

Precision Analog-to-Digital Converter (ADC) and Digital-to-Analog Converters (DACs) with 8051 Microcontroller and Flash Memory

FEATURES

ANALOG FEATURES

- 24-BITS NO MISSING CODES
- 22-BITS EFFECTIVE RESOLUTION AT 10Hz
Low Noise: 75nV
- PGA FROM 1 TO 128
- PRECISION ON-CHIP VOLTAGE REFERENCE:
Accuracy: 0.2%
Drift: 5ppm/°C
- 8 DIFFERENTIAL/SINGLE-ENDED CHANNELS
- ON-CHIP OFFSET/GAIN CALIBRATION
- OFFSET DRIFT: 0.02PPM/°C
- GAIN DRIFT: 0.5PPM/°C
- ON-CHIP TEMPERATURE SENSOR
- SELECTABLE BUFFER INPUT
- BURNOUT DETECT
- DUAL 16-BIT MONOTONIC VOLTAGE DACs:
VDACs Can Be Programmed as IDACs
8µs Settling Time

DIGITAL FEATURES

Microcontroller Core

- 8051 COMPATIBLE
- HIGH-SPEED CORE:
4 Clocks per Instruction Cycle
- DC TO 30MHz
- SINGLE INSTRUCTION 133ns
- DUAL DATA POINTER

Memory

- UP TO 32KB FLASH MEMORY
- FLASH MEMORY PARTITIONING
- ENDURANCE 1M ERASE/WRITE CYCLES,
100 YEAR DATA RETENTION
- IN-SYSTEM SERIALLY PROGRAMMABLE
- EXTERNAL PROGRAM/DATA MEMORY (64kB)
- 1,280 BYTES DATA SRAM
- FLASH MEMORY SECURITY
- 2kB BOOT ROM
- PROGRAMMABLE WAIT STATE CONTROL

Peripheral Features

- 34 I/O PINS
- ADDITIONAL 32-BIT ACCUMULATOR
- THREE 16-BIT TIMER/COUNTERS
- SYSTEM TIMERS
- PROGRAMMABLE WATCHDOG TIMER
- FULL DUPLEX DUAL USART
- MASTER/SLAVE SPI™ WITH DMA
- MULTI-MASTER I²C™ (MSC1213 ONLY)
- 16-BIT PWM
- POWER MANAGEMENT CONTROL
- INTERNAL CLOCK DIVIDER
- IDLE MODE CURRENT < 200µA
- STOP MODE CURRENT < 100nA
- PROGRAMMABLE BROWNOUT RESET
- PROGRAMMABLE LOW VOLTAGE DETECT
- 21 INTERRUPT SOURCES
- TWO HARDWARE BREAKPOINTS

GENERAL FEATURES

- PIN-COMPATIBLE WITH MSC121x FAMILY
- PACKAGE: TQFP-64
- LOW POWER: 4mW
- INDUSTRIAL TEMPERATURE RANGE:
-40°C TO +85°C
- POWER SUPPLY: 2.7V to 5.25V

APPLICATIONS

- INDUSTRIAL PROCESS CONTROL
- INSTRUMENTATION
- LIQUID/GAS CHROMATOGRAPHY
- BLOOD ANALYSIS
- SMART TRANSMITTERS
- PORTABLE INSTRUMENTS
- WEIGH SCALES
- PRESSURE TRANSDUCERS
- INTELLIGENT SENSORS
- PORTABLE APPLICATIONS
- DAS SYSTEMS

PRODUCT PREVIEW



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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PACKAGE/ORDERING INFORMATION(1)

PRODUCT	FLASH MEMORY	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING
MSC1213Y2	4k	TQFP-64	PAG	-40°C to +85°C	MSC1213Y2
MSC1213Y3	8k				MSC1213Y3
MSC1213Y4	16k				MSC1213Y4
MSC1213Y5	32k				MSC1213Y5
MSC1214Y2	4k	TQFP-64	PAG	-40°C to +85°C	MSC1214Y2
MSC1214Y3	8k				MSC1214Y3
MSC1214Y4	16k				MSC1214Y4
MSC1214Y5	32k				MSC1214Y5

(1) For the most current package and ordering information, see the Package Option Addendum located at the end of this datasheet,

ABSOLUTE MAXIMUM RATINGS(1)

Analog Inputs	
Input Current	100mA, Momentary
Input Current	10mA, Continuous
Input Voltage	AGND – 0.5V to AV _{DD} + 0.5V
Power Supply	
DV _{DD} to DGND	-0.3V to 6V
AV _{DD} to AGND	-0.3V to 6V
AGND to DGND	-0.3V to +0.3V
V _{REF} to AGND	-0.3V to AV _{DD} +0.3V
Digital Input Voltage to DGND	-0.3V to DV _{DD} +0.3V
Digital Output Voltage to DGND	-0.3V to DV _{DD} +0.3V
Maximum Junction Temperature (T _J Max)	+150°C
Operating Temperature Range	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (soldering, 10s)	+300°C
Thermal Resistance, Junction-to-Ambient (θ _{JA})	66.6°C/W
Thermal Resistance, Junction-to-Case (θ _{JC})	4.3°C/W
Package Power Dissipation	(T _J Max – T _{Ambient}) / θ _{JA}
Output Current All Pins	200mA
Output Pin Short Circuit	10s
Digital Outputs	
Output Current	100mA, Continuous
I/O Source/Sink Current	100mA
Power Pin Maximum	300mA



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

(1) Stresses above those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

MSC121xYX FAMILY FEATURES

FEATURES(1)	MSC121xY2(2)	MSC121xY3(2)	MSC121xY4(2)	MSC121xY5(2)
Flash Program Memory (Bytes)	Up to 4k	Up to 8k	Up to 16k	Up to 32k
Flash Data Memory (Bytes)	Up to 4k	Up to 8k	Up to 16k	Up to 32k
Internal Scratchpad SRAM (Bytes)	256	256	256	256
Internal MOVX RAM (Bytes)	1024	1024	1024	1024
Externally Accessible Memory (Bytes)	64k Program, 64k Data	64k Program, 64k Data	64k Program, 64k Data	64k Program, 64k Data

(1) All peripheral features are the same on all devices; the flash memory size is the only difference.

(2) The last digit of the part number (N) represents the onboard flash size = (2^N)kBytes.

ELECTRICAL CHARACTERISTICS: $V_{DD} = 5V$

All specifications from T_{MIN} to T_{MAX} , $DV_{DD} = +2.7V$ to $5.25V$, $AV_{DD} = +5V$, $f_{MOD} = 15.625kHz$, $PGA = 1$, filter = Sinc³, Buffer ON, $f_{DATA} = 10Hz$, Bipolar, $f_{CLK} = 8MHz$, and $V_{REF} = (REF IN+) - (REF IN-) = +2.5V$, unless otherwise noted. For V_{DAC} , $V_{REF} = AV_{DD}$, $R_{LOAD} = 10k\Omega$, and $C_{LOAD} = 200pF$, unless otherwise noted.

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
ANALOG INPUTS (AIN0–AIN7, AINCOM)					
Analog Input Range	Buffer OFF	AGND – 0.1		$AV_{DD} + 0.1$	V
	Buffer ON	AGND + 50mV		$AV_{DD} - 1.5$	V
Full-Scale Input Voltage Range	(AIN+) – (AIN–)			$\pm V_{REF}/PGA$	V
Differential Input Impedance	Buffer OFF		$7/PGA^{(1)}$		M Ω
Input Current	Buffer ON		0.5		nA
Bandwidth					
Fast Settling Filter	–3dB		$0.469 \cdot f_{DATA}$		
Sinc ² Filter	–3dB		$0.318 \cdot f_{DATA}$		
Sinc ³ Filter	–3dB		$0.262 \cdot f_{DATA}$		
Programmable Gain Amplifier	User-Selectable Gain Range	1		128	
Input Capacitance	Buffer ON		9		pF
Input Leakage Current	Multiplexer Channel ON, $T = +25^{\circ}C$		0.5		pA
Burnout Current Sources	Buffer ON		± 2		μA
ADC OFFSET DAC					
Offset DAC Range	Bipolar Mode		$\pm V_{REF}/(2 \cdot PGA)$		V
Offset DAC Monotonicity		8			Bits
Offset DAC Gain Error			± 1.5		% of Range
Offset DAC Gain Error Drift			1		ppm/ $^{\circ}C$
SYSTEM PERFORMANCE					
Resolution		24			Bits
ENOB	See Typical Characteristics		22		Bits
Output Noise			See Typical Characteristics		
No Missing Codes	Sinc ³ Filter, Decimation >360	24			Bits
Integral Nonlinearity	End Point Fit, Bipolar Mode			± 0.0015	%FSR
Offset Error	After Calibration		± 7.5		ppm of FS
Offset Drift ⁽²⁾	Before Calibration		0.02		ppm of FS/ $^{\circ}C$
Gain Error ⁽³⁾	After Calibration		–0.005		%
Gain Error Drift ⁽²⁾	Before Calibration		0.5		ppm/ $^{\circ}C$
System Gain Calibration Range		80		120	% of FS
System Offset Calibration Range		–50		50	% of FS
Common-Mode Rejection	At DC	100	115		dB
	$f_{CM} = 60Hz, f_{DATA} = 10Hz$		130		dB
	$f_{CM} = 50Hz, f_{DATA} = 50Hz$		120		dB
	$f_{CM} = 60Hz, f_{DATA} = 60Hz$		120		dB
Normal Mode Rejection	$f_{SIG} = 50Hz, f_{DATA} = 50Hz$		100		dB
	$f_{SIG} = 60Hz, f_{DATA} = 60Hz$		100		dB
Power-Supply Rejection	At DC, dB = $-20\log(\Delta V_{OUT}/\Delta V_{DD})^{(4)}$		88		dB
VOLTAGE REFERENCE INPUTS					
Reference Input Range	REF IN+, REF IN–	AGND		$AV_{DD}^{(3)}$	V
ADC V_{REF}	$V_{REF} = (REF IN+) - (REF IN-)$	0.1	2.5	AV_{DD}	V
Common-Mode Rejection	At DC		110		dB
Input Current ⁽⁵⁾	$V_{REF} = 2.5V$, ADC Only		1		μA
DAC Reference Input Resistance	For Each DAC, $PGA = 1$		20		k Ω

- (1) The input impedance for $PGA = 128$ is the same as that for $PGA = 64$ (that is, $7M\Omega/64$).
- (2) Calibration can minimize these errors.
- (3) The self gain calibration cannot have a REF IN+ of more than $AV_{DD} - 1.5V$ with Buffer ON. To calibrate gain, turn Buffer OFF.
- (4) ΔV_{OUT} is change in digital result.
- (5) 9pF switched capacitor at f_{SAMP} clock frequency (see Figure 14).
- (6) Linearity calculated using a reduced code range of 512 to 65024; output unloaded.
- (7) Ensured by design and characterization; not production tested.
- (8) Analog Brownout Detect OFF (HCR1.3 = 1), Analog LVD OFF (LVDCON.7 = 1).

ELECTRICAL CHARACTERISTICS: AV_{DD} = 5V (continued)

All specifications from T_{MIN} to T_{MAX}, DV_{DD} = +2.7V to 5.25V, AV_{DD} = +5V, f_{MOD} = 15.625kHz, PGA = 1, filter = Sinc³, Buffer ON, f_{DATA} = 10Hz, Bipolar, f_{CLK} = 8MHz, and V_{REF} = (REF IN+) – (REF IN-) = +2.5V, unless otherwise noted. For V_{DAC}, V_{REF} = AV_{DD}, R_{LOAD} = 10kΩ, and C_{LOAD} = 200pF, unless otherwise noted.

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
ON-CHIP VOLTAGE REFERENCE					
Output Voltage	VREFH = 1 at +25°C, REFCLK = 250kHz VREFH = 0	2.495	2.5 1.25	2.505	V V
Power-Supply Rejection Ratio			65		dB
Short-Circuit Current Source			2.6		mA
Short-Circuit Current Sink			50		μA
Short-Circuit Duration	Sink or Source		Indefinite		
Drift			5		ppm/°C
Output Impedance	Sourcing 100μA		3		Ω
Startup Time from Power ON	C _{REFOUT} = 0.1μF		8		ms
Temperature Sensor					
Temperature Sensor Voltage	Buffer ON, T = +25°C		115		mV
Temperature Sensor Coefficient	Buffer ON		375		μV/°C
VOLTAGE DAC STATIC PERFORMANCE⁽⁶⁾					
Resolution		16			Bits
Relative Accuracy			±0.05	±0.146	%
Differential Nonlinearity				±1	LSB
Zero Code Error	All 0s Loaded to DAC Register		+13	+35	mV
Full-Scale Error	All 1s Loaded to DAC Register	-1.25	0		% of FSR
Gain Error		-1.25	0	+1.25	% of FSR
Zero Code Error Drift			±20		μV/°C
Gain Temperature Coefficient			±5		ppm of FSR/°C
VOLTAGE DAC OUTPUT CHARACTERISTICS⁽⁷⁾					
Output Voltage Range	REFIN+ = AV _{DD}	AGND		AV _{DD}	V
Output Voltage Settling Time	To ±0.003% FSR, 0200 _H to FD00 _H		8		μs
Slew Rate			1		V/μs
DC Output Impedance			7		Ω
Short-Circuit Current	All 1s Loaded to DAC Register		20		mA
IDAC OUTPUT CHARACTERISTICS					
Full-Scale Output Current	Maximum V _{REF} = 2.5V		25		mA
Maximum Short-Circuit Current Duration			Indefinite		
Compliance Voltage			AV _{DD} – 1.5		V
Relative Accuracy			0.185		% of FSR
Zero Code Error	All 0s Loaded to DAC Register		0.5		μA
Full-Scale Error	All 1s Loaded to DAC Register		-0.4		% of FSR
Gain Error			-0.6		% of FSR
ANALOG POWER-SUPPLY REQUIREMENTS					
Power-Supply Voltage	AV _{DD}	4.75	5	5.25	V
Analogue Off Current ⁽⁸⁾	Analog OFF, PDCON = 48 _H		< 1		nA
ADC Current	I _{ADC}	PGA = 1, Buffer OFF	200		μA
		PGA = 128, Buffer OFF	500		μA
		PGA = 1, Buffer ON	240		μA
		PGA = 128, Buffer ON	850		μA
VDAC Current	I _{VDAC}	Excluding Load Current, External Reference	250		μA
V _{REF} Supply Current	I _{VREF}	ADC ON, V _{DAC} OFF	250		μA

- (1) The input impedance for PGA = 128 is the same as that for PGA = 64 (that is, 7MΩ/64).
- (2) Calibration can minimize these errors.
- (3) The self gain calibration cannot have a REF IN+ of more than AV_{DD} – 1.5V with Buffer ON. To calibrate gain, turn Buffer OFF.
- (4) ΔV_{OUT} is change in digital result.
- (5) 9pF switched capacitor at f_{SAMP} clock frequency (see Figure 14).
- (6) Linearity calculated using a reduced code range of 512 to 65024; output unloaded.
- (7) Ensured by design and characterization; not production tested.
- (8) Analog Brownout Detect OFF (HCR1.3 = 1), Analog LVD OFF (LVDCON.7 = 1).

ELECTRICAL CHARACTERISTICS: $AV_{DD} = 3V$

All specifications from T_{MIN} to T_{MAX} , $DV_{DD} = +2.7V$ to $5.25V$, $AV_{DD} = +3V$, $f_{MOD} = 15.625kHz$, $PGA = 1$, filter = Sinc³, Buffer ON, $f_{DATA} = 10Hz$, Bipolar, $f_{CLK} = 8MHz$, and $V_{REF} = (REF\ IN+) - (REF\ IN-) = +1.25V$, unless otherwise noted. For V_{DAC} , $V_{REF} = AV_{DD}$, $R_{LOAD} = 10k\Omega$, and $C_{LOAD} = 200pF$, unless otherwise noted.

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
ANALOG INPUTS (AIN0–AIN7, AINCOM)					
Analog Input Range	Buffer OFF	AGND – 0.1		$AV_{DD} + 0.1$	V
	Buffer ON	AGND + 50mV		$AV_{DD} - 1.5$	V
Full-Scale Input Voltage Range	(AIN+) – (AIN–)			$\pm V_{REF}/PGA$	V
Differential Input Impedance	Buffer OFF		$7/PGA^{(1)}$		M Ω
Input Current	Buffer ON		0.5		nA
Bandwidth					
Fast Settling Filter	–3dB		$0.469 \cdot f_{DATA}$		
Sinc ² Filter	–3dB		$0.318 \cdot f_{DATA}$		
Sinc ³ Filter	–3dB		$0.262 \cdot f_{DATA}$		
Programmable Gain Amplifier	User-Selectable Gain Range	1		128	
Input Capacitance	Buffer ON		9		pF
Input Leakage Current	Modulator OFF, T = +25°C		0.5		pA
Burnout Current Sources	Sensor Input Open Circuit		± 2		μA
ADC OFFSET DAC					
Offset DAC Range	Bipolar Mode		$\pm V_{REF}/(2 \cdot PGA)$		V
Offset DAC Monotonicity		8			Bits
Offset DAC Gain Error			± 1.5		% of Range
Offset DAC Gain Error Drift			1		ppm/°C
SYSTEM PERFORMANCE					
Resolution		24			Bits
ENOB			22		Bits
Output Noise			See Typical Characteristics		
No Missing Codes	Sinc ³ Filter	24			Bits
Integral Nonlinearity	End Point Fit, Bipolar Mode			± 0.0015	%FSR
Offset Error	After Calibration		± 7.5		ppm of FS
Offset Drift ⁽²⁾	Before Calibration		0.02		ppm of FS/°C
Gain Error ⁽³⁾	After Calibration		–0.005		%
Gain Error Drift ⁽²⁾	Before Calibration		1.0		ppm/°C
System Gain Calibration Range		80		120	% of FS
System Offset Calibration Range		–50		50	% of FS
Common-Mode Rejection	At DC	100	115		dB
	$f_{CM} = 60Hz, f_{DATA} = 10Hz$		130		dB
	$f_{CM} = 50Hz, f_{DATA} = 50Hz$		120		dB
	$f_{CM} = 60Hz, f_{DATA} = 60Hz$		120		dB
Normal Mode Rejection	$f_{SIG} = 50Hz, f_{DATA} = 50Hz$		100		dB
	$f_{SIG} = 60Hz, f_{DATA} = 60Hz$		100		dB
Power-Supply Rejection	At DC, dB = $-20\log(\Delta V_{OUT}/\Delta V_{DD})^{(4)}$		85		dB
VOLTAGE REFERENCE INPUTS					
Reference Input Range	REF IN+, REF IN–	AGND		$AV_{DD}^{(3)}$	V
ADC V_{REF}	$V_{REF} = (REF\ IN+) - (REF\ IN-)$	0.1	1.25	AV_{DD}	V
Common-Mode Rejection	At DC		110		dB
Input Current ⁽⁵⁾	$V_{REF} = 1.25V$, ADC Only		3		μA
DAC Reference Input Resistance	For Each DAC, PGA = 1		20		k Ω

(1) The input impedance for PGA = 128 is the same as that for PGA = 64 (that is, 7M Ω /64).

