pushed onto the stack and execution continues at the address specified by the unique interrupt vector (see Table 10.). This process takes five instruction cycles. At the end of the interrupt service routine, a return from interrupt (RETI) instruction is executed. The RETI instruction causes the saved address to be pulled off the stack in reverse order. The G bit is set and instruction execution resumes at the return address.

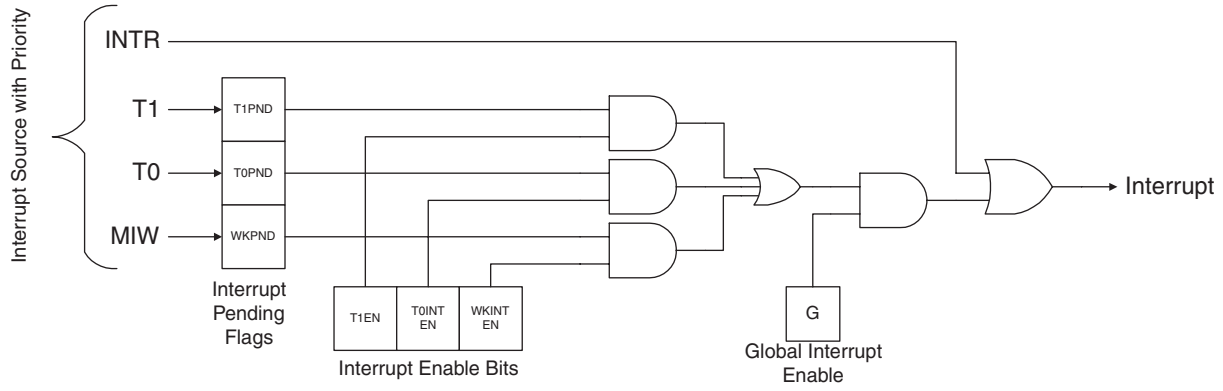
The ACEx microcontroller is capable of supporting four interrupts. Three are maskable through the G bit of the SR and the fourth (software interrupt) is not inhibited by the G bit (Figure 13.) The software interrupt is generated by the execution of the INTR instruction. Once the INTR instruction is executed, the ACEx core will interrupt whether the G bit is set or not. The INTR interrupt is executed in the same manner as the other maskable interrupts where the program counter register is stacked and the G bit is cleared. This means, if the G bit was enabled prior to the software interrupt the RETI instruction must be used to return from interrupt in order to restore the G bit to its previous state. However, if the G bit was not enabled prior to the software interrupt the RET instruction must be used.

In case of multiple interrupts occurring at the same time, the ACEx microcontroller core has prioritized the interrupts. The interrupt priority sequence in shown in Table 7.

Table 7: Interrupt Priority Sequence

Priority (4 highest, 1 lowest)	Interrupt
4	MIW (EDGEI)
3	Timer0 (TMRI0)
2	Timer1 (TMRI1)
1	Software (INTR)

Figure 13. Basic Interrupt Structure



3.3 Addressing Modes

The ACEx microcontroller has seven addressing modes indexed, indirect, direct, immediate, absolute jump, and relative jump.

Indexed

The instruction allows an 8-bit unsigned offset value to be added to the 11-LSBs of the X-pointer yielding a new effective address. This mode can be used to address either data or program memory space.

Indirect

The instruction allows the X-pointer to address any location within the data memory space.

Direct

The instruction contains an 8-bit address field that directly points to the data memory space as an operand.

Immediate

The instruction contains an 8-bit immediate field as an operand.

Inherent

This instruction has no operands associated with it.

Absolute

The instruction contains an 11-bit address that directly points to a location in the program memory space. There are two operands associated with this addressing mode. Each operand contains a byte of an address. This mode is used only for the long jump (JMP) and JSR instructions.

Relative

This mode is used for the short jump (JP) instructions where the operand is a value relative to the current PC address. With this instruction, software is limited to the number of bytes it can jump, -31 or +32.

Table 8. Instruction Addressing Modes

Instruction	Immediate			Direct		Indexed	Indirect	Inherent		Relative	Absolute
ADC	A, #			A, M		A, [#, X]	A, [X]				
ADD	A, #			A, M		A, [#, X]	A, [X]				
AND	A, #			A, M		A, [#, X]	A, [X]				
OR	A, #			A, M		A, [#, X]	A, [X]				
SUBC	A, #			A, M		A, [#, X]	A, [X]				
XOR	A, #			A, M		A, [#, X]	A, [X]				
CLR				M				A	X		
INC				M				A	X		
DEC				M				A	X		
IFEQ	A, #	X, #	M,#	A, M		A, [#, X]	A, [X]				
IFGT	A, #	X, #		A, M		A, [#, X]	A, [X]				
IFNE	A, #	X, #	M,#	A, M		A, [#, X]	A, [X]				
IFLT		X, #									
SC								no-op			
RC								no-op			
IFC								no-op			
IFNC								no-op			
INVC								no-op			
LDC				#, M							
STC				#, M							
RLC				M				A			
RRC				M				A			
LD	A, #	M, #	X, #	A, M	M, M	A, [#, X]	A, [X]				
ST				A, M		A, [#, X]	A, [X]				
NOP								no-op			
IFBIT	#, A			#, M			[#, X]				
IFNBIT	#, A			#, M			[#, X]				
SBIT				#, M			[#, X]				
RBIT				#, M			[#, X]				
JP										Rel	
JSR						[#, X]					M
JMP						[#, X]					M
RET								no-op			
RETI								no-op			
INTR								no-op			

Table 9. Instruction Cycles and Bytes

Mnemonic	Operand	Bytes	Cycles	Flags affected
ADC	A, [X]	1	1	C,H,Z,N
ADC	A, [#,X]	2	3	C,H,Z,N
ADC	A, M	2	2	C,H,Z,N
ADC	A, #	2	2	C,H,Z,N
ADD	A, [X]	1	1	Z,N
ADD	A, [#,X]	2	3	Z,N
ADD	A, M	2	2	Z,N
ADD	A, #	2	2	Z,N
AND	A, [X]	1	1	Z,N
AND	A, [#,X]	2	3	Z,N
AND	A, M	2	2	Z,N
AND	A, #	2	2	Z,N
CLR	X	1	1	Z
CLR	A	1	1	C,H,Z,N
CLR	M	2	1	C,H,Z,N
DEC	X	1	1	Z
DEC	A	1	1	Z,N
DEC	M	2	2	Z,N
IFBIT	#, A	1	1	None
IFBIT	#, M	2	2	None
IFBIT	#, [X]	1	1	None
IFC		1	1	None
IFEQ	A, [#, X]	2	3	None
IFEQ	A, [X]	1	1	None
IFEQ	A, #	2	2	None
IFEQ	A, M	2	2	None
IFEQ	M, #	3	3	None
IFEQ	X, #	3	3	None
IFGT	A, [#, X]	2	3	None
IFGT	A, [X]	1	1	None
IFGT	A, #	2	2	None
IFGT	A, M	2	2	None
IFGT	X, #	3	3	None
IFLT	X, #	3	3	None
IFNBIT	#, A	1	1	None
IFNBIT	#, M	2	2	None
IFNBIT	#, [X]	1	1	None
IFNC		1	1	None
IFNE	A, [#, X]	2	3	None
IFNE	A, [X]	1	1	None
IFNE	A, #	2	2	None
IFNE	A, M	2	2	None
IFNE	X, #	3	3	None
IFNE	M, #	3	3	None
INC	A	1	1	Z,N
INC	M	2	2	Z,N