(2) Calibration can minimize these errors.

(3) The gain calibration cannot have a REF IN+ of more than $AV_{DD} - 1.5V$ with Buffer ON. To calibrate gain, turn Buffer OFF.

(4) ΔV_{OUT} is change in digital result.

(5) 9pF switched capacitor at f_{SAMP} clock frequency (see Figure 14).

(6) Linearity calculated using a reduced code range of 512 to 65024; output unloaded.

(7) Ensured by design and characterization, not production tested.

(8) Analog Brownout Detect OFF (HCR1.3 = 1), Analog LVD OFF (LVDCON.7 = 1).

ELECTRICAL CHARACTERISTICS: AV_{DD} = 3V (continued)

All specifications from T_{MIN} to T_{MAX}, DV_{DD} = +2.7V to 5.25V, AV_{DD} = +3V, f_{MOD} = 15.625kHz, PGA = 1, filter = Sinc³, Buffer ON, f_{DATA} = 10Hz, Bipolar, f_{CLK} = 8MHz, and V_{REF} = (REF IN+) – (REF IN-) = +1.25V, unless otherwise noted. For V_{DAC}, V_{REF} = AV_{DD}, R_{LOAD} = 10kΩ, and C_{LOAD} = 200pF, unless otherwise noted.

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
ON-CHIP VOLTAGE REFERENCE					
Output Voltage	VREFH = 0 at +25°C, REFCLK = 250kHz	1.245	1.25	1.255	V
Power-Supply Rejection Ratio			65		dB
Short-Circuit Current Source			2.6		mA
Short-Circuit Current Sink			50		μA
Short-Circuit Duration	Sink or Source		Indefinite		
Drift			5		ppm/°C
Output Impedance	Sourcing 100μA		3		Ω
Startup Time from Power ON	C _{REFOUT} = 0.1μF		8		ms
Temperature Sensor					
Temperature Sensor Voltage	Buffer ON, T = +25°C		115		mV
Temperature Sensor Coefficient	Buffer ON		375		μV/°C
VOLTAGE DAC STATIC PERFORMANCE⁽⁶⁾					
Resolution		16			Bits
Relative Accuracy			±0.05	±0.146	% of FSR
Differential Nonlinearity	Ensured Monotonic by Design			±1	LSB
Zero Code Error	All 0s Loaded to DAC Register		+13	+35	mV
Full-Scale Error	All 1s Loaded to DAC Register		0		% of FSR
Gain Error		-1.25	0		% of FSR
Zero Code Error Drift			±20		μV/°C
Gain Temperature Coefficient			±5		ppm of FSR/°C
VOLTAGE DAC OUTPUT CHARACTERISTICS⁽⁷⁾					
Output Voltage Range		AGND		AV _{DD}	V
Output Voltage Settling Time	To ±0.003% FSR, 0200H to FD00H		8		μs
Slew Rate			1		V/μs
DC Output Impedance			7		Ω
Short-Circuit Current	All 1s Loaded to DAC Register		16		mA
IDAC OUTPUT CHARACTERISTICS					
Full-Scale Output Current	Maximum V _{REF} = 1.25V		25		mA
Maximum Short-Circuit Current Duration			Indefinite		
Compliance Voltage			AV _{DD} – 1.5		V
Relative Accuracy	Over Full Range		0.185		% of FSR
Zero Code Error			0.5		% of FSR
Full-Scale Error			-0.4		% of FSR
Gain Error			-0.6		% of FSR
ANALOG POWER-SUPPLY REQUIREMENTS					
Power-Supply Voltage	AV _{DD}	2.7	3.0	3.6	V
Analog Off Current ⁽⁸⁾	Analog OFF, PDCON = 47H		< 1		nA
ADC Current	I _{ADC} PGA = 1, Buffer OFF		200		μA
	PGA = 128, Buffer ON		500		μA
	PGA = 1, Buffer OFF		240		μA
	PGA = 128, Buffer ON		850		μA
VDAC Current	I _{VDAC} Excluding Load Current, External Reference		250		μA
V _{REF} Supply Current	I _{VDAC}		250		μA

(1) The input impedance for PGA = 128 is the same as that for PGA = 64 (that is, 7MΩ/64).

(2) Calibration can minimize these errors.

(3) The gain calibration cannot have a REF IN+ of more than AV_{DD} – 1.5V with Buffer ON. To calibrate gain, turn Buffer OFF.

(4) ΔV_{OUT} is change in digital result.

(5) 9pF switched capacitor at f_{SAMP} clock frequency (see Figure 14).

(6) Linearity calculated using a reduced code range of 512 to 65024; output unloaded.

(7) Ensured by design and characterization, not production tested.

(8) Analog Brownout Detect OFF (HCR1.3 = 1), Analog LVD OFF (LVDCON.7 = 1).

DIGITAL CHARACTERISTICS: $DV_{DD} = 2.7V$ to $5.25V$

All specifications from T_{MIN} to T_{MAX} , unless otherwise specified.

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
POWER-SUPPLY REQUIREMENTS Digital Supply Current	DV_{DD} Normal Mode, $f_{OSC} = 1MHz$ Normal Mode, $f_{OSC} = 8MHz$ Crystal Operation Stop Mode ⁽¹⁾	2.7	3 1.3 6 100	3.6	V mA mA nA
	DV_{DD} Normal Mode, $f_{OSC} = 1MHz$ Normal Mode, $f_{OSC} = 8MHz$ Crystal Operation Stop Mode ⁽¹⁾	4.75	5 2.2 14 100	5.25	V mA mA nA
DIGITAL INPUT/OUTPUT (CMOS) Logic Level: V_{IH} (except XIN pin) V_{IL} (except XIN pin) I/O Pin Hysteresis Ports 0–3, Input Leakage Current, Input Mode Pins \overline{EA} , \overline{RST} Input Leakage Current V_{OL} , \overline{ALE} , \overline{PSEN} , Ports 0–3, All Output Modes V_{OL} , \overline{ALE} , \overline{PSEN} , Ports 0–3, All Output Modes V_{OH} , \overline{ALE} , \overline{PSEN} , Ports 0–3, Strong Drive Output V_{OH} , \overline{ALE} , \overline{PSEN} , Ports 0–3, Strong Drive Output Ports 0–3, Pull-Up Resistors Pins \overline{ALE} , \overline{PSEN} , Pull-Up Resistors During Reset	$V_{IH} = DV_{DD}$ or $V_{IH} = 0V$ $I_{OL} = -1mA$ $I_{OL} = -30mA$ (5V), $-20mA$ (3V) $I_{OH} = 1mA$ $I_{OH} = 30mA$ (5V), $20mA$ (5V) Flash Programming Mode Only	$0.6 \cdot DV_{DD}$ DGND	700 < 1 < 1	DV_{DD} $0.2 \cdot DV_{DD}$	V V mV pA pA V V V k Ω k Ω
		$I_{OL} = -30mA$ (5V), $-20mA$ (3V) $I_{OH} = 1mA$ $I_{OH} = 30mA$ (5V), $20mA$ (5V) Flash Programming Mode Only	DGND $DV_{DD} - 0.4$	1.5 $DV_{DD} - 0.1$ $DV_{DD} - 1.5$ 9 9	0.4 DV_{DD}
OSCILLATOR/CLOCK INPUT/OUTPUT External Oscillator/Clock V_{IH} (except XIN pin) V_{IL} (except XIN pin)	XOUT must be unconnected XOUT must be unconnected	$0.6 \cdot DV_{DD}$ DGND		DV_{DD} $0.2 \cdot DV_{DD}$	V V

(1) Digital Brownout Detect disabled (HCR1.2 = 1), Low Voltage Detect disabled (LVDCON.3 = 1). Ports configured for input or CMOS output.

FLASH MEMORY CHARACTERISTICS: $DV_{DD} = 2.7V$ to $5.25V$

PARAMETER	CONDITIONS	MSC1213Yx, MSC1214Yx			UNITS
		MIN	TYP	MAX	
Flash Memory Endurance		100,000	1,000,000		Cycles
Flash Memory Data Retention		100			Years
Mass and Page Erase Time	Set with FER in FTCON	10			ms
Flash Memory Write Time	Set with FWR in FTCON	30		40	μs
Flash Programming Current ⁽¹⁾	$DV_{DD} = 3.0V$			10	mA
	$DV_{DD} = 5.0V$			25	mA

(1) Peak current during Mass and Page Erase Time and Memory Write Time.

AC ELECTRICAL CHARACTERISTICS⁽¹⁾⁽²⁾: $V_{DD} = 2.7V$ to $5.25V$

SYMBOL	FIGURE	PARAMETER	2.7V to 3.6V		4.75V to 5.25V		UNITS
			MIN	MAX	MIN	MAX	
System Clock							
$f_{OSC}^{(3)}$	4	External Crystal Frequency (f_{OSC})	1	16	1	30	MHz
$1/t_{OSC}^{(3)}$	4	External Clock Frequency (f_{OSC})	0	16	0	30	MHz
$f_{OSC}^{(3)}$	4	External Ceramic Resonator Frequency (f_{OSC})	1	12	1	12	MHz
Program Memory							
t_{LHLL}	1	ALE Pulse Width	$1.5t_{CLK} - 5$		$1.5t_{CLK} - 5$		ns
t_{AVLL}	1	Address Valid to ALE LOW	$0.5t_{CLK} - 10$		$0.5t_{CLK} - 7$		ns
t_{LLAX}	1	Address Hold After ALE LOW	$0.5t_{CLK}$		$0.5t_{CLK}$		ns
t_{LLIV}	1	ALE LOW to Valid Instruction In		$2.5t_{CLK} - 35$		$2.5t_{CLK} - 25$	ns
t_{LLPL}	1	ALE LOW to \overline{PSEN} LOW	$0.5t_{CLK}$		$0.5t_{CLK}$		ns
t_{PLPH}	1	\overline{PSEN} Pulse Width	$2t_{CLK} - 5$		$2t_{CLK} - 5$		ns
t_{PLIV}	1	\overline{PSEN} LOW to Valid Instruction in		$2t_{CLK} - 40$		$2t_{CLK} - 30$	ns
t_{PXIX}	1	Input Instruction Hold After \overline{PSEN}	5		-5		ns
t_{PXIZ}	1	Input Instruction Float After \overline{PSEN}		$t_{CLK} - 5$		t_{CLK}	ns
t_{AVIV}	1	Address to Valid Instruction In		$3t_{CLK} - 40$		$3t_{CLK} - 25$	ns
t_{PLAZ}	1	\overline{PSEN} LOW to Address Float		0		0	ns
Data Memory							
t_{RLRH}	2	\overline{RD} Pulse Width ($t_{MCS} = 0$) ⁽⁵⁾	$2t_{CLK} - 5$		$2t_{CLK} - 5$		ns
	2	\overline{RD} Pulse Width ($t_{MCS} > 0$) ⁽⁵⁾	$t_{MCS} - 5$		$t_{MCS} - 5$		ns
t_{WLWH}	3	\overline{WR} Pulse Width ($t_{MCS} = 0$) ⁽⁵⁾	$2t_{CLK} - 5$		$2t_{CLK} - 5$		ns
	3	\overline{WR} Pulse Width ($t_{MCS} > 0$) ⁽⁵⁾	$t_{MCS} - 5$		$t_{MCS} - 5$		ns
t_{RLDV}	2	\overline{RD} LOW to Valid Data In ($t_{MCS} = 0$) ⁽⁵⁾		$2t_{CLK} - 40$		$2t_{CLK} - 30$	ns
	2	\overline{RD} LOW to Valid Data In ($t_{MCS} > 0$) ⁽⁵⁾		$t_{MCS} - 40$		$t_{MCS} - 30$	ns
t_{RHDX}	2	Data Hold After Read	-5		-5		ns
t_{RHDZ}	2	Data Float After Read ($t_{MCS} = 0$) ⁽⁵⁾		t_{CLK}		t_{CLK}	ns
	2	Data Float After Read ($t_{MCS} > 0$) ⁽⁵⁾		$2t_{CLK}$		$2t_{CLK}$	ns
t_{LLDV}	2	ALE LOW to Valid Data In ($t_{MCS} = 0$) ⁽⁵⁾		$2.5t_{CLK} - 40$		$2.5t_{CLK} - 25$	ns
	2	ALE LOW to Valid Data In ($t_{MCS} > 0$) ⁽⁵⁾		$t_{CLK} + t_{MCS} - 40$		$t_{CLK} + t_{MCS} - 25$	ns
t_{AVDV}	2	Address to Valid Data In ($t_{MCS} = 0$) ⁽⁵⁾		$3t_{CLK} - 40$		$3t_{CLK} - 25$	ns
	2	Address to Valid Data In ($t_{MCS} > 0$) ⁽⁵⁾		$1.5t_{CLK} + t_{MCS} - 40$		$1.5t_{CLK} + t_{MCS} - 25$	ns
t_{LLWL}	2, 3	ALE LOW to \overline{RD} or \overline{WR} LOW ($t_{MCS} = 0$) ⁽⁵⁾	$0.5t_{CLK} - 5$	$0.5t_{CLK} + 5$	$0.5t_{CLK} - 5$	$0.5t_{CLK} + 5$	ns
	2, 3	ALE LOW to \overline{RD} or \overline{WR} LOW ($t_{MCS} > 0$) ⁽⁵⁾	$t_{CLK} - 5$	$t_{CLK} + 5$	$t_{CLK} - 5$	$t_{CLK} + 5$	ns
t_{AVWL}	2, 3	Address to \overline{RD} or \overline{WR} LOW ($t_{MCS} = 0$) ⁽⁵⁾	$t_{CLK} - 5$		$t_{CLK} - 5$		ns
	2, 3	Address to \overline{RD} or \overline{WR} LOW ($t_{MCS} > 0$) ⁽⁵⁾	$2t_{CLK} - 5$		$2t_{CLK} - 5$		ns
t_{QVWX}	3	Data Valid to \overline{WR} Transition	-8		-5		ns
t_{WHQX}	3	Data Hold After \overline{WR}	$t_{CLK} - 8$		$t_{CLK} - 5$		ns
t_{RLAZ}	2	\overline{RD} LOW to Address Float		$-0.5t_{CLK} - 5$		$-0.5t_{CLK} - 5$	ns
t_{WHLH}	2, 3	\overline{RD} or \overline{WR} HIGH to ALE HIGH ($t_{MCS} = 0$) ⁽⁵⁾	-5	5	-5	5	ns
	2, 3	\overline{RD} or \overline{WR} HIGH to ALE HIGH ($t_{MCS} > 0$) ⁽⁵⁾	$t_{CLK} - 5$	$t_{CLK} + 5$	$t_{CLK} - 5$	$t_{CLK} + 5$	ns
External Clock							
t_{HIGH}	4	HIGH Time ⁽⁴⁾	15		10		ns
t_{LOW}	4	LOW Time ⁽⁴⁾	15		10		ns
t_R	4	Rise Time ⁽⁴⁾		5		5	ns
t_F	4	Fall Time ⁽⁴⁾		5		5	ns

- (1) Parameters are valid over operating temperature range, unless otherwise specified.
- (2) Load capacitance for Port 0, ALE, and $\overline{PSEN} = 100pF$; load capacitance for all other outputs = $80pF$.
- (3) $t_{CLK} = 1/f_{OSC} =$ one oscillator clock period for clock divider = 1.
- (4) These values are characterized but not 100% production tested.
- (5) t_{MCS} is a time period related to the Stretch MOVX selection. The following table shows the value of t_{MCS} for each stretch selection:

MD2	MD1	MD0	MOVX DURATION	t_{MCS}
0	0	0	2 Machine Cycles	0
0	0	1	3 Machine Cycles (default)	$4t_{CLK}$
0	1	0	4 Machine Cycles	$8t_{CLK}$
0	1	1	5 Machine Cycles	$12t_{CLK}$
1	0	0	6 Machine Cycles	$16t_{CLK}$
1	0	1	7 Machine Cycles	$20t_{CLK}$
1	1	0	8 Machine Cycles	$24t_{CLK}$
1	1	1	9 Machine Cycles	$28t_{CLK}$

EXPLANATION OF THE AC SYMBOLS

Each Timing Symbol has five characters. The first character is always 't' (= time). The other characters, depending on their positions, indicate the name of a signal or the logical status of that signal. The designators are:

A—Address

C—Clock

D—Input Data

H—Logic Level HIGH

I—Instruction (program memory contents)

L—Logic Level LOW, or ALE

P—PSEN

Q—Output Data

R—RD Signal

t—Time

V—Valid

W—WR Signal

X—No Longer a Valid Logic Level

Z—Float

Examples:

(1) t_{AVLL} = Time for address valid to ALE LOW.

(2) t_{LLPL} = Time for ALE LOW to PSEN LOW.

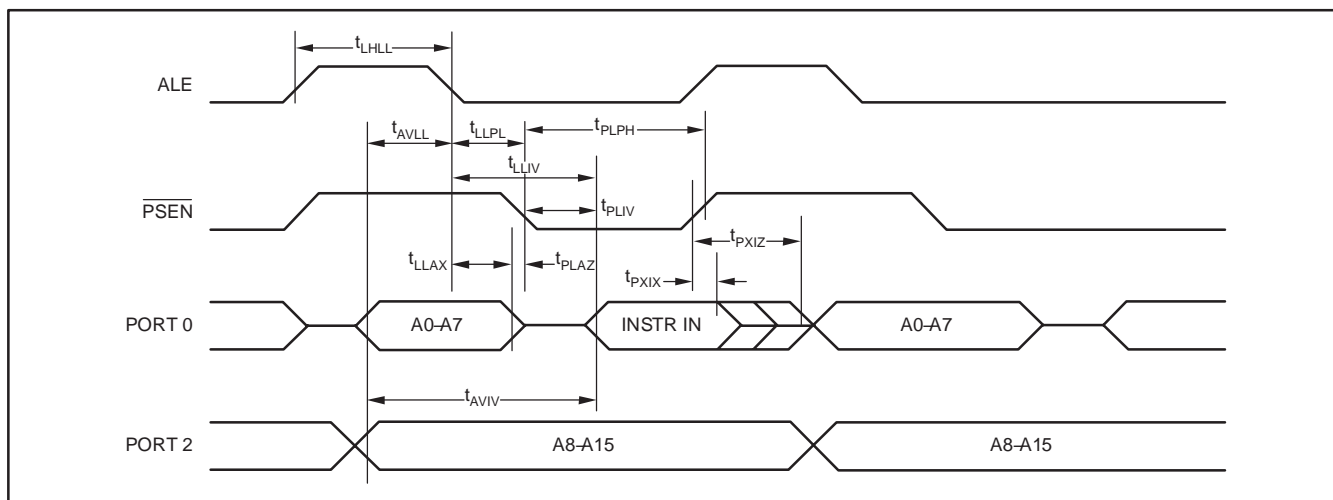


Figure 1. External Program Memory Read Cycle

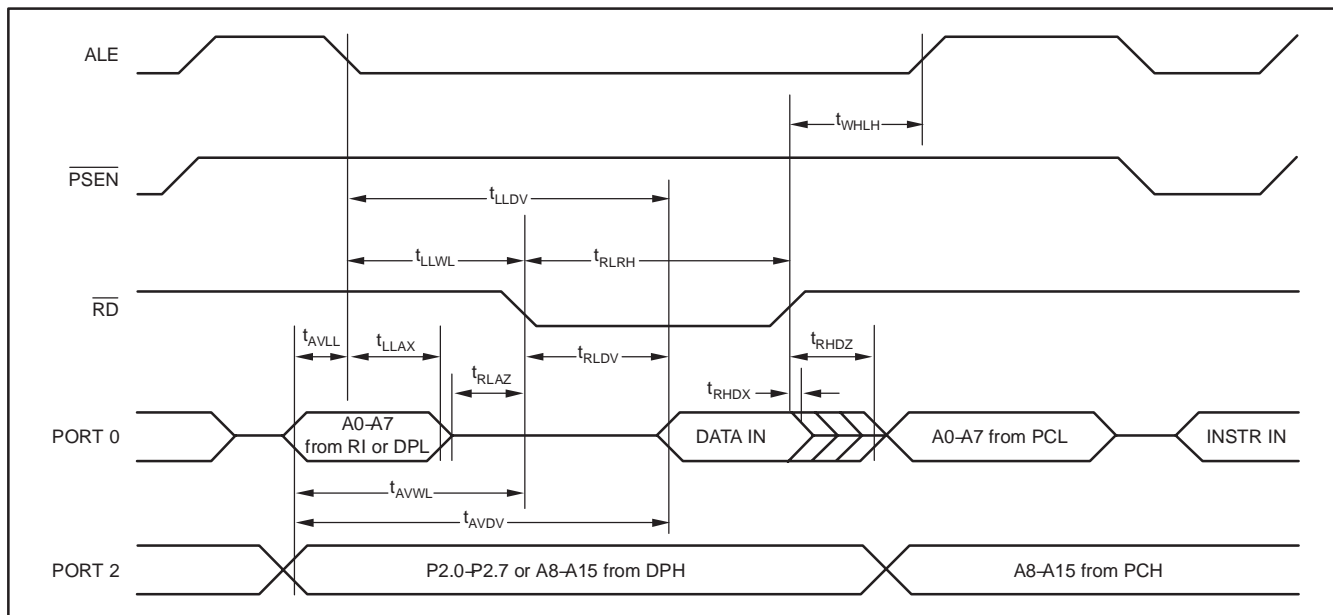


Figure 2. External Data Memory Read Cycle

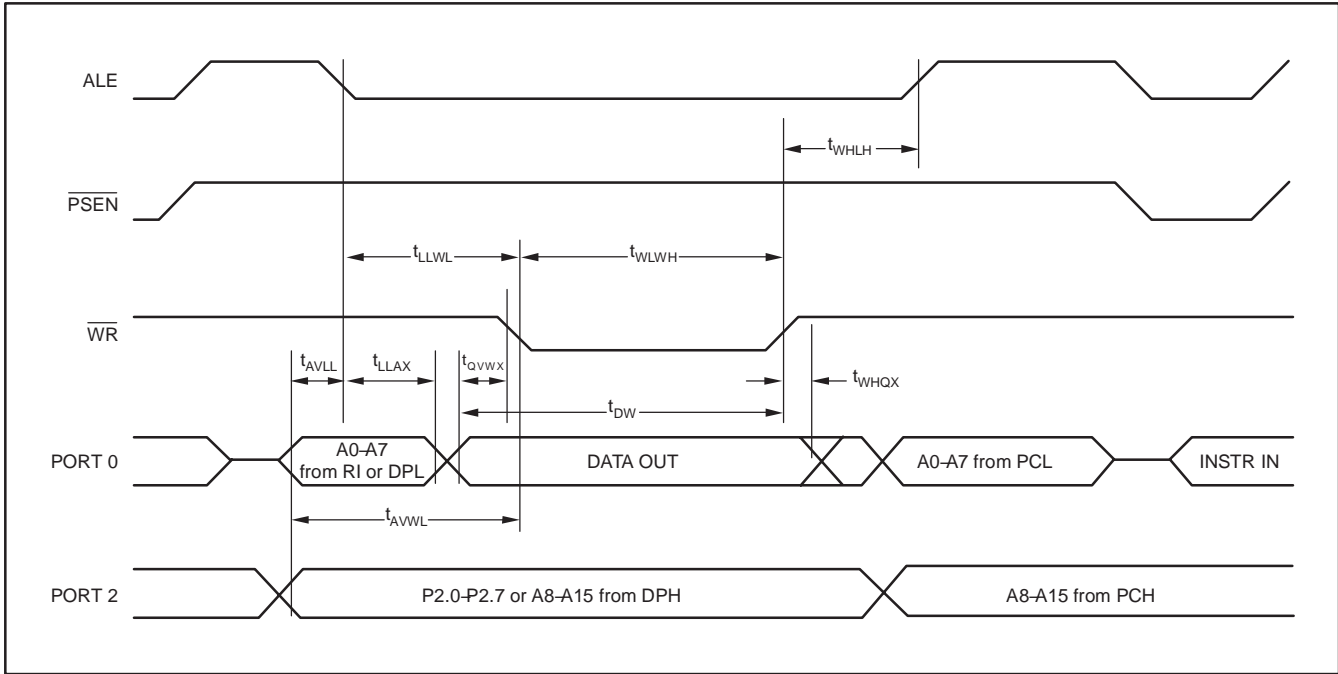


Figure 3. External Data Memory Write Cycle

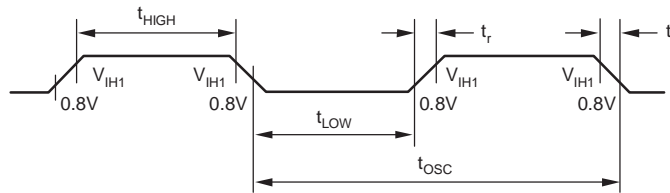


Figure 4. External Clock Drive CLK

PRODUCT PREVIEW

RESET AND POWER-ON TIMING

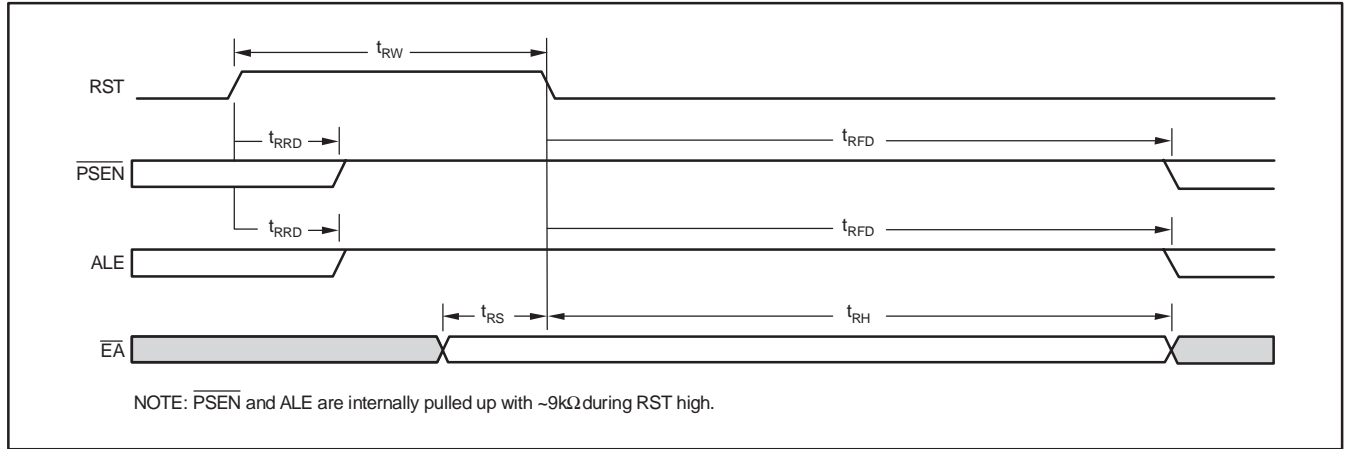


Figure 5. Reset Timing, User Application Mode

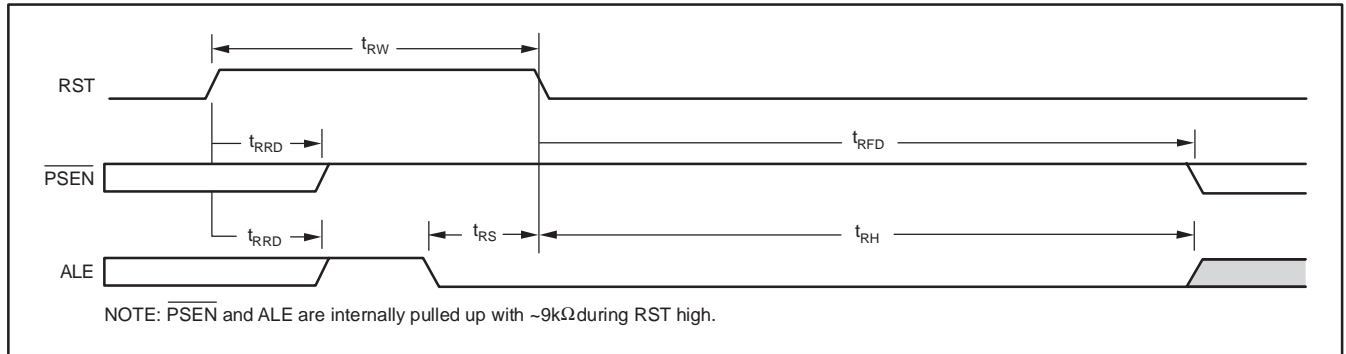


Figure 6. Parallel Flash Programming Power-On Timing ($\overline{\text{EA}}$ is ignored)

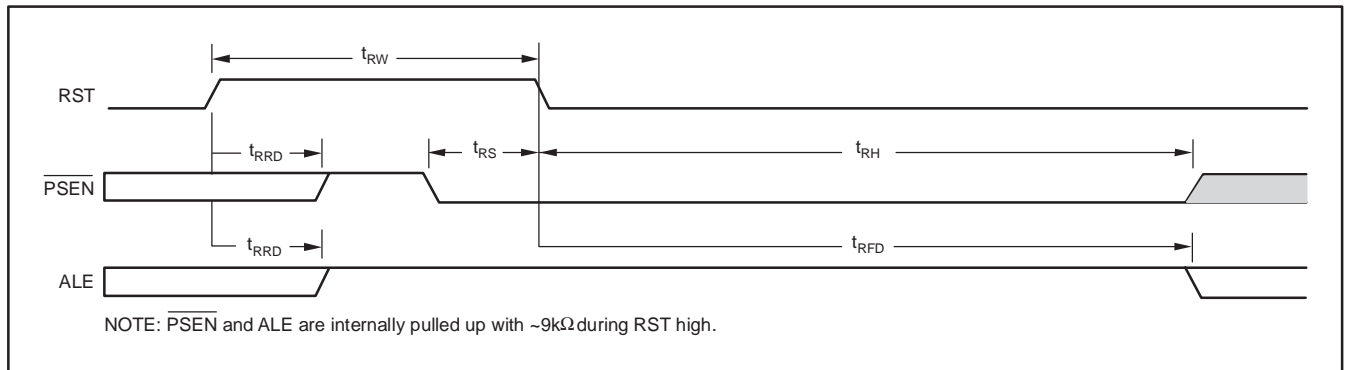
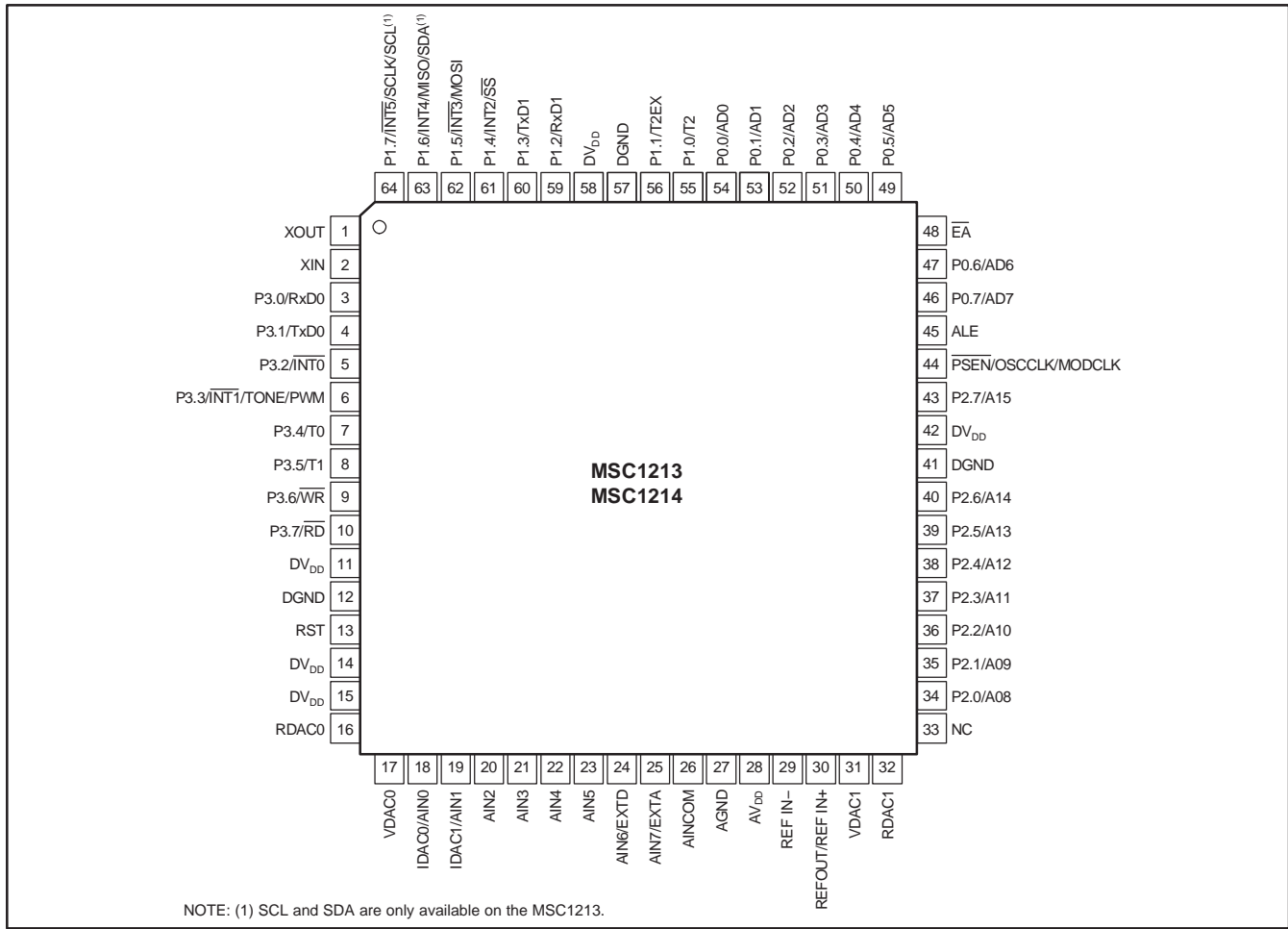


Figure 7. Serial Flash Programming Power-On Timing ($\overline{\text{EA}}$ is ignored)

Table 1. Serial Flash Programming Timing

SYMBOL	PARAMETER	MIN	MAX	UNIT
t_{RW}	RST width	$2t_{OSC}$	—	—
t_{RRD}	RST rise to $\overline{\text{PSEN}}$ ALE internal pull HIGH	—	5	μs
t_{RFD}	RST falling to $\overline{\text{PSEN}}$ and ALE start	—	$(2^{17} + 512)t_{OSC}$	—
t_{RS}	Input signal to RST falling setup time	t_{OSC}	—	—
t_{RH}	RST falling to input signal hold time	$(2^{17} + 512)t_{OSC}$	—	—