Mnemonic	Operand	Bytes	Cycles	Flags affected
INC	X	1	1	Z
INTR		1	5	None
INVC		1	1	C
JMP	M	3	4	None
JMP	[#, X]	2	3	None
JP		1	1	None
JSR	M	3	5	None
JSR	[#, X]	2	5	None
LD	A, #	2	2	None
LD	A, [#,X]	2	3	None
LD	A, [X]	1	1	None
LD	A, M	2	2	None
LD	M, #	3	3	None
LD	M, M	3	3	None
LD	X, #	3	3	None
LDC	#, M	2	2	C
NOP		1	1	None
OR	A, [X]	1	1	Z, N
OR	A, [#,X]	2	3	Z,N
OR	A, M	2	2	Z,N
OR	A, #	2	2	Z,N
RBIT	#, [X]	1	2	Z,N
RBIT	#, M	2	2	Z,N
RC		1	1	C,H
RET		1	5	None
RETI		1	5	None
RLC	A	1	1	C,Z,N
RLC	M	2	2	C,Z,N
RRC	A	1	1	C,Z,N
RRC	M	2	2	C,Z,N
SBIT	#, [X]	1	2	Z,N
SBIT	#, M	2	2	Z,N
SC		1	1	C,H
ST	A, [#,X]	2	3	None
ST	A, [X]	1	1	None
ST	A, M	2	2	None
STC	#, M	2	2	Z,N
SUBC	A, [X]	1	1	C,H,Z,N
SUBC	A, [#,X]	2	3	C,H,Z,N
SUBC	A, M	2	2	C,H,Z,N
SUBC	A, #	2	2	C,H,Z,N
XOR	A, [X]	1	1	Z,N
XOR	A, [#,X]	2	3	Z,N
XOR	A, M	2	2	Z,N
XOR	A, #	2	2	Z,N

3.5 Memory

The ACEx microcontroller has 64 bytes of SRAM and 64 bytes of EEPROM available for data storage. The device also has 2K bytes of EEPROM for program storage. Software can read and write to SRAM and data EEPROM but can only read from the code EEPROM. While in normal mode, the code EEPROM is protected from any writes. The code EEPROM can only be rewritten when the device is in program mode and if the write disable (WDIS) bit of the initialization register is not set to 1.

While in normal mode, the user can write to the data EEPROM array by 1) polling the ready (R) flag of the SR, then 2) executing the appropriate instruction. If the R flag is 1, the data EEPROM block is ready to perform the next write. If the R flag is 0, the data EEPROM is busy. The data EEPROM array will reset the R flag after the completion of a write cycle. Attempts to read, write, or enter HALT/IDLE mode while the data EEPROM is busy (R = 0) can affect the current data being written.

3.6 Initialization Registers

The ACEx microcontroller has two 8-bit wide initialization registers. These registers are read from the memory space on power-up to initialize certain on-chip peripherals. Figure 14 provides a detailed description of Initialization Register 1. The Initialization Register 2 is used to trim the internal oscillator to its appropriate frequency. This register is pre-programmed in the factory to yield an internal instruction clock of 1MHz.

The Initialization Registers 1 and 2 can be read from and written to during programming mode. However, re-trimming the internal oscillator (writing to the Initialization Register 2) once it has left the factory is *discouraged*.

Figure 14. Initialization Register 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CMODE[0]	CMODE[1]	WDEN	BOREN	LDBEN	UBD	WDIS	RDIS

(0) RDIS — If set, disables attempts to read the contents from the memory while in programming mode. Once this bit is set, it is no longer possible to unset this option even though the write disable option is not enabled.

(1) WDIS — If set, disables attempts to write new contents to the memory while in programming mode

(2) UBD — If set, the device will not allow any writes to occur in the upper block of data EEPROM (0x60-0x7F)

(3) LBDEN — If set, the Low Battery Detection circuit is enabled

(4) BOREN — If set, allows a BOR to occur if Vcc falls below the voltage reference level

(5) WDEN — If set, enables the on-chip processor watchdog circuit

(6) CMODE[1] — Clock mode select bit 1 (See Table 16)

(7) CMODE[0] — Clock mode select bit 0 (See Table 16)

4. Timer 1

Timer 1 is a versatile 16-bit timer that can operate in one of four modes:

- **Pulse Width Modulation** (PWM) mode, which generates pulses of a specified width and duty cycle
- **External Event Counter** mode, which counts occurrences of an external event
- **Standard Input Capture** mode, which measures the elapsed time between occurrences of external events
- **Difference Input Capture** mode, which automatically measures the difference between edges.

Timer 1 contains a 16-bit timer/counter register (TMR1), a 16-bit auto-reload/capture register (T1RA), a secondary 16-bit auto-reload register (T1RB), and an 8-bit control register (T1CNTRL). All register are memory-mapped for simple access through the core with both the 16-bit registers organized as a pair of 8-bit register bytes {TMR1HI, TMR1LO}, {T1RAHI, T1RALO}, and {T1RBHI, T1RBLO}. Depending on the operating mode, the timer contains an external input or output (T1) that is multiplexed with the I/O pin G2. By default, the TMR1 is reset to 0xFFFF, T1RA/T1RB is reset to 0x0000, and T1CNTRL is reset to 0x00.

The timer can be started or stopped through the T1CNTRL register bit T1C0. When running, the timer counts down (decrements) every clock cycle. Depending on the operating mode, the timer's clock is either the instruction clock or a transition on the T1 input. In addition, occurrences of timer underflow (transitions from 0x0000 to 0xFFFF/T1RA/T1RB value) can either generate an interrupt and/or toggle the T1 output pin.

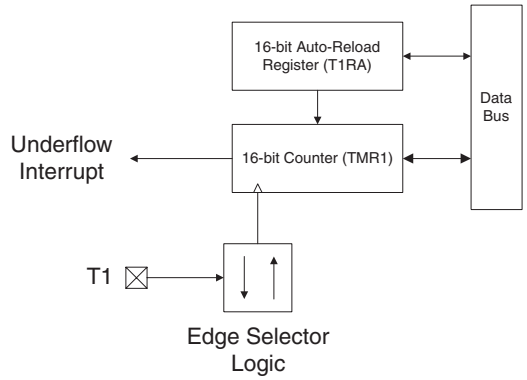
Timer 1's interrupt (TMRI1) can be enabled by interrupt enable (T1EN) bit in the T1CNTRL register. When the timer interrupt is enabled, depending on the operating mode, the source of the interrupt is a timer underflow and/or a timer capture.

4.1 Timer control bits

Reading and writing to the T1CNTRL register controls the timer's operation. By writing to the control bits, the user can enable or disable the timer interrupts, set the mode of operation, and start or stop the timer. The T1CNTRL register bits are described in Table 11 and Table 12.

5. Write the appropriate control value to the T1CNTRL register to select External Event Counter mode, to clock every falling edge, to set the enable bit, to clear the pending flag, and to start the counter. (See Table 11 and Table 12)
   - LD T1CNTRL, #34H (#00h) ;Setting the T1C0 bit starts the timer
6. When the counter underflows, the interrupt service routine must clear the T1PND flag and take whatever action is required once the number of events occurs. If the software wishes to merely count the number of events and the anticipated number may exceed 65,536, the interrupt service routine should record the number of underflows by incrementing a counter in memory. Software can then calculate the correct event count.
   - RBIT T1PND, T1CNTRL ; T1PND equals 3

Figure 16. External Event Counter Mode



4.4 Mode 3: Input Capture Mode

In the Input Capture mode, the timer is used to measure elapsed time between edges of an input signal. Once the timer is configured for this mode, the timer starts counting down immediately at the instruction clock rate. The Timer 1 will then transfer the current value of the TMR1 register into the T1RA register as soon as the selected edge of T1 is sensed. The input signal on T1 must have a pulse width equal to or greater than one instruction clock cycle. At every T1RA capture, software can then store the values into RAM to calculate the elapsed time between edges on T1. At any given time (with proper consideration of the state of T1) the timer can be configured to capture on positive-going or negative-going edges. A block diagram of the timer's Input Capture mode of operation is shown in Figure 17.

The timer has one interrupt (TMRI1) that is maskable through the T1EN bit of the T1CNTRL register. However, the core is only interrupted if the T1EN bit and the G (Global Interrupt enable) bit of the SR is set. The Input Capture mode contains two interrupt pending flags 1) the TMR1 register capture in T1RA (T1PND) and 2) timer underflow (T1C0). If interrupts are enabled, the timer will generate an interrupt each time a pending flag is set (provided that the pending flag was previously cleared.) The interrupt service routine is responsible for proper handling of the T1PND flag, T1C0 flag, and the T1EN bit.

For this operating mode, the T1C0 control bit serves as the timer underflow interrupt pending flag. The Timer 1 interrupt service routine must read both the T1PND and T1C0 flags to determine the cause of the interrupt. A set T1C0 flag means that a timer underflow occurred whereas a set T1PND flag means that a capture occurred in T1RA. It is possible that both flags will be found set, meaning that both events occurred at the same time. The interrupt service routine should take this possibility into consideration.

Because the T1C0 bit is used as the underflow interrupt pending flag, it is not available for use as a start/stop bit as in the other modes.

The TMR1 register counts down continuously at the instruction clock rate starting from the time that the input capture mode is selected. (See Table 11 and Table 12) To stop the timer from running, you must change the mode to an alternate mode (PWM or External Event Counter) while resetting the T1C0 bit.

The input pins can be independently configured to sense positive-going or negative-going transitions. The edge sensitivity of pin T1 is controlled by bit T1C1 as indicated in Table 12.

The edge sensitivity of a pin can be changed without leaving the input capture mode even while the timer is running. This feature allows you to measure the width of a pulse received on an input pin.

For example, the T1 pin can be programmed to be sensitive to a positive-going edge. When the positive edge is sensed, the TMR1 register contents is transferred to the T1RA register and a Timer 1 interrupt is generated. The Timer 1 interrupt service routine records the contents of the T1RA register, changes the edge sensitivity from positive to negative-going edge, and clears the T1PND flag. When the negative-going edge is sensed another Timer 1 interrupt is generated. The interrupt service routine reads the T1RA register again. The difference between the previous reading and the current reading reflects the elapsed time between the positive edge and negative edge of the T1 input signal i.e. the width of the positive-going pulse.

Remember that the Timer1 interrupt service routine must test the T1C0 and T1PND flags to determine the cause of the interrupt. If the T1C0 flag caused the interrupt, the interrupt service routine should record the occurrence of an underflow by incrementing a counter in memory or by some other means. The software that calculates the elapsed time between captures should take into account the number of underflow that occurred when making its calculation.

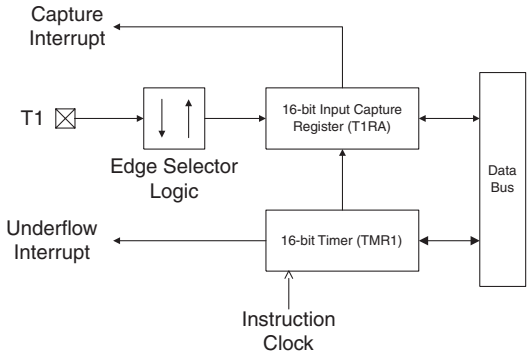
The following steps show how to properly configure Timer 1 to operate in the Input Capture mode.

1. Configure T1 as an input by clearing bit 2 of PORTGC.
   - RBIT 2, PORTGC ; Configure G2 as an input
2. Initialize T1 to input with pull-up by setting bit 2 of PORTGD.
   - SBIT 2, PORTGD ; Set G2 high
3. Enable the global interrupt enable bit.
   - SBIT 4, STATUS
4. With the timer stopped, load the initial time into the TMR1 register (typically the value is 0xFFFF.)
   - LD TMR1LO, #0FFH
   - LD TMR1HI, #0FFH
5. Write the appropriate control value to the T1CNTRL register to select Input Capture mode, to sense the appropriate edge, to set the enable bit, and to clear the pending flags.

(See Table 11 and Table 12)
- LD T1CNTRL, #64H ; T1C1 is the edge select bit

6. As soon as the input capture mode is enabled, the timer starts counting. When the selected edge is sensed on T1, the T1RA register is loaded and a Timer 1 interrupt is triggered.

Figure 17. Input Capture Mode



4.5 Mode 4: Difference Input Capture Mode

The Difference Input Capture mode works similarly to the standard Input Capture mode. However, for the Difference Input Capture the timer automatically captures the elapsed time between the selected edges without the core needing to perform the calculation.

For example, the standard Input Capture mode requires that the timer be configured to capture a particular edge (rising or falling) at which time the timer's value is copied into the capture register. If the elapsed time is required, software must move the captured data into RAM and reconfigure the Input Capture mode to capture on the next edge (rising or falling). Software must then subtract the difference between the two edges to yield useful information.

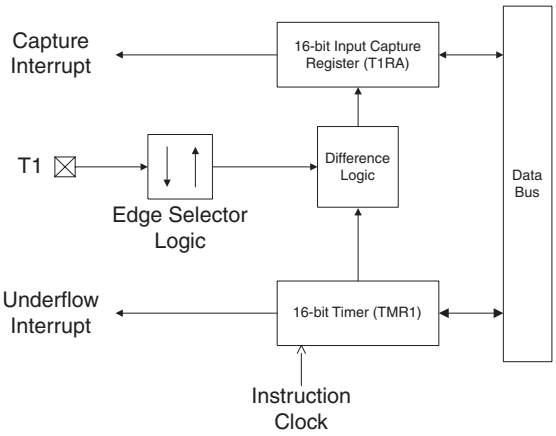
The Difference Capture mode eliminates the need for software intervention and allows for capturing very short pulse or cycle widths. It can be configured to capture the elapsed time between:

1. rising edge to falling edge
2. rising edge to rising edge
3. falling edge to rising edge
4. falling edge to falling edge

Once configured, the Difference Capture timer waits for the first selected edge. When the edge transition has occurred, the 16-bit timer starts counting up based every instruction clock cycle. It will continue to count until the second selected edge transition occurs at which time the timer stops and stores the elapse time into the T1RA register.

Software can now read the difference between transitions directly without using any processor resources. However, like the standard Input Capture mode both the capture (T1PND) and the underflow (T1C0) flags must be monitored and handled appropriately. This feature allows the ACEx microcontroller to capture very small pulses where standard microcontrollers might have missed cycles due to the limited bandwidth.

Figure 18. Difference Capture Mode



5. Timer 0

Timer 0 is a 12-bit free running idle timer. Upon power-up or any reset, the timer is reset to 0x000 and then counts up continuously based on the instruction clock of 1MHz (1 µs). Software cannot read from or write to this timer. However, software can monitor the timer's pending (T0PND) bit that is set every 8192 cycles (initially 4096 cycles after a reset). The T0PND flag is set every other time the timer overflows (transitions from 0xFFF to 0x000) through a divide-by-2 circuit. After an overflow, the timer will reset and restart its counting sequence.

Software can either poll the T0PND bit or vector to an interrupt subroutine. In order to interrupt on a T0PND, software must be sure to enable the Timer 0 interrupt enable (T0INTEN) bit in the Timer 0 control (T0CNTRL) register and also make sure the G bit is set in SR. Once the timer interrupt is serviced, software should reset the T0PND bit before exiting the routine. Timer 0 supports the following functions:

1. Exiting from IDLE mode (See Section 16 for details.)
2. Start up delay from HALT mode
3. Watchdog pre-scalar (See Section 6 for details.)