PIN DESCRIPTIONS

PIN #	NAME	DESCRIPTION																											
1	XOUT	The crystal oscillator pin XOUT supports parallel resonant AT cut fundamental frequency crystals and ceramic resonators. XOUT serves as the output of the crystal amplifier.																											
2	XIN	The crystal oscillator pin XIN supports parallel resonant AT cut fundamental frequency crystals and ceramic resonators. XIN can also be an input if there is an external clock source instead of a crystal.																											
3-10	P3.0-P3.7	Port 3 is a bidirectional I/O port. The alternate functions for Port 3 are listed below. Refer to P3DDR, SFR B3H-B4H. <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>PORT</th> <th>ALTERNATE</th> <th>MODE</th> </tr> </thead> <tbody> <tr> <td>P3.0</td> <td>RxD0</td> <td>Serial Port 0 Input</td> </tr> <tr> <td>P3.1</td> <td>TxD0</td> <td>Serial Port 0 Output</td> </tr> <tr> <td>P3.2</td> <td>INT0</td> <td>External Interrupt 0</td> </tr> <tr> <td>P3.3</td> <td>INT1/TONE/PWM</td> <td>External Interrupt 1/TONE/PWM Output</td> </tr> <tr> <td>P3.4</td> <td>T0</td> <td>Timer 0 External Input</td> </tr> <tr> <td>P3.5</td> <td>T1</td> <td>Timer 1 External Input</td> </tr> <tr> <td>P3.6</td> <td>WR</td> <td>External Data Memory Write Strobe</td> </tr> <tr> <td>P3.7</td> <td>RD</td> <td>External Data Memory Read Strobe</td> </tr> </tbody> </table>	PORT	ALTERNATE	MODE	P3.0	RxD0	Serial Port 0 Input	P3.1	TxD0	Serial Port 0 Output	P3.2	INT0	External Interrupt 0	P3.3	INT1/TONE/PWM	External Interrupt 1/TONE/PWM Output	P3.4	T0	Timer 0 External Input	P3.5	T1	Timer 1 External Input	P3.6	WR	External Data Memory Write Strobe	P3.7	RD	External Data Memory Read Strobe
PORT	ALTERNATE	MODE																											
P3.0	RxD0	Serial Port 0 Input																											
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P3.4	T0	Timer 0 External Input																											
P3.5	T1	Timer 1 External Input																											
P3.6	WR	External Data Memory Write Strobe																											
P3.7	RD	External Data Memory Read Strobe																											
11, 14, 15, 42, 58	DV _{DD}	Digital Power Supply																											
12, 41, 57	DGND	Digital Ground																											
13	RST	A HIGH on the reset input for two t _{OSC} periods will reset the device.																											
16	RDAC0	IDAC0 Reference Resistor Pin																											
17	VDAC0	VDAC0 Output																											
27	AGND	Analog Ground																											
18	IDAC0/AIN0	IDAC0 Output/Analog Input Channel 0																											
19	IDAC1/AIN1	IDAC1 Output/Analog Input Channel 1																											

PIN DESCRIPTIONS (Continued)

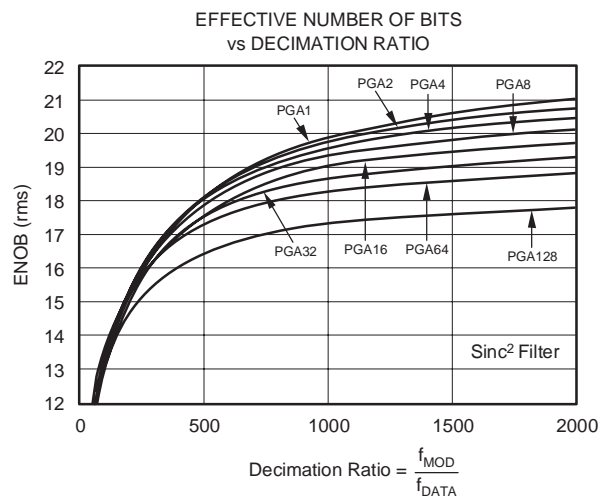
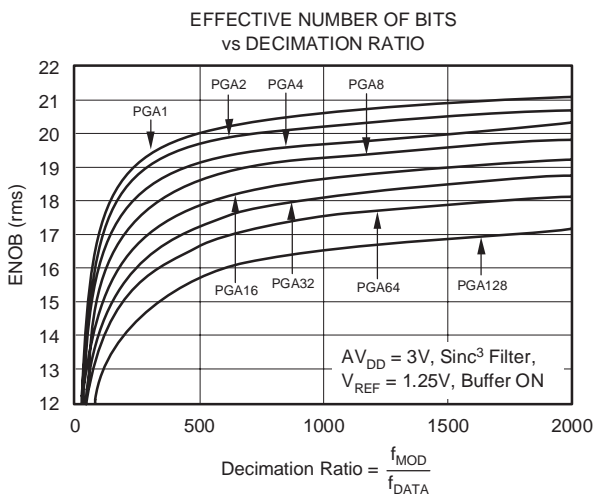
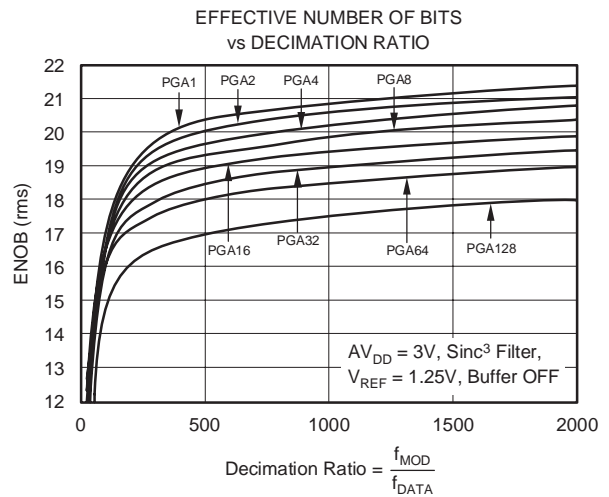
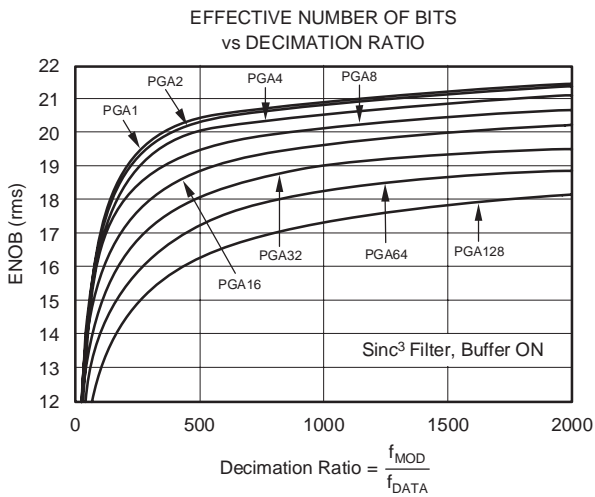
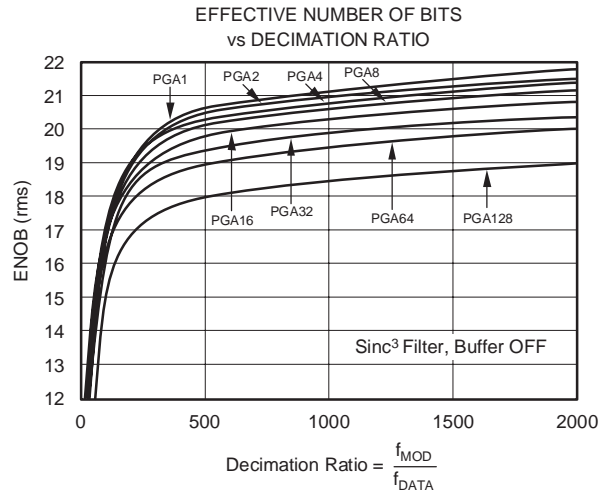
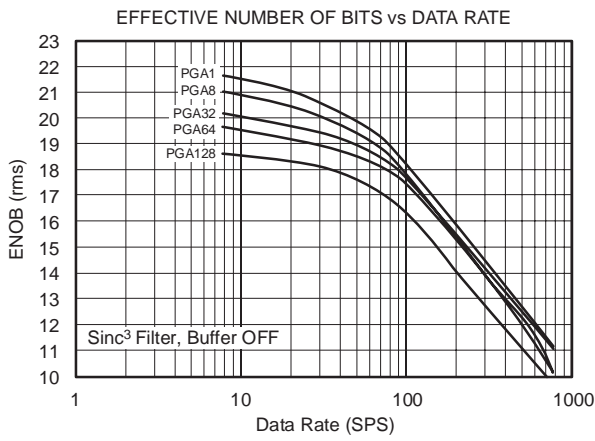
PIN #	NAME	DESCRIPTION																											
20	AIN2	Analog Input Channel 2																											
21	AIN3	Analog Input Channel 3																											
22	AIN4	Analog Input Channel 4																											
23	AIN5	Analog Input Channel 5																											
24	AIN6, EXT _D	Analog Input Channel 6, LVD Comparator Input, Generates DLVD Interrupt																											
25	AIN7, EXT _A	Analog Input Channel 7, LVD Comparator Input, Generates ALVD Interrupt																											
26	AINCOM	Analog Common; can be used like any analog input except during Offset – Inputs shorted to this pin.																											
28	AV _{DD}	Analog Power Supply																											
29	REF IN ₋	Voltage Reference Negative Input (must be tied to AGND for internal V _{REF} use)																											
30	REFOUT/REF IN ₊	Internal Voltage Reference Output/Voltage Reference Positive Input																											
31	VDAC1	VDAC1 Output																											
32	RDAC1	IDAC1 Reference Resistor Pin																											
33	NC	No Connection																											
34-40, 43	P2.0-P2.7	Port 2 is a bidirectional I/O port. The alternate functions for Port 2 are listed below. Refer to P2DDR, SFR B1 _H -B2 _H . <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>PORT</th> <th>ALTERNATE</th> <th>MODE</th> </tr> </thead> <tbody> <tr><td>P2.0</td><td>A8</td><td>Address Bit 8</td></tr> <tr><td>P2.1</td><td>A9</td><td>Address Bit 9</td></tr> <tr><td>P2.2</td><td>A10</td><td>Address Bit 10</td></tr> <tr><td>P2.3</td><td>A11</td><td>Address Bit 11</td></tr> <tr><td>P2.4</td><td>A12</td><td>Address Bit 12</td></tr> <tr><td>P2.5</td><td>A13</td><td>Address Bit 13</td></tr> <tr><td>P2.6</td><td>A14</td><td>Address Bit 14</td></tr> <tr><td>P2.7</td><td>A15</td><td>Address Bit 15</td></tr> </tbody> </table>	PORT	ALTERNATE	MODE	P2.0	A8	Address Bit 8	P2.1	A9	Address Bit 9	P2.2	A10	Address Bit 10	P2.3	A11	Address Bit 11	P2.4	A12	Address Bit 12	P2.5	A13	Address Bit 13	P2.6	A14	Address Bit 14	P2.7	A15	Address Bit 15
PORT	ALTERNATE	MODE																											
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P2.5	A13	Address Bit 13																											
P2.6	A14	Address Bit 14																											
P2.7	A15	Address Bit 15																											
44	PSEN OSCCLK MODCLK	Program Store Enable: Connected to optional external memory as a chip enable. PSEN will provide an active low pulse. In programming mode, PSEN is used as an input along with ALE to define serial or parallel programming mode. PSEN is held HIGH for parallel programming and held LOW for serial programming. This pin can also be selected (when not using external memory) to output the Oscillator clock, Modulator clock, HIGH, or LOW. Care should be taken so that loading on this pin should not inadvertently cause the device to enter programming mode. <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>ALE</th> <th>PSEN</th> <th>PROGRAM MODE SELECTION DURING RESET</th> </tr> </thead> <tbody> <tr><td>NC</td><td>NC</td><td>Normal Operation (user application mode)</td></tr> <tr><td>0</td><td>NC</td><td>Parallel Programming</td></tr> <tr><td>NC</td><td>0</td><td>Serial Programming</td></tr> <tr><td>0</td><td>0</td><td>Reserved</td></tr> </tbody> </table>	ALE	PSEN	PROGRAM MODE SELECTION DURING RESET	NC	NC	Normal Operation (user application mode)	0	NC	Parallel Programming	NC	0	Serial Programming	0	0	Reserved												
ALE	PSEN	PROGRAM MODE SELECTION DURING RESET																											
NC	NC	Normal Operation (user application mode)																											
0	NC	Parallel Programming																											
NC	0	Serial Programming																											
0	0	Reserved																											
45	ALE	Address Latch Enable: Used for latching the low byte of the address during an access to external memory. ALE is emitted at a constant rate of 1/4 the oscillator frequency, and can be used for external timing or clocking. One ALE pulse is skipped during each access to external data memory. In programming mode, ALE is used as an input along with PSEN to define serial or parallel programming mode. ALE is held HIGH for serial programming and held LOW for parallel programming. This pin can also be selected (when not using external memory) to output HIGH or LOW. Care should be taken so that loading on this pin should not inadvertently cause the device to enter programming mode.																											
48	EA	External Access Enable: EA must be externally held LOW to enable the device to fetch code from external program memory locations starting with 0000 _H . No internal pull-up on this pin.																											
46, 47, 49-54	P0.0-P0.7	Port 0 is a bidirectional I/O port. The alternate functions for Port 0 are listed below. <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>PORT</th> <th>ALTERNATE</th> <th>MODE</th> </tr> </thead> <tbody> <tr><td>P0.0</td><td>AD0</td><td>Address/Data Bit 0</td></tr> <tr><td>P0.1</td><td>AD1</td><td>Address/Data Bit 1</td></tr> <tr><td>P0.2</td><td>AD2</td><td>Address/Data Bit 2</td></tr> <tr><td>P0.3</td><td>AD3</td><td>Address/Data Bit 3</td></tr> <tr><td>P0.4</td><td>AD4</td><td>Address/Data Bit 4</td></tr> <tr><td>P0.5</td><td>AD5</td><td>Address/Data Bit 5</td></tr> <tr><td>P0.6</td><td>AD6</td><td>Address/Data Bit 6</td></tr> <tr><td>P0.7</td><td>AD7</td><td>Address/Data Bit 7</td></tr> </tbody> </table>	PORT	ALTERNATE	MODE	P0.0	AD0	Address/Data Bit 0	P0.1	AD1	Address/Data Bit 1	P0.2	AD2	Address/Data Bit 2	P0.3	AD3	Address/Data Bit 3	P0.4	AD4	Address/Data Bit 4	P0.5	AD5	Address/Data Bit 5	P0.6	AD6	Address/Data Bit 6	P0.7	AD7	Address/Data Bit 7
PORT	ALTERNATE	MODE																											
P0.0	AD0	Address/Data Bit 0																											
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P0.5	AD5	Address/Data Bit 5																											
P0.6	AD6	Address/Data Bit 6																											
P0.7	AD7	Address/Data Bit 7																											
55, 56, 59-64	P1.0-P1.7	Port 1 is a bidirectional I/O port. The alternate functions for Port 1 are listed below. Refer to P1DDR, SFR AE _H -AF _H . <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>PORT</th> <th>ALTERNATE</th> <th>MODE</th> </tr> </thead> <tbody> <tr><td>P1.0</td><td>T2</td><td>T2 Input</td></tr> <tr><td>P1.1</td><td>T2EX</td><td>T2 External Input</td></tr> <tr><td>P1.2</td><td>RxD1</td><td>Serial Port Input</td></tr> <tr><td>P1.3</td><td>TxD1</td><td>Serial Port Output</td></tr> <tr><td>P1.4</td><td>INT2/SS</td><td>External Interrupt/Slave Select</td></tr> <tr><td>P1.5</td><td>INT3/MOSI</td><td>External Interrupt/Master Out-Slave In</td></tr> <tr><td>P1.6</td><td>INT4/MISO/SDA⁽¹⁾</td><td>External Interrupt/Master In-Slave Out/SDA</td></tr> <tr><td>P1.7</td><td>INT5/SCK/SCL⁽¹⁾</td><td>External Interrupt/Serial Clock</td></tr> </tbody> </table>	PORT	ALTERNATE	MODE	P1.0	T2	T2 Input	P1.1	T2EX	T2 External Input	P1.2	RxD1	Serial Port Input	P1.3	TxD1	Serial Port Output	P1.4	INT2/SS	External Interrupt/Slave Select	P1.5	INT3/MOSI	External Interrupt/Master Out-Slave In	P1.6	INT4/MISO/SDA ⁽¹⁾	External Interrupt/Master In-Slave Out/SDA	P1.7	INT5/SCK/SCL ⁽¹⁾	External Interrupt/Serial Clock
PORT	ALTERNATE	MODE																											
P1.0	T2	T2 Input																											
P1.1	T2EX	T2 External Input																											
P1.2	RxD1	Serial Port Input																											
P1.3	TxD1	Serial Port Output																											
P1.4	INT2/SS	External Interrupt/Slave Select																											
P1.5	INT3/MOSI	External Interrupt/Master Out-Slave In																											
P1.6	INT4/MISO/SDA ⁽¹⁾	External Interrupt/Master In-Slave Out/SDA																											
P1.7	INT5/SCK/SCL ⁽¹⁾	External Interrupt/Serial Clock																											

NOTE: (1) SDA and SCL are only available on the MSC1213.