The T0INTEN bit is a read/write bit. If set to 0, interrupt requests from the Timer 0 are ignored. If set to 1, interrupt requests are accepted. Upon reset, the T0INTEN bit is reset to 0.

The T0PND bit is a read/write bit. If set to 1, it indicates that a Timer 0 interrupt is pending. This bit is set by a Timer 0 overflow and is reset by software or system reset.

The WKINTEN bit is used in the Multi-input Wakeup/Interrupt block. See Section 8 for details.

Figure 19. Timer 0 Control Register Definition (T0CNTRL)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
WKINTEN	x	x	x	x	x	T0PND	T0INTEN

The OCFLAG signal is read only and goes high when the last encoded bit of the DAT0 frame is transmitting. The OCFLAG signal is used to inform software that the DAT0 frame transmission operation is completing (see Figure 25). If multiple DAT0 frames are to be transmitted consecutively, software should poll the OCFLAG signal for a 1. Once OCFLAG is 1, DAT0 must be reload and the START / STOP bit must be restored to 1 in order to begin the new frame transmission without interruptions (the synchronization period). Since OCFLAG remains high during the entire last encoded DAT0 frame bit transmission, software should wait for the HBC to clear the OCFLAG signal before polling for the new OCFLAG high pulse. If new data is not reloaded into DAT0 and the START signal (STOP is active) is not set before the OCFLAG is 0, the transmission process will end (TXBUSY is cleared) and a new process will begin starting with the synchronization period.

Figure 24 and Figure 25 shows how the HBC performs its data encoding. In the example, two frames are encoded and transmitted consecutively with the following bit encoding format specification:

1. Transmission frequency = 62.5KHz
2. Data to be encoded = 0x52, 0x92 (all 8-bits)
3. Each bit should be encoded as a 3-bit binary value, '1' = 110b and '0' = 100b
4. Transmission output port : G2

To perform the data transmission, software must first initialize the PSCALE, BPSEL, HPATTERN, LPATTERN, and DAT0 registers with the appropriate values.

```
LD   PSCALE, #03H        ; (1MHz ?? 4) ?? 4 = 62.5KHz
LD   BPSEL, #012H        ; BPH = 2, BPL = 2 (3 bits each)
LD   HPATTERN, #0C0H     ; HPATTERN = 0xC0
LD   LPATTERN, #090H     ; LPATTERN = 0x90
LD   DAT0, #052H         ; DAT0 = 0x52
```

Once the basic registers are initialized, the HBC can be started. (At the same time, software must set the number of data bits per data frame and select the desired output port.)

```
LD   HBCNTRL, #27H       ; START / STOP = 1,
                         FRAME = 7, IOSEL = 0
```

After the HBC has started, software must then poll the OCFLAG for a high pulse and restore the DAT0 register and the START signal to continue with the next data transmission.

```
LOOP_HI:
  IFBIT  OCFLAG, HBCNTRL     ; Wait for OCFLAG = 1
  JP     NXT_FRAME
  JP     LOOP_HI

NXT_FRAME:
  LD     DAT0, #092H         ; DAT0 = 0x92
  SBIT   START, HBCNTRL      ; START / STOP = 1
```

If software is to proceed with another data transmission, the OCFLAG must be zero before polling for the next OCFLAG high pulse. However, since the specification in the example requires no other data transmission software can proceed as desired.

```
LOOP_LO:
  IFBIT  OCFLAG, HBCNTRL     ; Wait for OCFLAG = 0
  JP     LOOP_LO
  Etc.                       ; Program proceeds
                             as desired
```

Figure 21. Hardware Bit-coder (HBC) Block Diagram

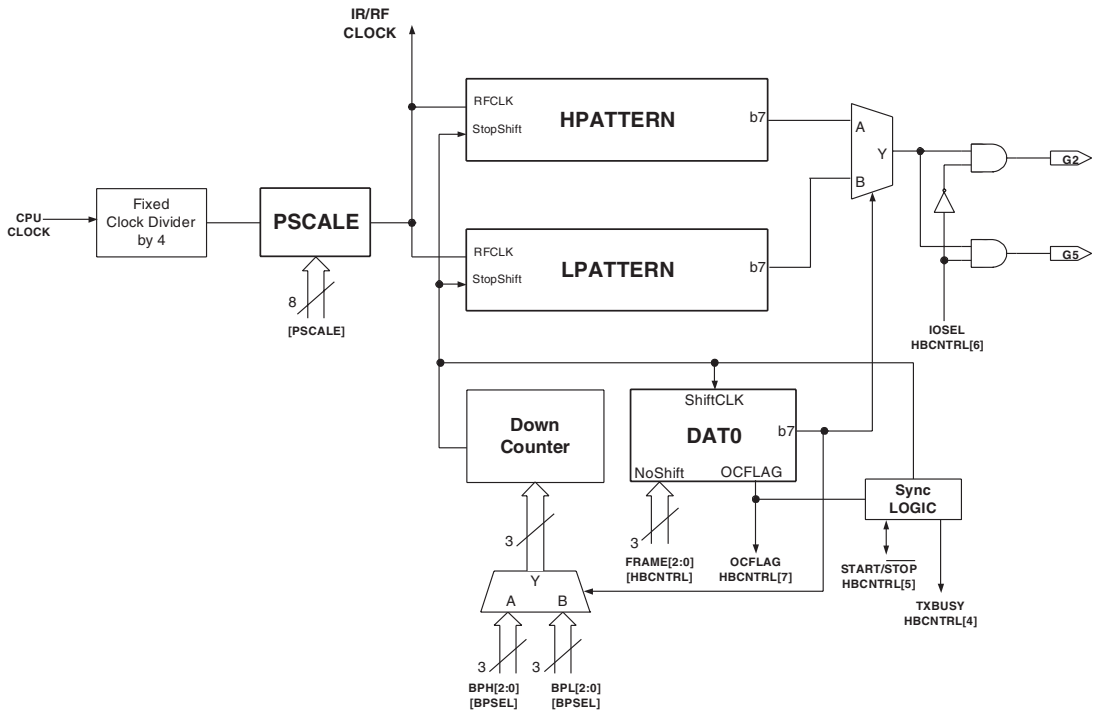


Figure 22. Bit Period Configuration (BPSEL) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	BPL[2:0]			BPH[2:0]		

Figure 23. HBC Control (HBCNTRL) Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
OCFLAG	IOSEL	START / STOP	TXBUSY	0	FRAME[2:0]		

Figure 24. HBC signals for one byte message in PWM format

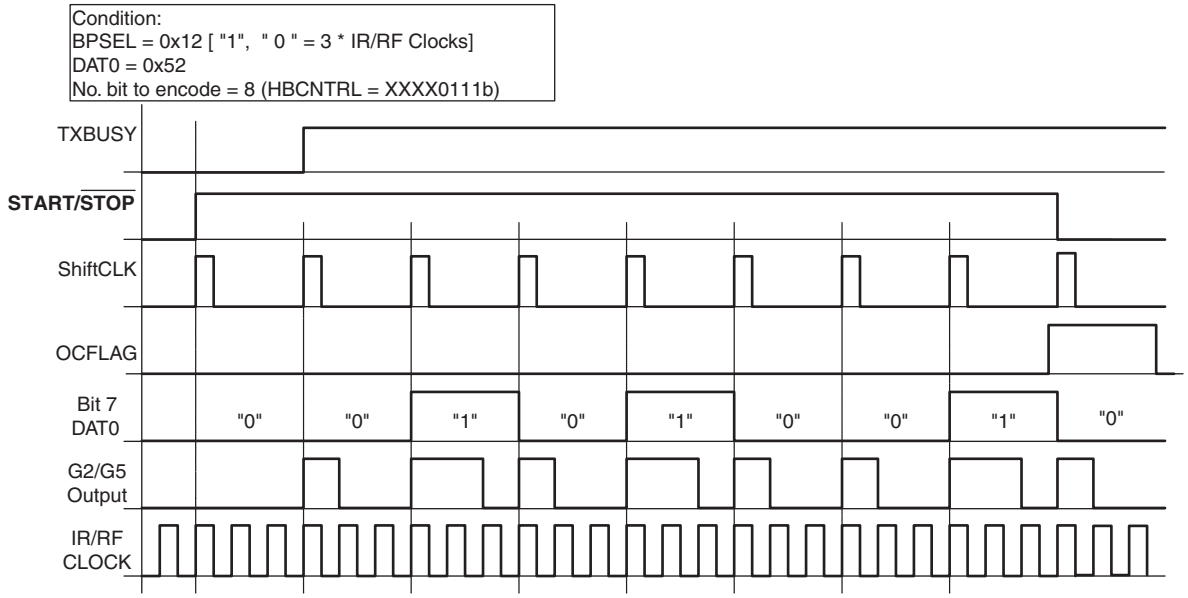
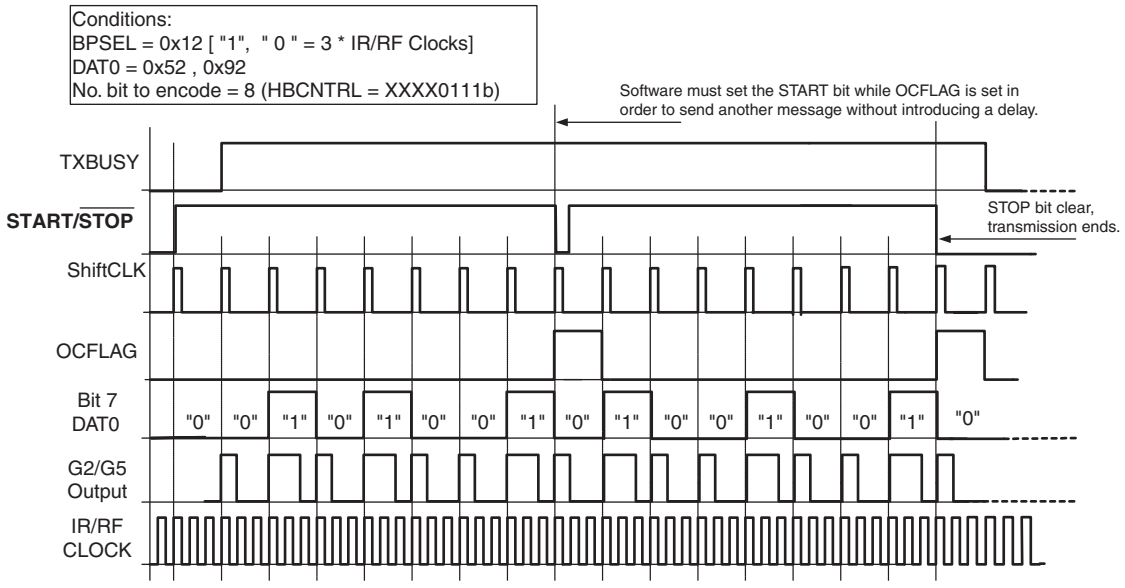


Figure 25. Sending series of encoded messages



8. Multi-Input Wakeup/Interrupt Block

The Multi-Input Wakeup (MIW)/Interrupt contains three memory-mapped registers associated with this circuit: WKEDG (Wakeup Edge), WKEN (Wakeup Enable), and WKPND (Wakeup Pending). Each register has 8-bits with each bit corresponding to an input pins as shown in Figure 27. All three registers are initialized to zero upon reset.

The WKEDG register establishes the edge sensitivity for each of the wake-up input pin: either positive going-edge (0) or negative-going edge (1).

The WKEN register enables (1) or disables (0) each of the port pins for the Wakeup/Interrupt function. The wakeup I/Os used for the Wakeup/Interrupt function must also be configured as an input pin in its associated port configuration register. However, an interrupt of the core will not occur unless interrupts are enabled for the block via bit 7 of the T0CNTRL register (see Figure 19) and the G (global interrupt enable) bit of the SR is set.

The WKPND register contains the pending flags corresponding to each of the port pins (1 for wakeup/interrupt pending, 0 for wakeup/interrupt not pending). If an I/O is not selected to become a wakeup input, the pending flag will not be generated.

To use the Multi-Input Wakeup/Interrupt circuit, perform the steps listed below making sure the MIW edge is selected before enabling the I/O to be used as a wakeup input thus preventing false pending flag generation. This same procedure should be used following any type of reset because the wakeup inputs are left floating after resets resulting in unknown data on the port inputs.

1. Clear the WKEN register.
   - CLR WKEN
2. Clear the WKPND register to cancel any pending bits.
   - CLR WKPND
3. If necessary, write to the port configuration register to select the desired port pins to be configured as inputs.
   - RBIT 4, PORTGC ; G4
4. If necessary, write to the port data register to select the desired port pins input state.
   - SBIT 4, PORTGD ; Pull-up
5. Write the WKEDG register to select the desired type of edge sensitivity for each of the pins used.
   - LD WKEDG, #0FFH ; All negative-going edges
6. Set the WKEN bits associated with the pins to be used, thus enabling those pins for the Wakeup/Interrupt function.
   - LD WKEN, #10H ; Enabling G4

Once the Multi-Input Wakeup/Interrupt function has been configured, a transition sensed on any of the I/O pins will set the corresponding bit in the WKPND register. The WKPND bits, where the corresponding enable (WKEN) bits are set, will bring the device out of the HALT mode and can also trigger an interrupt if interrupts are enabled. The interrupt service routine can read the WKPND register to determine which pin sensed the interrupt.

The interrupt service routine or other software should clear the pending bit. The device will not enter HALT mode as long as a WKPND pending bit is pending and enabled. The user has the responsibility of clearing the pending flags before attempting to enter the HALT mode.

Upon reset, the WKEDG register is configured to select positive-going edge sensitivity for all wakeup inputs. If the user wishes to change the edge sensitivity of a port pin, use the following procedure to avoid false triggering of a Wakeup/Interrupt condition.

1. Clear the WKEN bit associated with the pin to disable that pin.
2. Clear the WKPND bit associated with the pin.
3. Write the WKEDG register to select the new type of edge sensitivity for the pin.
4. Set the WKEN bit associated with the pin to re-enable it.

PORTG provides the user with three fully selectable, edge sensitive interrupts that are all vectored into the same service subroutine. The interrupt from PORTG shares logic with the wakeup circuitry. The WKEN register allows interrupts from PORTG to be individually enabled or disabled. The WKEDG register specifies the trigger condition to be either a positive or a negative edge. The WKPND register latches in the pending trigger conditions.

Since PORTG is also used for exiting the device from the HALT mode, the user can elect to exit the HALT mode either with or without the interrupt enabled. If the user elects to disable the interrupt, then the device restarts execution from the point at which it was stopped (first instruction cycle of the instruction following HALT mode entrance instruction). In the other case, the device finishes the instruction that was being executed when the part was stopped and then branches to the interrupt service routine. The device then reverts to normal operation.