TYPICAL CHARACTERISTICS

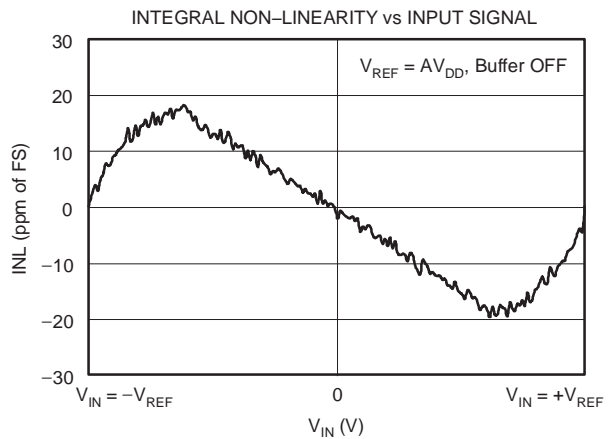
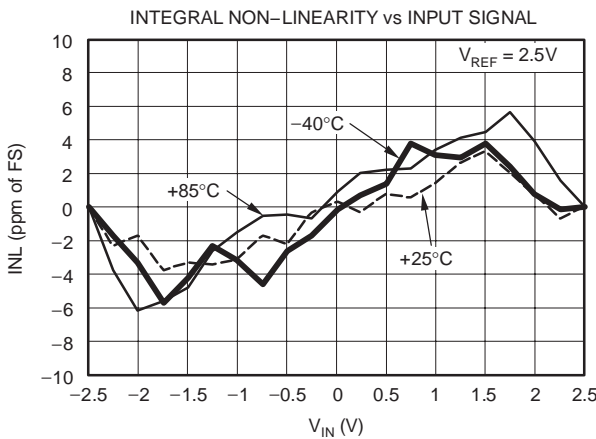
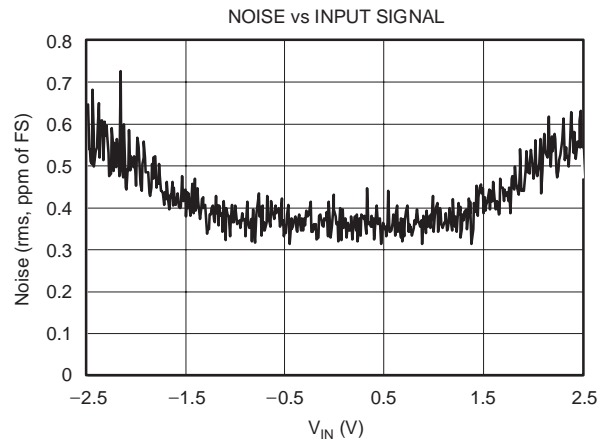
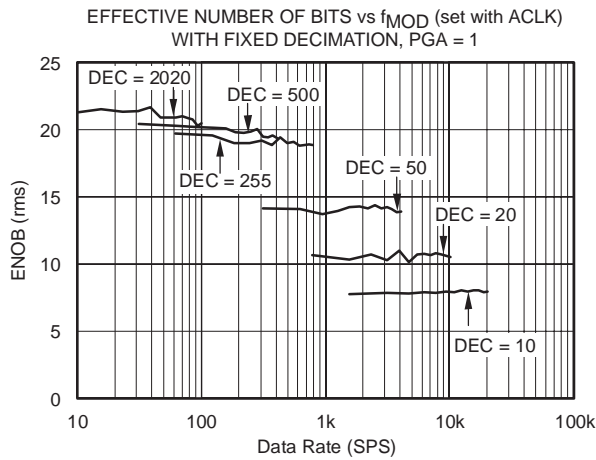
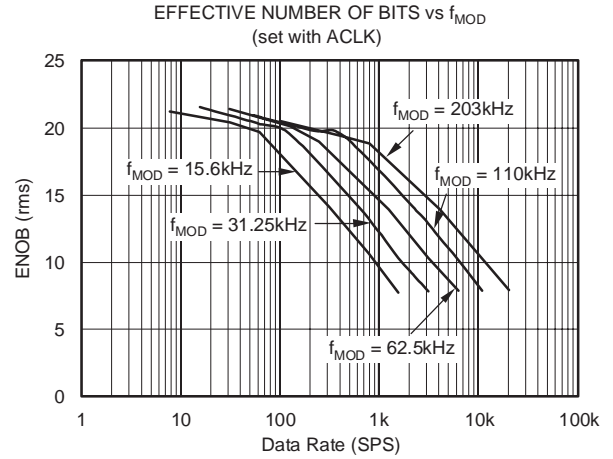
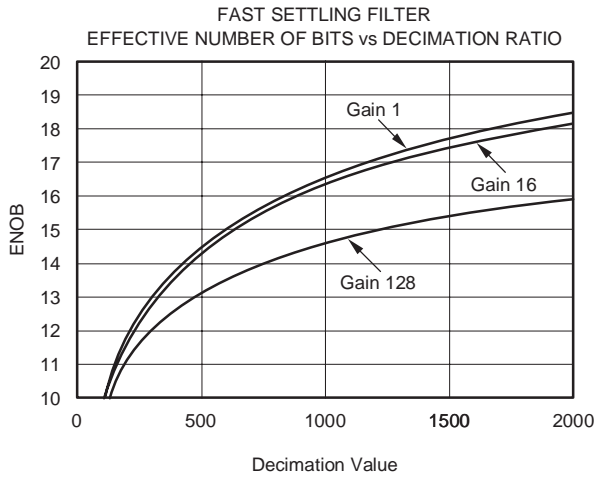
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PRODUCT PREVIEW



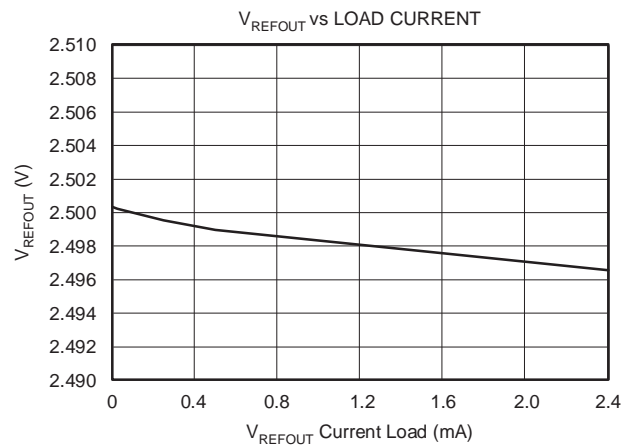
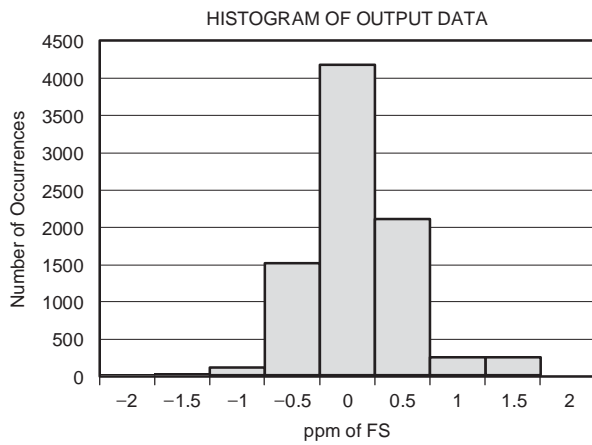
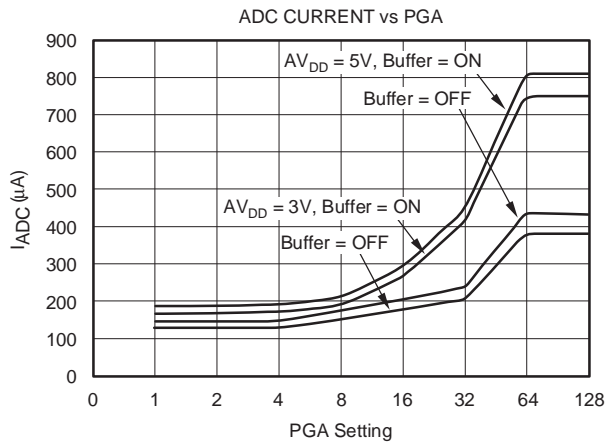
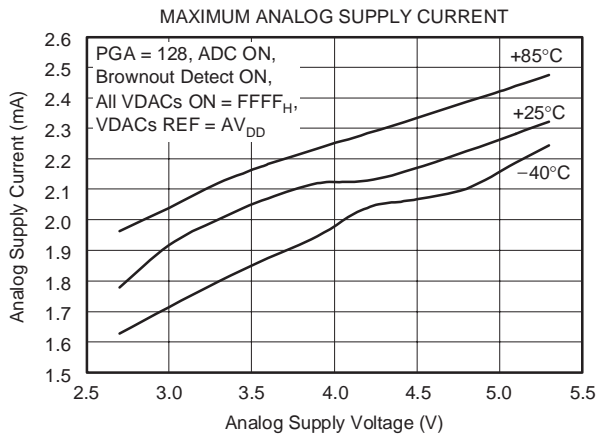
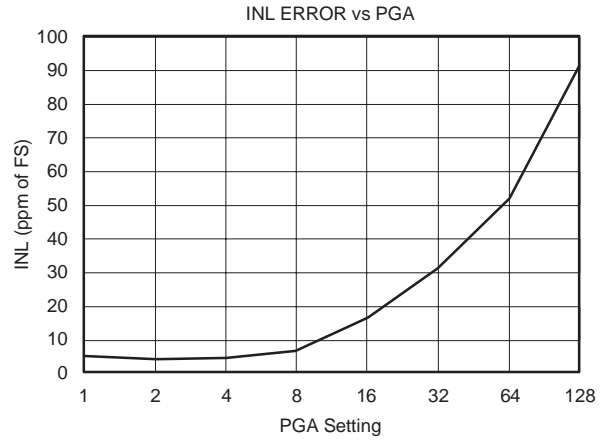
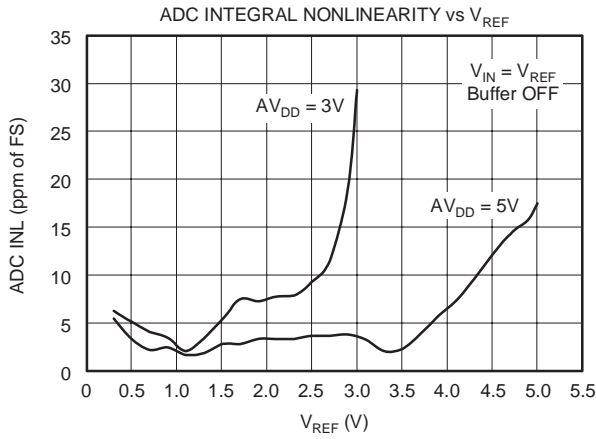
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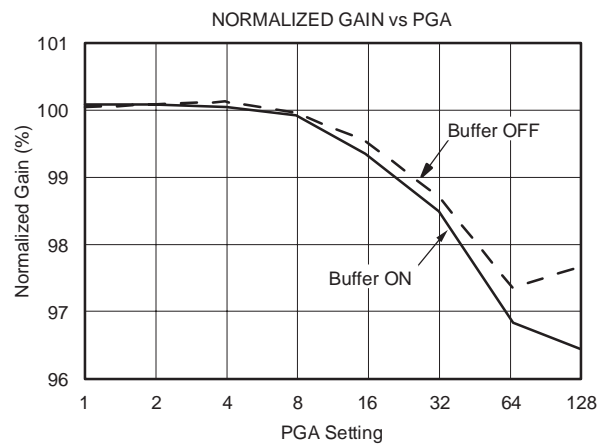
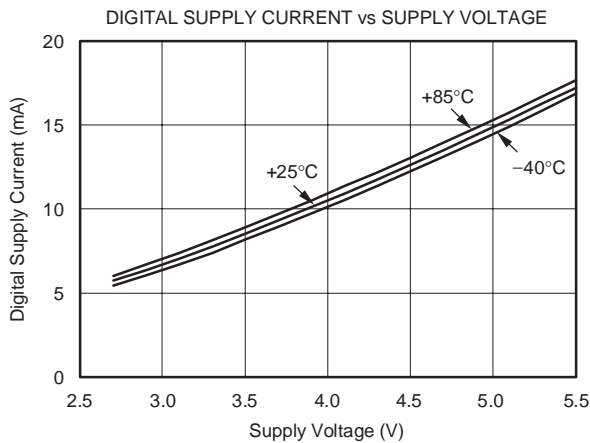
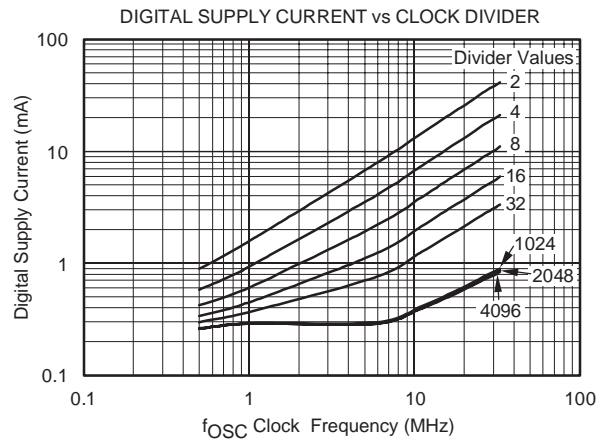
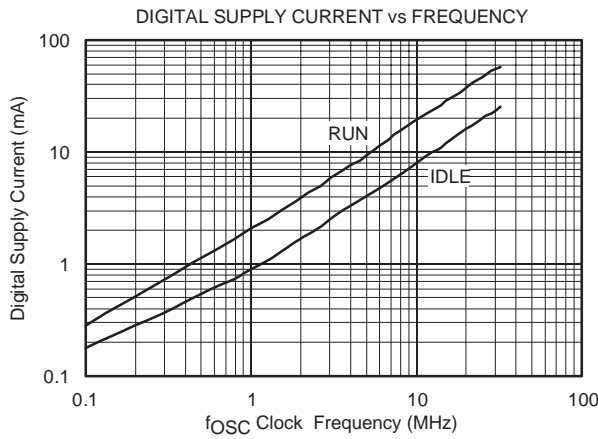
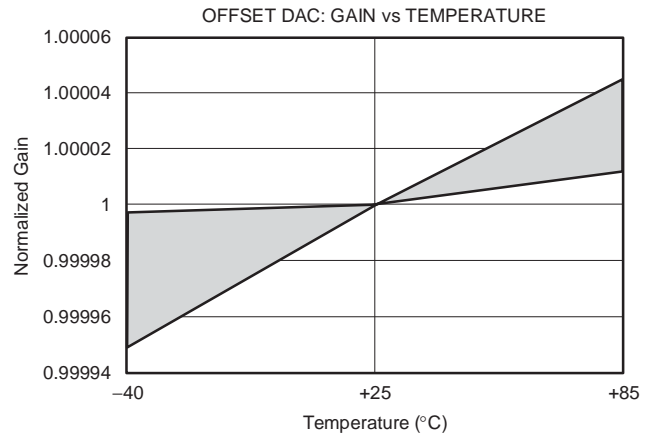
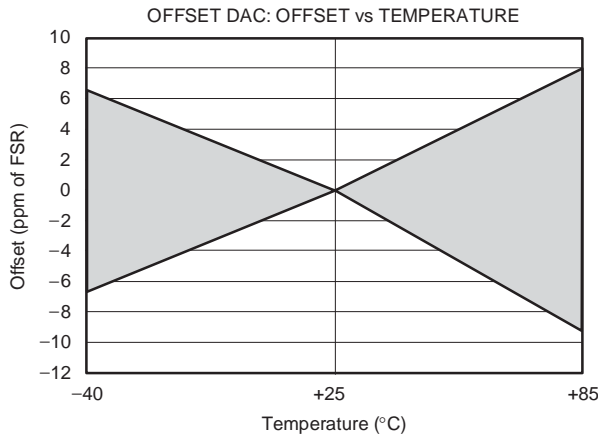
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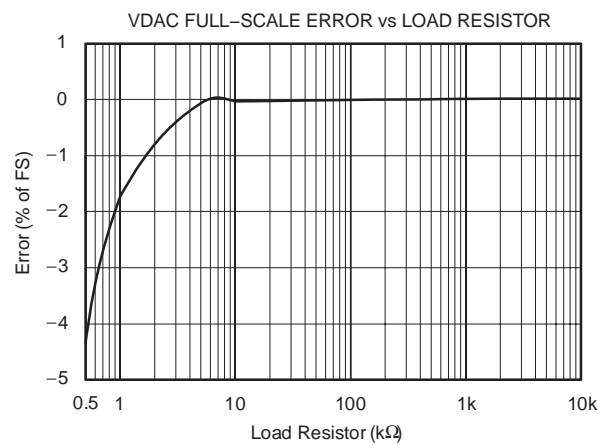
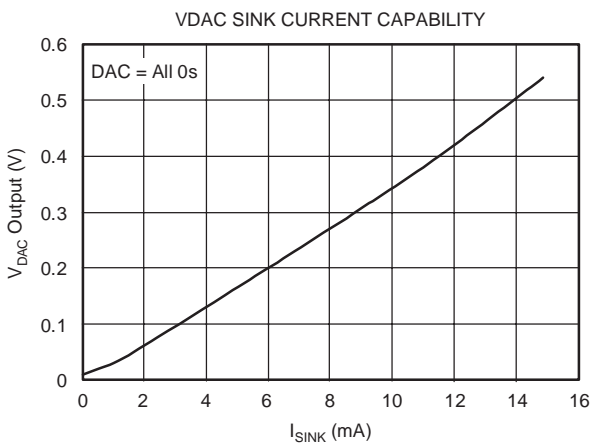
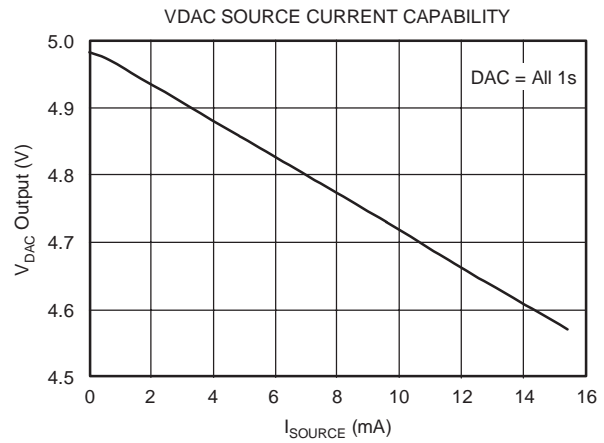
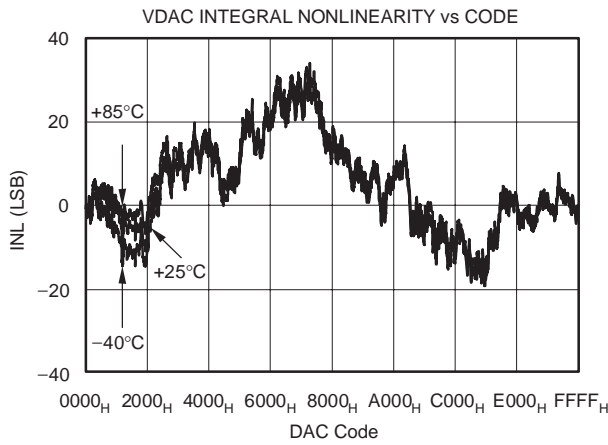
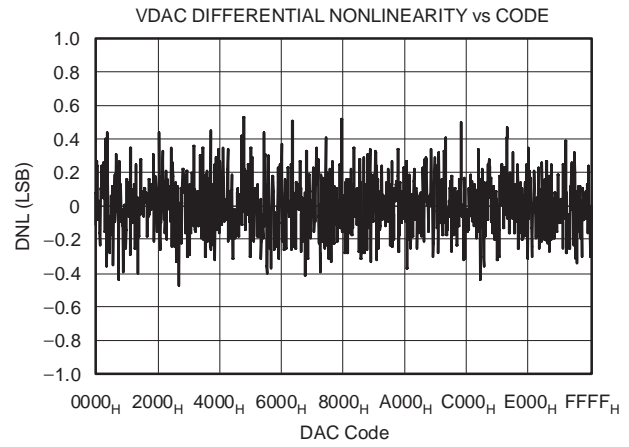
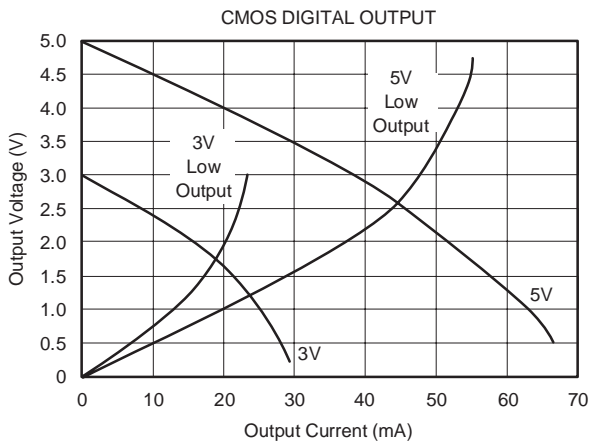
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TYPICAL CHARACTERISTICS (Continued)