Figure 26. Multi-input Wakeup (MIW) Register bit assignments

WKEDG, WKEN, WKPND							
Bit 7	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
[9] G7	[9] G6	G5	G4	G3	G2	G1	G0

9. Available only on the 14-pin package option

10. In-circuit Programming Specification

The ACEx microcontroller supports in-circuit programming of the internal data EEPROM, code EEPROM, and the initialization registers.

In order to enter into program mode a 10-bit opcode (0x34B) must be shifted into the ACE1502 while the device is executing the internal power on reset (T_{RESET}). The shifting protocol follows the same timing rules as the programming protocol defined in Figure 30.

The opcode is shifted into the ACE1502 serially, MSB first, with the data being valid by the rising edge of the clock. Once the pattern is shifted into the device, the current 10-bit pattern is matched to protocol entrance opcode of 0x34B. If the 10-bit pattern is a match, the device will enable the internal program mode flag so that the device will enter into program mode once reset has completed (see Figure 30.)

The opcode must be shifted in after Vcc settles to the nominal level and should end before the power on reset sequence (T_{reset}) completes; otherwise, the device will start normal execution of the program code. If the external reset is applied by bringing the reset pin low, once the reset pin is release the opcode may now be shifted in and again should end before the reset sequence completes.

10.3 Programming Protocol

After placing the device in program, the programming protocol and commands may be issued.

An externally controlled four-wire interface consisting of a LOAD control pin (G3), a serial data SHIFT-IN input pin (G4), a serial data SHIFT-OUT output pin (G2), and a CLOCK pin (G1) is used to access the on-chip memory locations. Communication between the ACEx microcontroller and the external programmer is made through a 32-bit command and response word described in Table 14. Be sure to either float or tie G5 to Vcc for proper programming functionality.

The serial data timing for the four-wire interface is shown in Figure 31 and the programming protocol is shown in Figure 30.

10.3.1 Write Sequence

The external programmer brings the ACEx microcontroller into programming then needs to set the LOAD pin to Vcc before shifting in the 32-bit serial command word using the SHIFT_IN and CLOCK signals. By definition, bit 31 of the command word is shifted in first. At the same time, the ACEx microcontroller shifts out the 32-bit serial response to the last command on the SHIFT_OUT pin. It is recommended that the external programmer samples this signal t_{ACCESS} (500 ns) after the rising edge of the CLOCK signal. The serial response word, sent immediately after entering programming mode, contains indeterminate data.

After 32 bits have been shifted into the device, the external programmer must set the LOAD signal to 0V, and then apply two clock pulses as shown in Figure 30 to complete program cycle.

The SHIFT_OUT pin acts as the handshaking signal between the device and programming hardware once the LOAD signal is brought low. The device sets SHIFT_OUT low by the time the programmer has sent the second rising edge during the LOAD = 0V phase (if the timing specifications in Figure 30 are obeyed).

The device will set the R bit of the Status register when the write operation has completed. The external programmer must wait for the SHIFT_OUT pin to go high before bringing the LOAD signal to Vcc to initiate a normal command cycle.

10.3.2 Read Sequence

When reading the device after a write, the external programmer must set the LOAD signal to Vcc before it sends the new command word. Next, the 32-bit serial command word (for during a READ) should be shifted into the device using the SHIFT_IN and the CLOCK signals while the data from the previous command is serially shifted out on the SHIFT_OUT pin. After the Read command has been shifted into the device, the external programmer must, once again, set the LOAD signal to 0V and apply two clock pulses as shown in Figure 30 to complete READ cycle. Data from the selected memory location, will be latched into the lower 8 bits of the command word shortly after the second rising edge of the CLOCK signal.

Writing a series of bytes to the device is achieved by sending a series of Write command words while observing the devices handshaking requirements.

Reading a series of bytes from the device is achieved by sending a series of Read command words with the desired addresses in sequence and reading the following response words to verify the correct address and data contents.

The addresses of the data EEPROM and code EEPROM locations are the same as those used in normal operation.

Powering down the device will cause the part to exit programming mode.

Table 14 32-Bit Command and Response Word

Bit Number	Input Command Word	Output Response Word
bits 31-30	Must be set to 0	X
bit 29	Set to 1 to read/write data EEPROM, or the initialization registers, otherwise 0	X
bit 28	Set to 1 to read/write code EEPROM, otherwise 0	X
bits 27-25	Must be set to 0	X
bit 24	Set to 1 to read, 0 to write	X
bits 23-19	Must be set to 0	X
bits 18 -8	Address of the byte to be read or written	Same as Input command word
bits 7-0	Data to be programmed or zero if data is to be read	Programmed data or data read at specified address

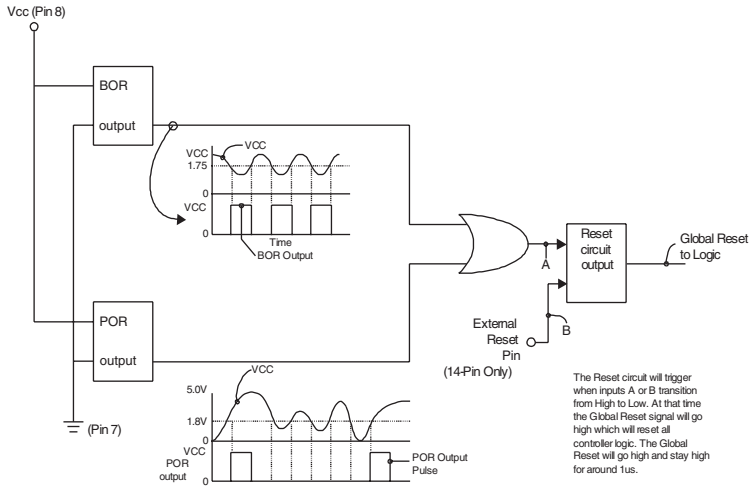
11.1 Brown-out Reset

The Brown-out Reset (BOR) function is used to hold the device in reset when Vcc drops below a fixed threshold (1.83V.) While in reset, the device is held in its initial condition until Vcc rises above the threshold value. Shortly after Vcc rises above the threshold value, an internal reset sequence is started. After the reset sequence, the core fetches the first instruction and starts normal operation.

The BOR should be used in situations when Vcc rises and falls slowly and in situations when Vcc does not fall to zero before rising back to operating range. The Brown-out Reset can be thought of as a supplement function to the Power-on Reset if Vcc does not fall below ~1.5V. The Power-on Reset circuit works best when Vcc starts from zero and rises sharply. In applications where Vcc is not constant, the BOR will give added device stability.

The BOR circuit must be enabled through the BOR enable bit (BOREN) in the initialization register. The BOREN bit can only be set while the device is in programming mode. Once set, the BOR will always be powered-up enabled. Software cannot disable the BOR. The BOR can only be disabled in programming mode by resetting the BOREN bit as long as the global write protect (WDIS) feature is not enabled.

Figure 33. BOR and POR Circuit Relationship Diagram



11.2 Low Battery Detect

The Low Battery Detect (LBD) circuit allows software to monitor the Vcc level at the lower voltage ranges. LBD has a 32-level software programmable voltage reference threshold that can be changed on the fly. Once Vcc falls below the selected threshold, the LBD flag in the LBD control register is set. The LBD flag will hold its value until Vcc rises above the threshold. (See Table 15)

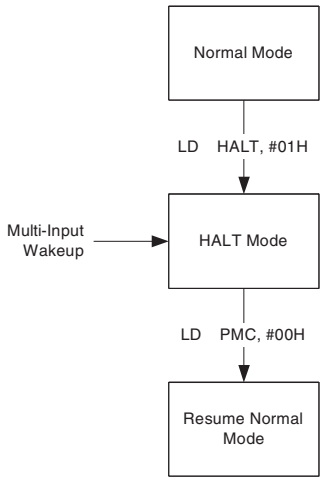
The LBD bit is read only. If LBD is 0, it indicates that the Vcc level is higher than the selected threshold. If LBD is 1, it indicates that the Vcc level is below the selected threshold. The threshold level can be adjusted up to eight levels using the three trim bits (BL[4:0]) of the LBD control register. The LBD flag does not cause any hardware actions or an interruption of the processor. It is for software monitoring only.

The VSEL bit of the LBD control register can be used to select an external voltage source rather than Vcc. If VSEL is 1, the voltage source for the LBD comparator will be an input voltage provided through G4. If VSEL is 0, the voltage source will be Vcc.

The LBD circuit must be enabled through the LBD enable bit (LBDEN) in the initialization register. The LBDEN bit can only be set while the device is in programming mode. Once set, the LBD will always be powered-up enabled. Software cannot disable the LBD. The LBD can only be disabled in programming mode by resetting the LBDEN bit as long as the global write protect (WDIS) feature is not enabled.

The LBD circuit is disabled during HALT/IDLE mode. After exiting HALT/IDLE, software must wait at lease 10 µs before reading the LBD bit to ensure that the internal circuit has stabilized.

Figure 36. Recommended HALT Flow

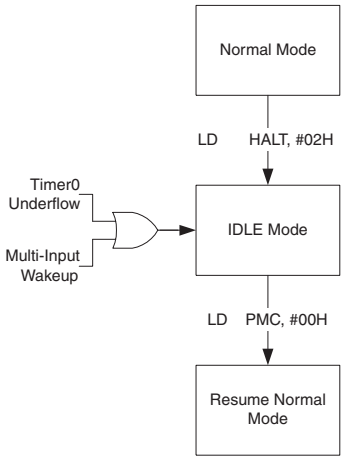


16. IDLE Mode

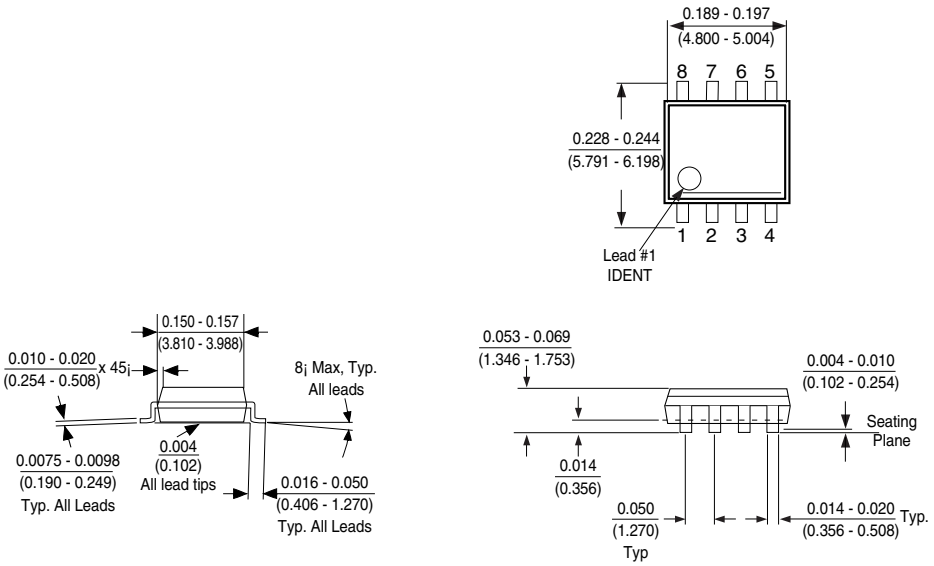
In addition to the HALT mode power saving feature, the device also supports an IDLE mode operation. The device is placed into IDLE mode by setting the IDLE enable bit (EIDLE) of the HALT register through software using only the “LD M, #” instruction. EIDLE is a write only bit and is automatically cleared upon exiting IDLE. The IDLE mode operation is similar to HALT except the internal oscillator, the Watchdog, and the Timer 0 remain active while the other on-chip systems including the LBD and the BOR circuits are shut down.

The device automatically wakes from IDLE mode by the Timer 0 overflow every 8192 cycles (see Section 5). Before entering IDLE mode, software must clear the WKEN register to disable the MIW block. Once a wake from IDLE mode is triggered, the core will begin normal operation by the next clock cycle. Immediately after exiting IDLE mode, software must clear the Power Mode Clear (PMC) register by using only the “LD M, #” instruction. (See Figure 37.)

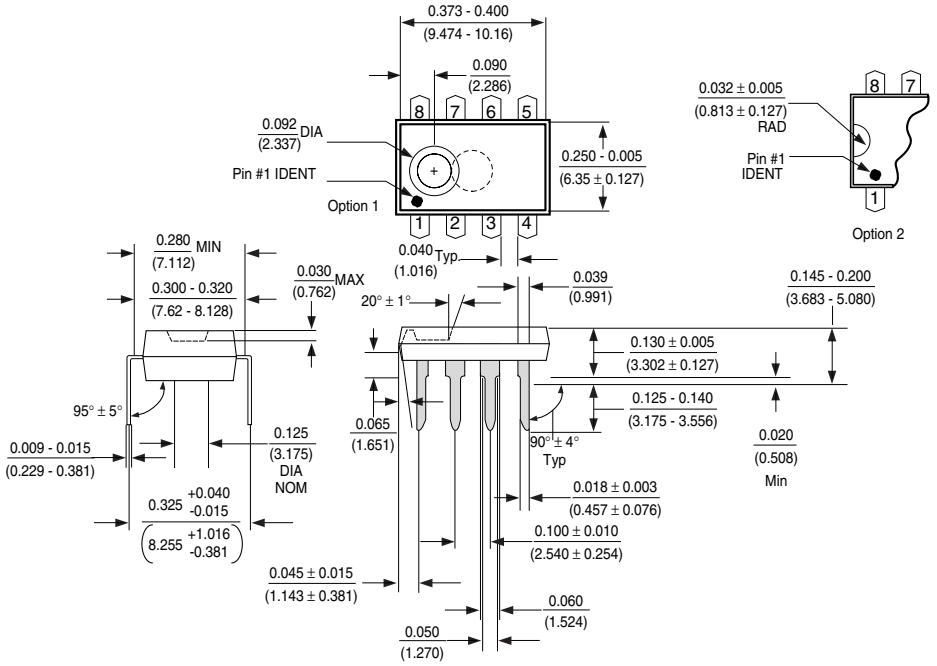
Figure 37. Recommended IDLE Flow



Physical Dimensions inches (millimeters) unless otherwise noted)

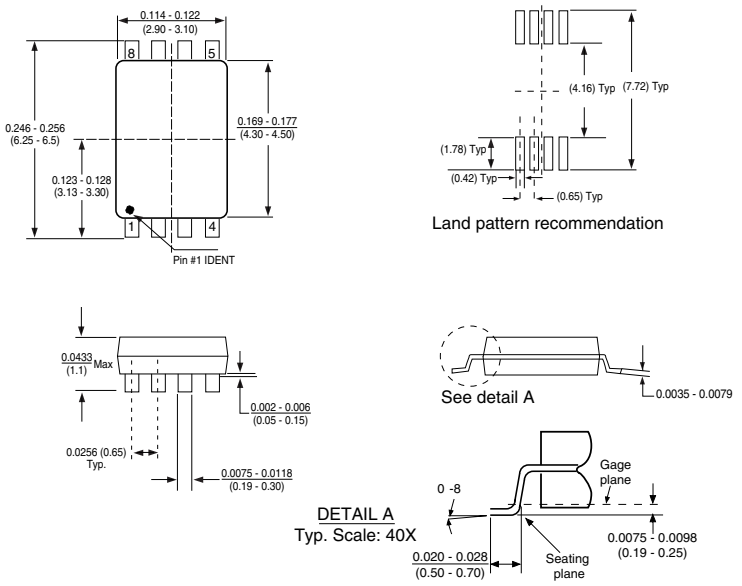


Molded Small Out-Line Package (M8)
Order Number ACE1502EM8/ACE1502VM8
Package Number M08A