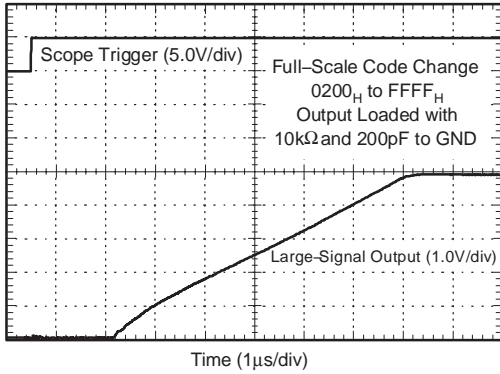
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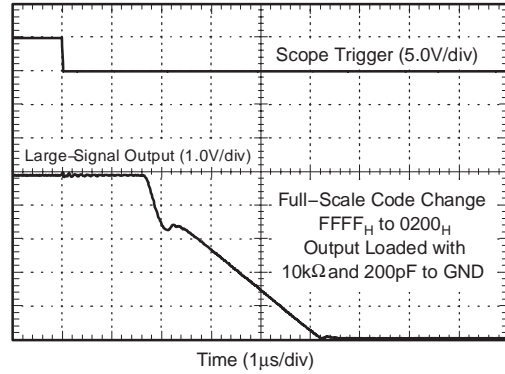
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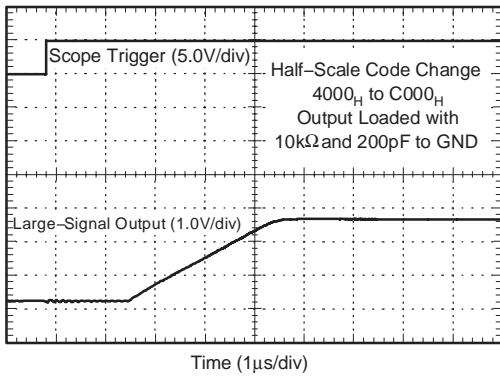
VDAC FULL-SCALE SETTLING TIME



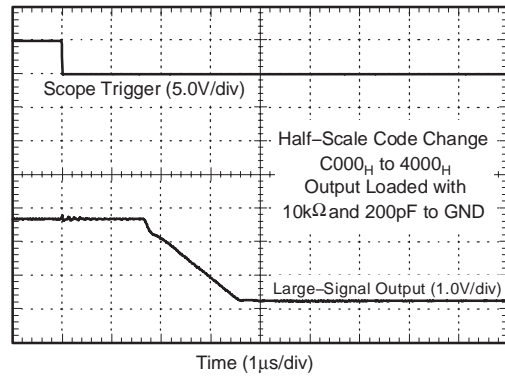
VDAC FULL-SCALE SETTLING TIME



VDAC HALF-SCALE SETTLING TIME

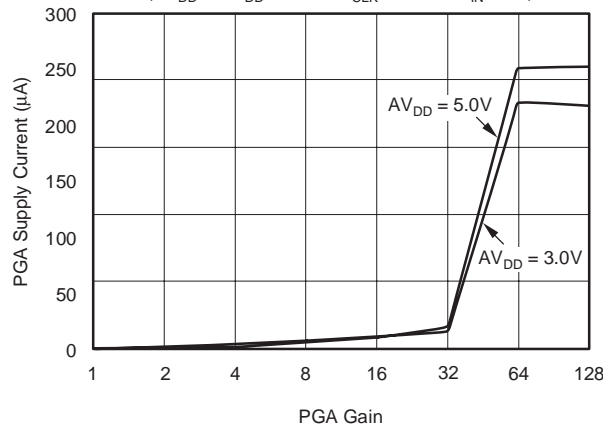


VDAC HALF-SCALE SETTLING TIME



PGA SUPPLY CURRENT

($A_{V_{DD}} = DV_{DD} = 3V/5V$, $f_{CLK} = 8MHz$, $V_{IN} = 0V$)



DESCRIPTION

The MSC1213Yx/MSC1214Yx are completely integrated families of mixed-signal devices incorporating a high-resolution delta-sigma ADC, dual 16-bit DACs, 8-channel multiplexer, burnout detect current sources, selectable buffered input, offset DAC (Digital-to-Analog Converter), Programmable Gain Amplifier (PGA), temperature sensor, voltage reference, 8-bit microcontroller, Flash Program Memory, Flash Data Memory, and Data SRAM, as shown in Figure 8.

On-chip peripherals include an additional 32-bit accumulator, an SPI compatible serial port with FIFO, dual USARTs, multiple digital input/output ports, watchdog timer, low-voltage detect, on-chip power-on reset, 16-bit PWM, breakpoints, brownout reset, three timer/counters, and a system clock divider. The MSC1213 also contains a hardware I²C peripheral.

The devices accept low-level differential or single-ended signals directly from a transducer. The ADC provides 24 bits of resolution and 24 bits of no-missing-code performance using a Sinc³ filter with a programmable sample rate. The ADC also has a selectable filter that allows for high-resolution single-cycle conversion.

The microcontroller core is 8051 instruction set compatible. The microcontroller core is an optimized 8051 core which executes up to three times faster than the standard 8051 core, given the same clock source. That makes it possible to run the devices at a lower external clock frequency and achieve the same performance at lower power than the standard 8051 core.

The MSC1213Yx/MSC1214Yx allow the user to uniquely configure the Flash and SRAM memory maps to meet the needs of their application. The Flash is programmable down to 2.7V using both serial and parallel programming methods. The Flash endurance is 100k Erase/Write cycles. In addition, 1280 bytes of RAM are incorporated on-chip.

The parts have separate analog and digital supplies, which can be independently powered from 2.7V to +5.5V. At +3V operation, the power dissipation for each part is typically less than 4mW. The MSC1213Yx/MSC1214Yx are both packaged in a TQFP-64 package.

The MSC1213Yx/MSC1214Yx are designed for high-resolution measurement applications in smart transmitters, industrial process control, weigh scales, chromatography, and portable instrumentation.

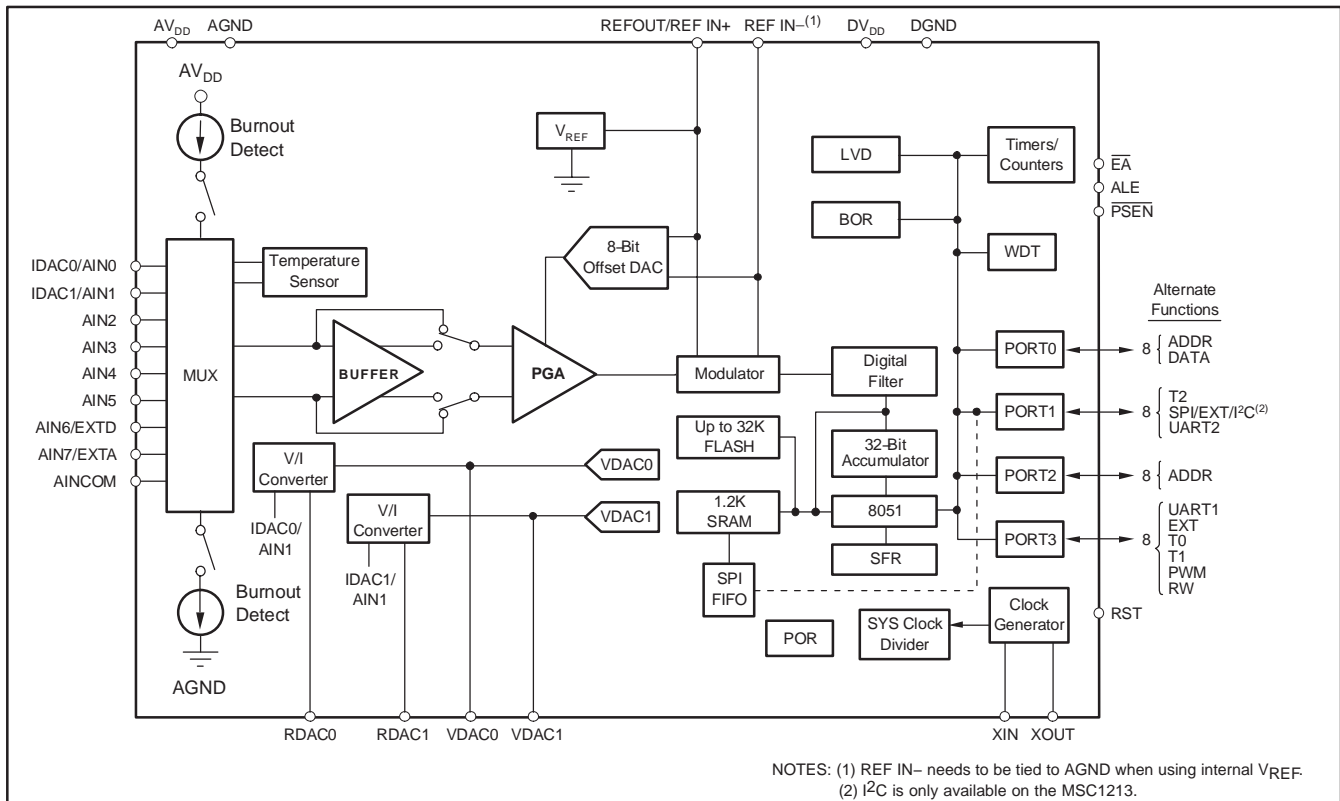


Figure 8. Block Diagram

ENHANCED 8051 CORE

All instructions in the MSC1213/14 families perform exactly the same functions as they would in a standard 8051. The effect on bits, flags, and registers is the same. However, the timing is different. The MSC1213/14 families utilize an efficient 8051 core which results in an improved instruction execution speed of between 1.5 and 3 times faster than the original core for the same external clock speed (4 clock cycles per instruction versus 12 clock cycles per instruction, as shown in Figure 9). This translates into an effective throughput improvement of more than 2.5 times, using the same code and same external clock speed. Therefore, a device frequency of 30MHz for the MSC1213Yx/MSC1214Yx actually performs at an equivalent execution speed of 75MHz compared to the standard 8051 core. This allows the user to run the device at slower external clock speeds which reduces system noise and power consumption, but provides greater throughput. This performance difference can be seen in Figure 10. The timing of software loops will be faster with the MSC1213/14. However, the timer/counter operation of the MSC1213/14 may be maintained at 12 clocks per increment or optionally run at 4 clocks per increment.

The MSC1213Yx/MSC1214Yx also provide dual data pointers (DPTRs) to speed block Data Memory moves.

Additionally, both devices can stretch the number of memory cycles to access external Data Memory from between two and nine instruction cycles in order to accommodate different speeds of memory or devices, as shown in Table 2. The MSC1213/14 provide an external memory interface with a 16-bit address bus (P0 and P2). The 16-bit address bus makes it necessary to multiplex the low address byte through the P0 port. To enhance P0 and P2 for high-speed memory access, hardware configuration control is provided to configure the ports for external memory/peripheral interface or general-purpose I/O.

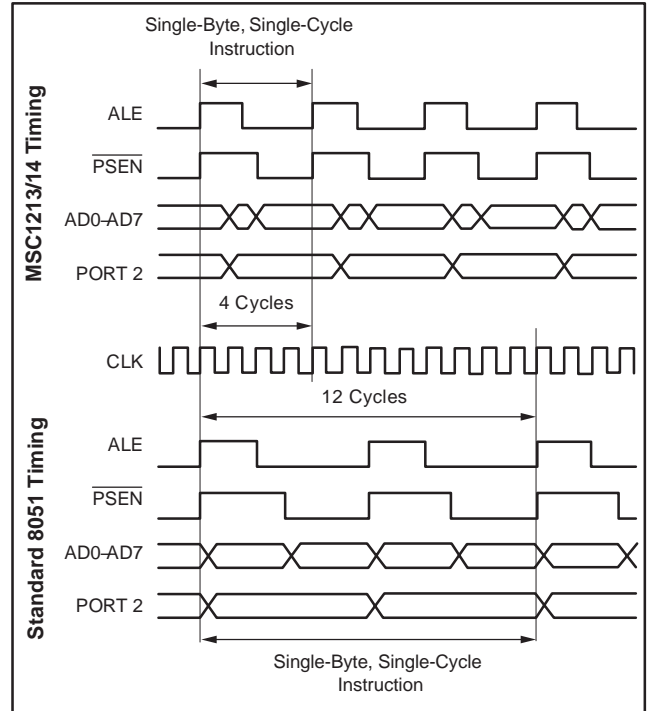


Figure 10. Comparison of MSC1213/14 Timing to Standard 8051 Timing

CKCON (8E _H) MD2:MD0	INSTRUCTION CYCLES (for MOVX)	RD or WR STROBE WIDTH (SYS CLKs)	RD or WR STROBE WIDTH (μs) AT 12MHz
000	2	2	0.167
001	3 (default)	4	0.333
010	4	8	0.667
011	5	12	1.000
100	6	16	1.333
101	7	20	1.667
110	8	24	2.000
111	9	28	2.333

Table 2. Memory Cycle Stretching. Stretching of MOVX timing as defined by MD2, MD1, and MD0 bits in CKCON register (address 8E_H).

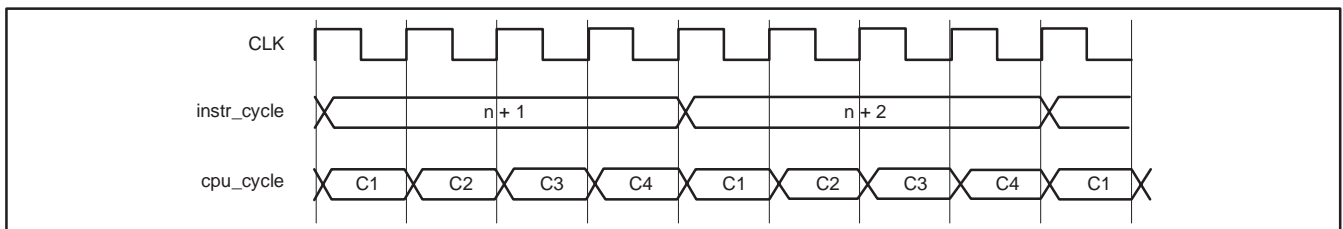


Figure 9. Instruction Timing Cycle

Furthermore, improvements were made to peripheral features that off-load processing from the core, and the user, to further improve efficiency. For instance, the SPI interface uses a FIFO, which allows the SPI interface to transmit and receive data with minimum overhead needed from the core. Also, a 32-bit accumulator was added to significantly reduce the processing overhead for the multiple byte data from the ADC or other sources. This allows for 32-bit addition, subtraction and shifting to be accomplished in a few instruction cycles, compared to hundreds of instruction cycles through software implementation.

Family Device Compatibility

The hardware functionality and pin configuration across the MSC1213/14 families are fully compatible. To the user, the only differences between family members are the memory configuration and the availability of I²C for the MSC1213. This makes migration between family

members simple. This gives the user the ability to add or subtract software functions and to freely migrate between family members. Thus, the MSC1213/14 can become a standard device used across several application platforms.

Family Development Tools

The MSC1213/14 are fully compatible with the standard 8051 instruction set. This means that the user can develop software for the MSC1213/14 with their existing 8051 development tools. Additionally, a complete, integrated development environment is provided with each demo board, and third-party developers also provide support.

Power-Down Modes

The MSC1213/14 can each power several of the on-chip peripherals and put the CPU into IDLE. This is accomplished by shutting off the clocks to those sections, as shown in Figure 11.

PRODUCT PREVIEW

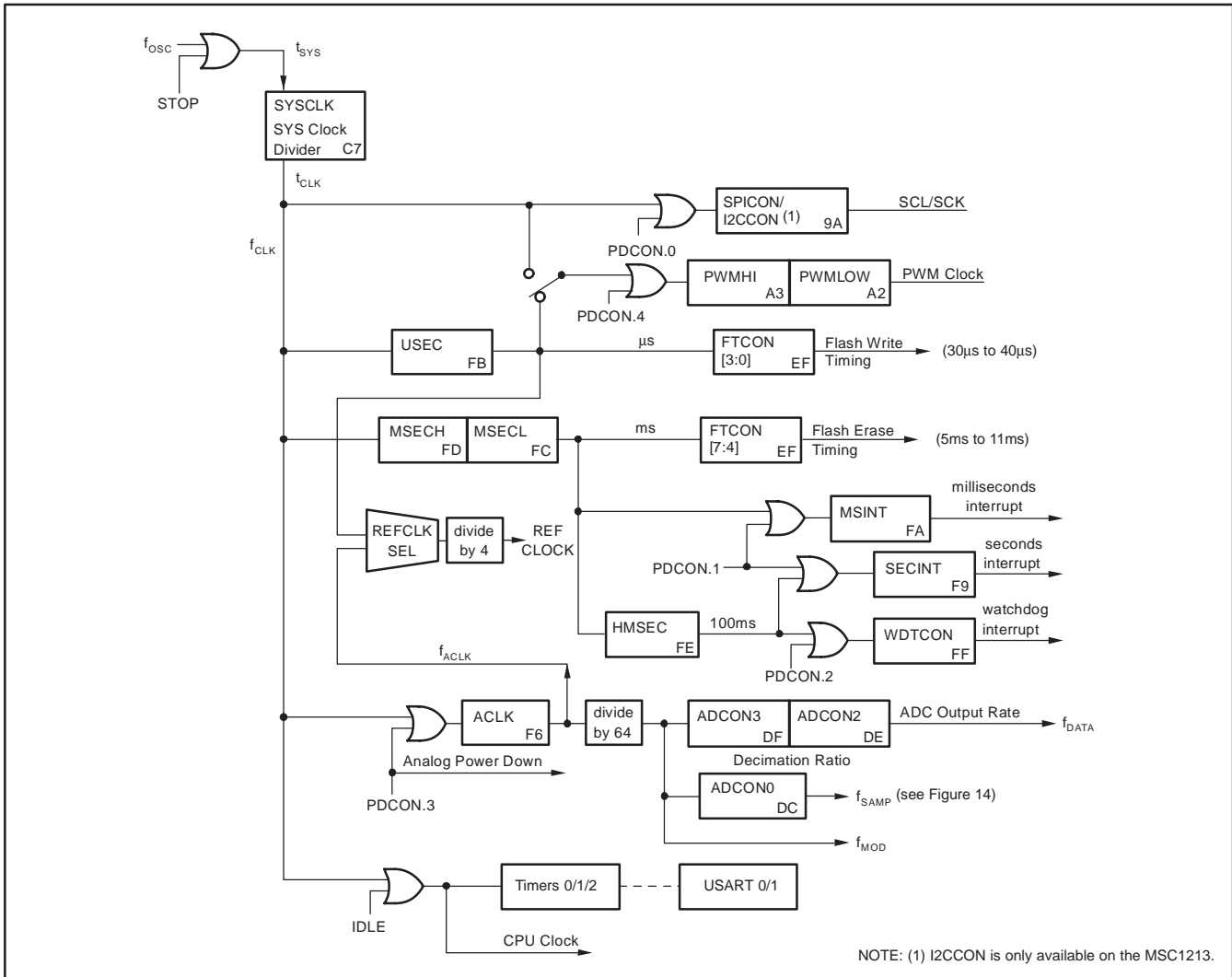


Figure 11. MSC1213/14 Timing Chain and Clock Control

OVERVIEW

The MSC1213/14 ADC structure is shown in Figure 12. The figure lists the components that make up the ADC, along with the corresponding special function register (SFR) associated with each component.