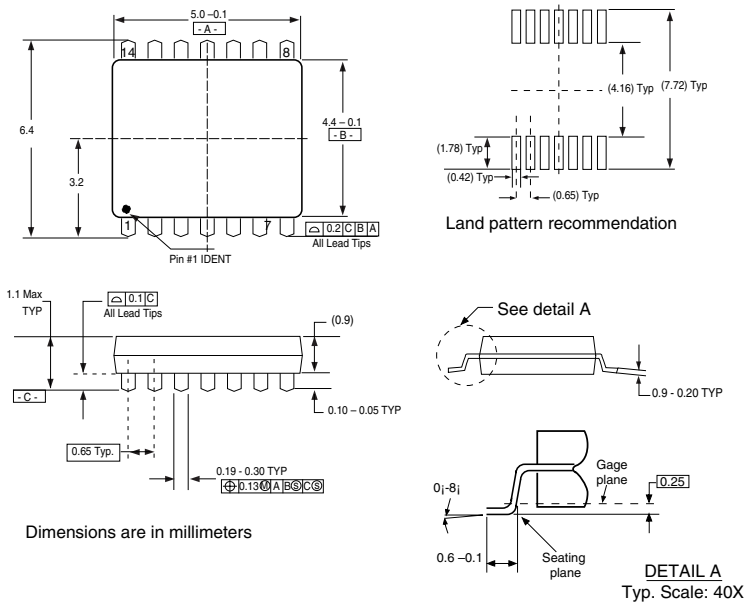
8-Pin DIP (N)
Order Number ACE1502EN/ACE1502VN
Package Number N08A

Physical Dimensions inches (millimeters) unless otherwise noted)



Notes: Unless otherwise specified
1. Reference JEDEC registration MO153. Variation AA. Dated 7/93

8-Pin TSSOP
Order Number ACE1502EMT8/ACE1502VMT8
Package Number MT08A

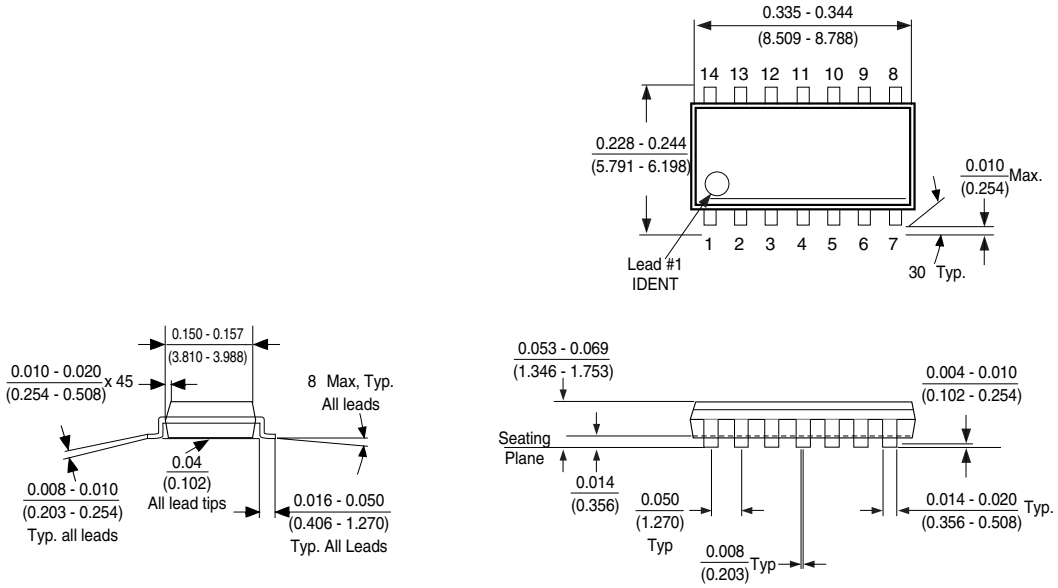


Dimensions are in millimeters

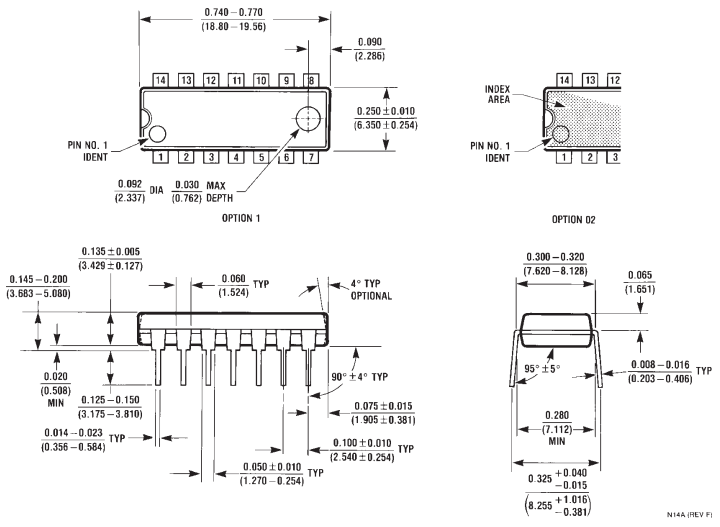
Notes: Unless otherwise specified
1. Reference JEDED registration MO153. Variation AB.
Ref. Note 6, dated 7/93

14-Pin TSSOP
Order Number ACE1502EMT/ACE1502VMT
Package Number MT14A

Physical Dimensions inches (millimeters) unless otherwise noted)



Molded Small Out-Line Package (M)
Order Number ACE1502EM/ACE1502EM
Package Number M14A



14-Pin DIP (N14)
Order Number ACE1502EN14/ACE1502VN14
Package Number N14A

ACEx Development Tools

General Information:

Fairchild Semiconductor offers different possibilities to evaluate and emulate software written for ACEx.

Simulator: Is a Windows program able to load, assemble, and debug ACEx programs. It is possible to place as many breakpoints as needed, trace the program execution in symbolic format, and program a device with the proper options. The ACEx Simulator is available free-of-charge and can be downloaded from Fairchild's web site at www.fairchildsemi.com/products/memory/ace

ACEx Emulator Kit: Fairchild also offers a low cost real-time in-circuit emulator kit that includes:

- Emulator board
- Emulator software
- Assembler and Manuals
- Power supply
- DIP14 target cable
- PC cable

The ACEx emulator allows for debugging the program code in a symbolic format. It is possible to place one breakpoint and watch various data locations. It also has built-in programming capability.

Prototype Board Kits: Fairchild offers two solutions for the simplification of the breadboard operation so that ACEx Applications can be quickly tested.

1) ACEDEMO can be used for general purpose applications
2) ACETXRX is for transmitting / receiving (RF, IR, RS232, RS485) applications.

ACEDEMO has 8 switches, 8 LEDs, RS232 voltage translator, buzzer, and a lamp with a small breadboard area.

Factory Programming:

Fairchild offers factory pre-programming and serialization (for justified quantities) for a small additional cost. Please refer to your local distributor for details regarding factory programming.

Ordering P/Ns

Emulator Kit and Programming adapters:

Please refer to your local distributor for details regarding development tools.

Life Support Policy

Fairchild's products are not authorized for use as critical components in life support devices or systems without the express written approval of the President of Fairchild Semiconductor Corporation. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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