ADC INPUT MULTIPLEXER

The input multiplexer provides for any combination of differential inputs to be selected as the input channel, as shown in Figure 13. If AIN0 is selected as the positive differential input channel, any other channel can be selected as the negative differential input channel. With this method, it is possible to have up to eight fully differential input channels. It is also possible to switch the polarity of the differential input pair to negate any offset voltages. In addition, current sources are supplied that will source or sink current to detect open or short circuits on the pins.

TEMPERATURE SENSOR

On-chip diodes provide temperature sensing capability. When the configuration register for the input MUX is set to all 1s, the diodes are connected to the inputs of the ADC. All other channels are open.

BURNOUT DETECT

When the Burnout Detect (BOD) bit is set in the ADC control configuration register (ADCON0 DC_H), two current sources are enabled. The current source on the positive input channel sources approximately 2 μ A of current. The current source on the negative input channel sinks approximately 2 μ A. This allows for the detection of an open circuit (full-scale reading) or short circuit (small differential reading) on the selected input differential pair. The buffer should be on for sensor burnout detection.

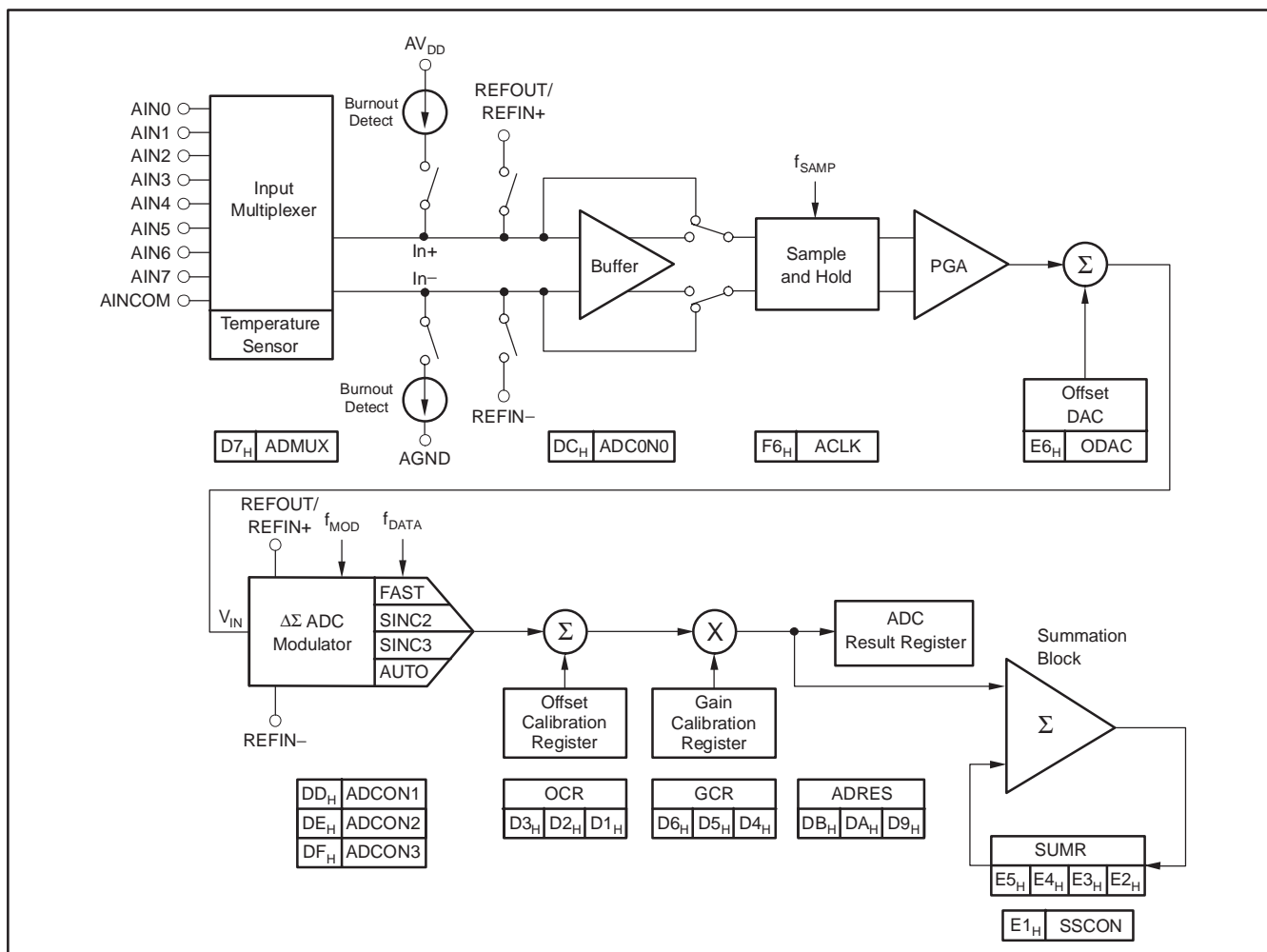


Figure 12. MSC1213/14 ADC Structure

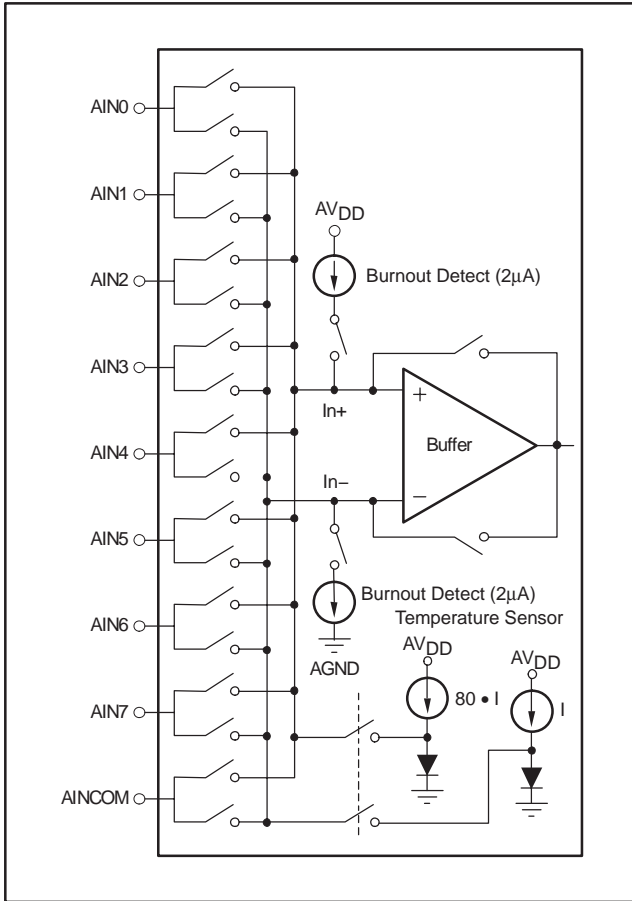


Figure 13. Input Multiplexer Configuration

ADC INPUT BUFFER

The analog input impedance is always high, regardless of PGA setting (when the buffer is enabled). With the buffer enabled, the input voltage range is reduced and the analog power-supply current is higher. If the limitation of input voltage range is acceptable, then the buffer is always preferred. The input impedance of the MSC1213/14 without the buffer is $7M\Omega/PGA$. The buffer is controlled by the state of the BUF bit in the ADC control register (ADCON0 DC_H).

ADC ANALOG INPUT

When the buffer is not selected, the input impedance of the analog input changes with ACLK clock frequency (ACLK F_{6H}) and gain (PGA). The relationship is:

$$\text{Impedance } (\Omega) = \frac{1}{f_{\text{SAMP}} \cdot C_s}$$

$$A_{\text{IN}} \text{ Impedance } (\Omega) = \left(\frac{1 \times 10^6}{\text{ACLK Frequency}} \right) \cdot \left(\frac{7M\Omega}{\text{PGA}} \right)$$

$$\text{where ACLK frequency } (f_{\text{ACLK}}) = \frac{f_{\text{CLK}}}{\text{ACLK} + 1}$$

$$\text{and modclk} = f_{\text{MOD}} = \frac{f_{\text{ACLK}}}{64}$$

NOTE: The input impedance for PGA = 128 is the same as that for PGA = 64 (that is, $\frac{7M\Omega}{64}$).

Figure 14 shows the basic input structure of the MSC1213/14. The sampling frequency varies according to the PGA settings, as shown in the table in Figure 14.

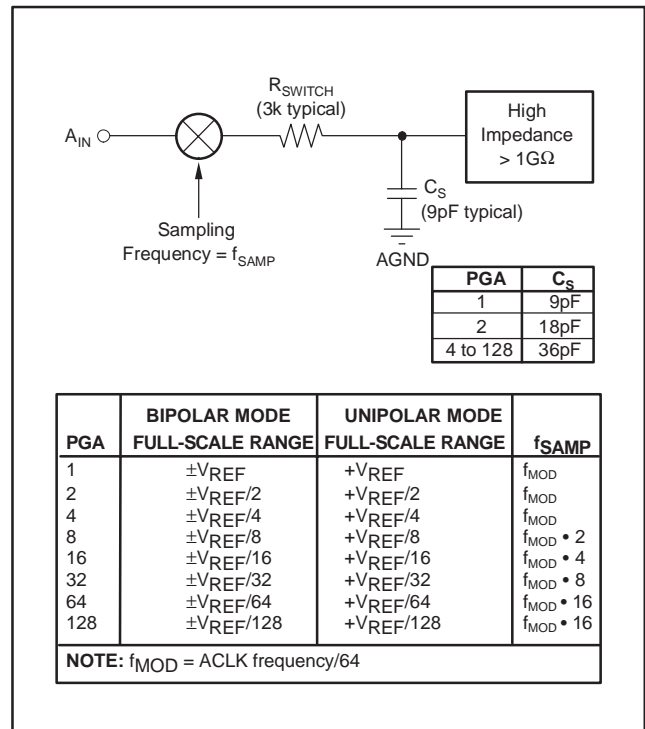


Figure 14. Analog Input Structure

ADC PGA

The PGA can be set to gains of 1, 2, 4, 8, 16, 32, 64, or 128. Using the PGA can actually improve the effective resolution of the ADC. For instance, with a PGA of 1 on a $\pm 2.5V$ full-scale range (FSR), the ADC can resolve to $1.5\mu V$. With a PGA of 128 on a $\pm 19mV$ FSR, the ADC can resolve to $75nV$, as shown in Table 3.

Table 3. Sampling Frequency versus PGA Setting

PGA SETTING	BIPOLAR MODE FULL-SCALE RANGE (V)	ENOB(1) AT 10HZ	RMS MEASUREMENT REVOLUTION (nV)
1	$\pm 2.5V$	21.7	1468
2	± 1.25	21.5	843
4	± 0.625	21.4	452
8	± 0.313	21.2	259
16	± 0.156	20.8	171
32	± 0.0781	20.4	113
64	± 0.039	20	74.5
128	± 0.019	19	74.5

NOTE: (1) $ENOB = \text{Log}_2(\text{FSR}/\text{RMS Noise}) = \text{Log}_2(2^{24}) - \text{Log}_2(\sigma_{\text{codes}}) = 24 - \text{Log}_2(\sigma_{\text{codes}})$

ADC OFFSET DAC

The analog input to the PGA can be offset (in bipolar mode) by up to half the full-scale input range of the PGA by using the ODAC register (SFR E6H). The ODAC (Offset DAC) register is an 8-bit value; the MSB is the sign and the seven LSBs provide the magnitude of the offset. Since the ODAC introduces an analog (instead of digital) offset to the PGA, using the ODAC does not reduce the range of the ADC.

ADC MODULATOR

The modulator is a single-loop 2nd-order system. The modulator runs at a clock speed (f_{MOD}) that is derived from the CLK using the value in the Analog Clock (ACLK) register (SFR F6H). The data output rate is:

$$\text{Data Rate} = f_{\text{DATA}} = \frac{f_{\text{MOD}}}{\text{Decimation Ratio}}$$

$$\text{where } f_{\text{MOD}} = \frac{f_{\text{CLK}}}{(\text{ACLK} + 1) \cdot 64} = \frac{f_{\text{ACLK}}}{64}$$

ADC CALIBRATION

The offset and gain errors in the MSC1213/14, or the complete system, can be reduced with calibration. Calibration is controlled through the ADCON1 register (SFR DDH), bits CAL2:CAL0. Each calibration process takes seven t_{DATA} periods (data conversion time) to complete. Therefore, it takes 14 t_{DATA} periods to complete both an offset and gain calibration.

For system calibration, the appropriate signal must be applied to the inputs. The system offset calibration requires a zero input signal. It then computes an offset that will nullify offset in the system. The system gain calibration requires a positive full-scale input signal. It then computes a value to nullify gain errors in the system. Each of these calibrations will take seven t_{DATA} periods to complete.

Calibration should be performed after power on, a change in temperature, decimation ratio, buffer, or a change of the Power Supply, reference, or PGA. Calibration will remove the effects of the Offset DAC, therefore, changes to the Offset DAC register must be done after calibration.

At the completion of calibration, the ADC Interrupt bit goes HIGH which indicates the calibration is finished and valid data is available.

ADC DIGITAL FILTER

The Digital Filter can use either the Fast Settling, Sinc², or Sinc³ filter, as shown in Figure 15. In addition, the Auto mode changes the Sinc filter after the input channel or PGA is changed. When switching to a new channel, it will use the Fast Settling filter, for the next two conversions the first of which should be discarded.

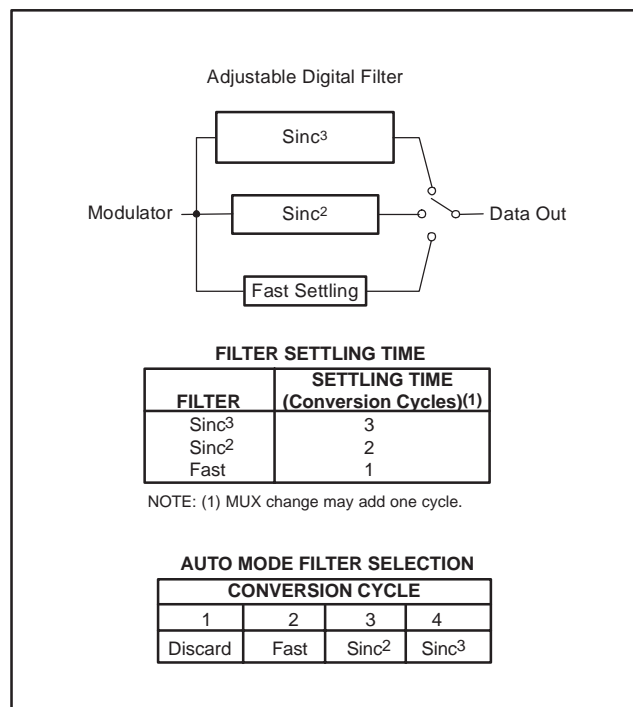


Figure 15. Filter Step Responses

It will then use the Sinc² followed by the Sinc³ filter to improve noise performance. This combines the low-noise advantage of the Sinc³ filter with the quick response of the Fast Settling Time filter. The frequency response of each filter is shown in Figure 16.

VOLTAGE REFERENCE

The voltage reference used for the MSC1213/14 can either be internal or external. The power-up configuration for the voltage reference is 2.5V internal. The selection for the voltage reference is made through the ADCON0 register (SFR DC_H).

The internal voltage reference is selectable as either 1.25V ($AV_{DD} = 2.7V$ to $5.25V$) or 2.5V ($AV_{DD} = 3.3V$ to $5.25V$). If the internal V_{REF} is not used, it should be turned off. The V_{REFOUT} pin should have a $0.1\mu F$ capacitor to AGND. If the internal reference is used, V_{REF} should be grounded.

The external voltage reference is differential and is represented by the voltage difference between the pins: REF IN+ and REF IN-. The absolute voltage on either pin (REF IN+ and REF IN-) can range from AGND to AV_{DD} . The differential voltage reference provides easy means of performing ratiometric measurement.

PRODUCT PREVIEW

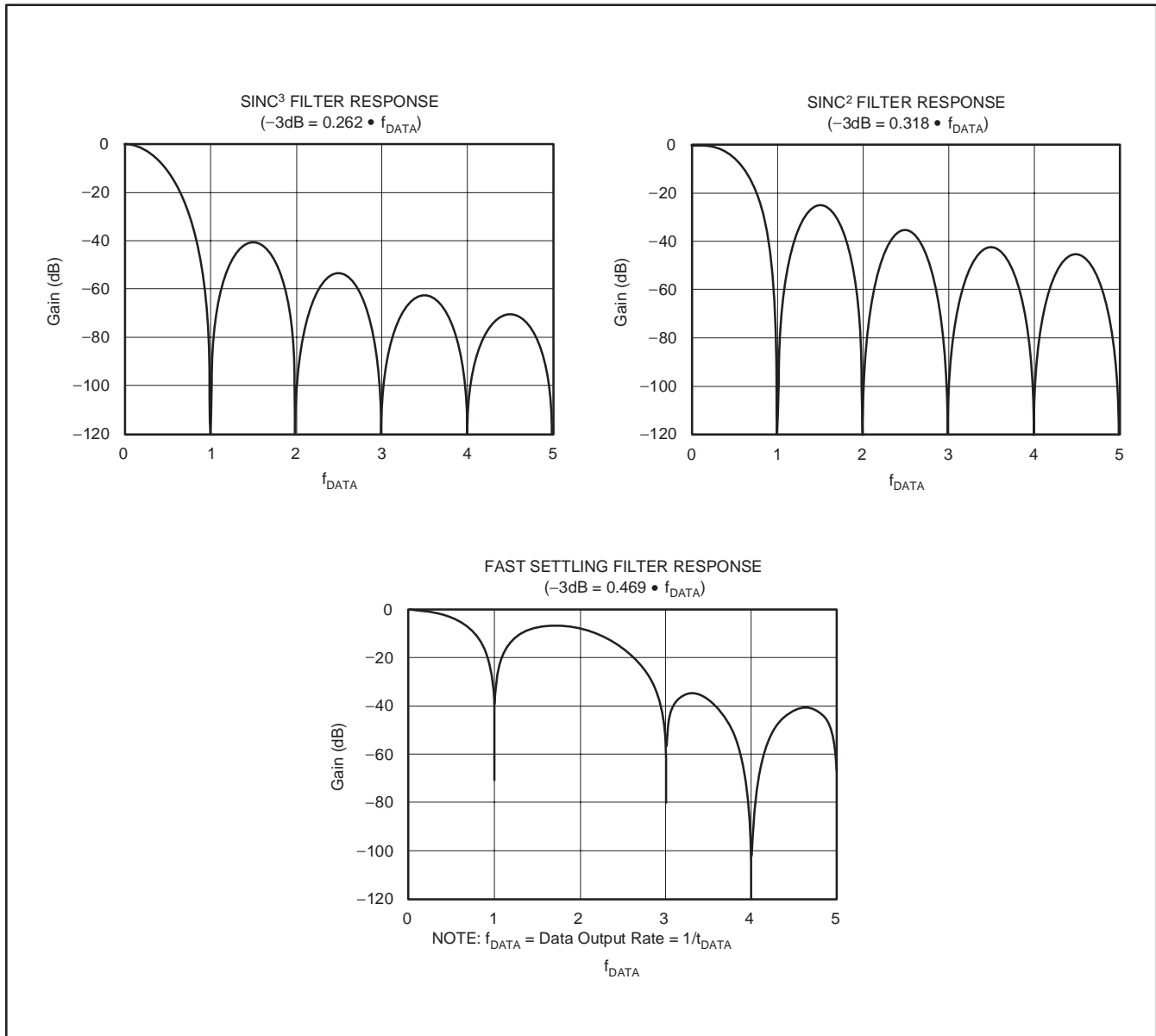


Figure 16. Filter Frequency Responses

DAC

The architecture consists of a string DAC followed by an output buffer amplifier. Figure 17 shows a block diagram of the DAC architecture.

The input coding to the DAC is straight binary, so the ideal output voltage is given by:

$$VDAC = V_{REF} \cdot \left(\frac{D}{65536} \right)$$

where D = decimal equivalent of the binary code that is loaded to the DAC register; it can range from 0 to 65535.

DAC RESISTOR STRING

The DAC selects the voltage from a string of resistors from the reference to AGND. It is essentially a string of resistors, each of value R. The code loaded into the DAC register determines at which node on the string the voltage is tapped off to be fed into the output amplifier by closing one of the switches connecting the string to the amplifier. It is ensured monotonic because it is a string of resistors.

DAC OUTPUT AMPLIFIER

The output buffer amplifier is capable of generating rail-to-rail voltages on its output which gives an output range of AGND to AV_{DD}. It is capable of driving a load of 2kΩ in parallel with 1000pF to GND. The source and sink capabilities of the output amplifier can be seen in the typical curves. The slew rate is 1V/μs with a full-scale settling time of 8μs.

DAC REFERENCE

Each DAC can be selected to use the REFOUT/REF IN+ pin voltage or the supply voltage AV_{DD} as the reference for the DAC. The full range of the voltage DAC is limited according to Table 4. The full range of the current DAC is limited according to Table 5.

Table 4. Voltage DAC Code Range

DAC REFERENCE	AV _{DD} = 5V	AV _{DD} = 3V	AV _{DD} < 3.0V
DAC _{REF} = AV _{DD}	Full Range	Full Range	Not Recommended
DAC _{REF} = 2.5V	Full Range	Not Recommended	Not Recommended
DAC _{REF} = 1.25V	Full Range	Full Range	Not Recommended

Table 5. Current DAC Code Range

DAC REFERENCE	AV _{DD} = 5V	AV _{DD} = 3V	AV _{DD} < 3.0V
DAC _{REF} = AV _{DD}	0000-7FFF _H	0000-3FFF _H	Not Recommended
DAC _{REF} = 2.5V	Full Range	Not Recommended	Not Recommended
DAC _{REF} = 1.25V	Full Range	Full Range	Not Recommended

DAC LOADING

The DAC can be selected to be turned off with a 1kΩ, 100kΩ, or open circuit on the DAC outputs.

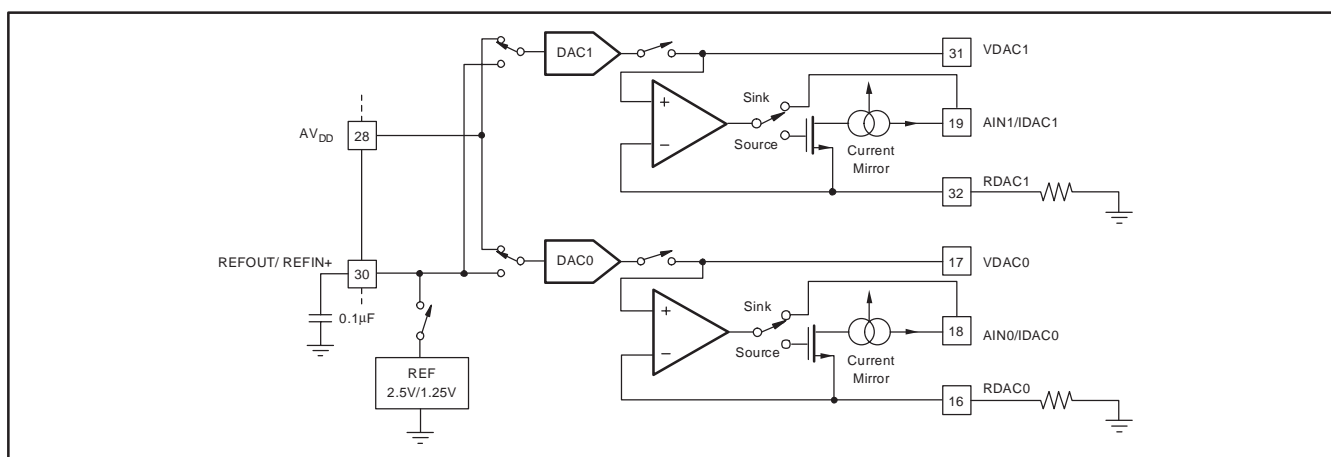


Figure 17. DAC Architecture

BIPOLAR OPERATION USING THE DAC

The DAC can be used for a bipolar output range, as shown in Figure 18. The circuit shown will give an output voltage range of $\pm V_{REF}$. Rail-to-rail operation at the amplifier output is achievable using an OPA703 as the output amplifier.

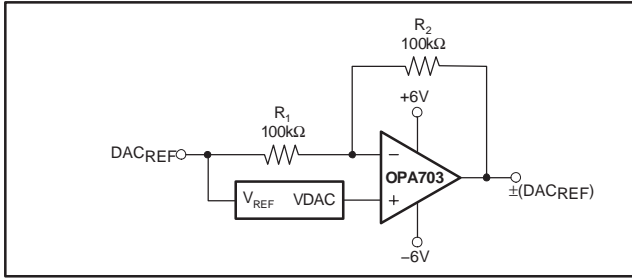


Figure 18. Bipolar Operation with the DAC

The output voltage for any input code can be calculated as follows:

$$V_O = \left[DAC_{REF} \cdot \left(\frac{D}{65536} \right) \cdot \left(\frac{R_1 + R_2}{R_1} \right) - DAC_{REF} \cdot \left(\frac{R_1}{R_2} \right) \right]$$

where D represents the input code in decimal (0–65535).

With $DAC_{REF} = 5V$, $R_1 = R_2 = 10k\Omega$:

$$V_O = \left(\frac{10 \cdot D}{65536} \right) - 5V$$

This is an output voltage range of $\pm 5V$. With 0000_H corresponding to a $-5V$ output and FFFF_H corresponding to a $+5V$ output. Similarly, using $V_{REF} = 2.5V$, a $\pm 2.5V$ output voltage can be achieved.

IDAC

The compliance specification of the IDAC output defines the maximum output voltage to achieve the expected current.

$$IDAC = \frac{4 \cdot V_{DAC}}{R_{DAC}} \quad \text{with } V_{DAC} \text{ less than } AV_{DD} - 2V$$

for maximum code. Refer to Figure 17 for the IDAC structure and to Table 5 for the DAC reference selection and code range.

ANALOG/DIGITAL LOW VOLTAGE DETECT

The MSC1213/14 contain an analog or digital low-voltage detect. When the analog or digital supply drops below the value programmed in LVDCON (SFR E7_H), an interrupt is generated (one for each supply).

POWER-UP—SUPPLY VOLTAGE RAMP RATE

The built-in (on-chip) power-on reset circuitry was designed to accommodate analog or digital supply ramp rates as slow as 1V/10ms. To ensure proper operation, the power supply should ramp monotonically at the specified rate. If Brownout Reset (BOR) is enabled, the ramp rate can be slower.

MEMORY MAP

The MSC1213/14 contain on-chip SFR, Flash Memory, Scratchpad SRAM Memory, Boot ROM, and SRAM. The SFR registers are primarily used for control and status. The standard 8051 features and additional peripheral features of the MSC1213/14 are controlled through the SFR. Reading from undefined SFR will return zero and writing to undefined SFR registers is not recommended and will have indeterminate effects.

Flash Memory is used for both Program Memory and Data Memory. The user has the ability to select the partition size of Program and Data Memories. The partition size is set through hardware configuration bits, which are programmed through either the parallel or serial programming methods. Both Program and Data Flash Memories are erasable and writable (programmable) in user application mode. However, program execution can only occur from Program Memory. As an added precaution, a lock feature can be activated through the hardware configuration bits, which disables erase and writes to 4kB of Program Flash Memory or the entire Program Flash Memory in user application mode.

The MSC1213/14 include 1kB of SRAM on-chip. SRAM starts at address 0 and is accessed through the MOVX instruction. This SRAM can also be located to start at 8400_H and can be accessed as both Program and Data Memory.

FLASH MEMORY

The MSC1213/14 use a memory addressing scheme that separates Program Memory (FLASH/ROM) from Data Memory (FLASH/RAM). Each area is 64kB beginning at address 0000_H and ending at FFFF_H, as shown in Figure 19. The program and data segments can overlap since they are accessed in different ways. Program Memory is fetched by the microcontroller automatically. There is one instruction (MOVC) that is used to explicitly read the program area. This is commonly used to read lookup tables. The Data Memory area is accessed explicitly using the MOVX instruction. This instruction provides multiple ways of specifying the target address. It is used to access the 64kB of Data Memory. The address and data range of devices with on-chip Program and Data Memory overlap the 64kB memory space. When on-chip memory is enabled, accessing memory in the on-chip range will cause the device to access internal memory. Memory accesses beyond the internal range will be addressed externally via Ports 0 and 2.

The MSC1213/14 have two Hardware Configuration registers (HCR0 and HCR1) that are programmable only during Flash Memory Programming mode.

The MSC1213/14 allow the user to partition the Flash Memory between Program Memory and Data Memory. For instance, the MSC1213Y5 contains 32kB of Flash Memory on-chip. Through the HW configuration registers, the user can define the partition between Program Memory (PM) and Data Memory (DM), as shown in Table 6 and Table 7. The MSC1213/14 families offer four memory configurations.

Table 6. MSC1213/14 Flash Partitioning

HCR0	MSC1213/ 14Y2		MSC1213/ 14Y3		MSC1213/ 14Y4		MSC1213/ 14Y5	
	PM	DM	PM	DM	PM	DM	PM	DM
000	0kB	4kB	0kB	8kB	0kB	16kB	0kB	32kB
001	0kB	4kB	0kB	8kB	0kB	16kB	0kB	32kB
010	0kB	4kB	0kB	8kB	0kB	16kB	16kB	16kB
011	0kB	4kB	0kB	8kB	8kB	8kB	24kB	8kB
100	0kB	4kB	4kB	4kB	12kB	4kB	28kB	4kB
101	2kB	2kB	6kB	2kB	14kB	2kB	30kB	2kB
110	3kB	1kB	7kB	1kB	15kB	1kB	31kB	1kB
111 (default)	4kB	0kB	8kB	0kB	16kB	0kB	32kB	0kB

NOTE: When a 0kB program memory configuration is selected, program execution is external.

Table 7. MSC1213/14 Flash Memory Partitioning

HCR0	MSC1213/ 14Y2		MSC1213/ 14Y3		MSC1213/ 14Y4		MSC1213/ 14Y5	
	PM	DM	PM	DM	PM	DM	PM	DM
000	0000	0400-13FF	0000	0400-23FF	0000	0400-43FF	0000	0400-83FF
001	0000	0400-13FF	0000	0400-23FF	0000	0400-43FF	0000	0400-83FF
010	0000	0400-13FF	0000	0400-23FF	0000	0400-43FF	0000-3FFF	0400-43FF
011	0000	0400-13FF	0000	0400-23FF	0000-1FFF	0400-23FF	0000-5FFF	0400-23FF
100	0000	0400-13FF	0000-0FFF	0400-13FF	0000-2FFF	0400-13FF	0000-6FFF	0400-13FF
101	0000-07FF	0400-0BFF	0000-17FF	0400-0BFF	0000-37FF	0400-0BFF	0000-77FF	0400-0BFF
110	0000-0BFF	0400-07FF	0000-1BFF	0400-07FF	0000-3BFF	0400-07FF	0000-7BFF	0400-07FF
111 (default)	0000-0FFF	--	0000-1FFF	--	0000-3FFF	--	0000-7FFF	--

NOTE: Program memory accesses above the highest listed address will access external program memory.

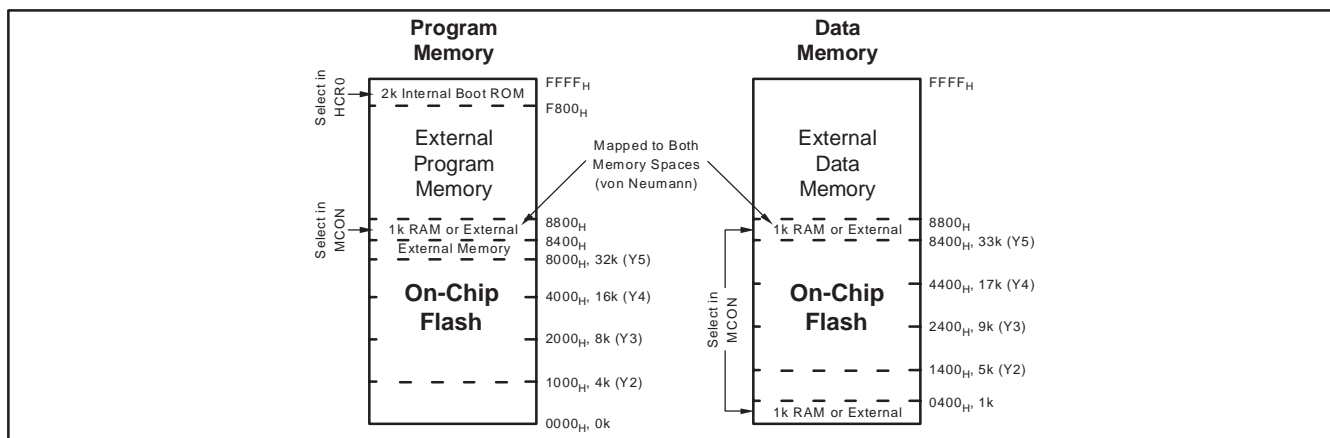


Figure 19. Memory Map

It is important to note that the Flash Memory is readable and writable by the user through the MOVX instruction when configured as either Program or Data Memory (via the MXWS bit in the MWS SFR 8F_H). This means that the user may partition the device for maximum Flash Program Memory size (no Flash Data Memory) and use Flash Program Memory as Flash Data Memory. This may lead to undesirable behavior if the PC points to an area of Flash Program Memory that is being used for data storage. Therefore, it is recommended to use Flash partitioning when Flash Memory is used for data storage. Flash partitioning prohibits execution of code from Data Flash Memory. Additionally, the Program Memory erase/write can be disabled through hardware configuration bits (HCR0), while still providing access (read/write/erase) to Data Flash Memory.

The effect of memory mapping on Program and Data Memory is straightforward. The Program Memory is decreased in size from the top of internal Program Memory. Therefore, for example, if the MSC1213Y5 is partitioned with 31kB of Flash Program Memory and 1kB of Flash Data Memory, external Program Memory execution will begin at 7C00_H (versus 8000_H for 32kB). The Flash Data Memory is added on top of the SRAM memory. Therefore, access to Data Memory (through MOVX) will access SRAM for addresses 0000_H–03FF_H and access Flash Memory for addresses 0400_H–07FF_H.

Data Memory

The MSC1213/14 can address 64kB of Data Memory. Scratchpad Memory provides 256 bytes in addition to the 64kB of Data Memory. The MOVX instruction is used to access the Data SRAM Memory. This includes 1024 bytes of on-chip Data SRAM Memory. The data bus values do not appear on Port 0 (during data bus timing) for internal memory access.

The MSC1213/14 also have on-chip Flash Data Memory which is readable and writable (depending on Memory Write Select register) during normal operation (full V_{DD} range). This memory is mapped into the external Data Memory space directly above the SRAM.

The MOVX instruction is used to write to flash memory. Flash memory must be erased before it can be written. Flash memory is erased in 128 byte pages.

REGISTER MAP

The Register Map is illustrated in Figure 20. It is entirely separate from the Program and Data Memory areas mentioned before. A separate class of instructions is used to access the registers. There are 256 potential register locations. In practice, the MSC1213/14 have 256 bytes of Scratchpad RAM and up to 128 SFRs. This is possible, since the upper 128 Scratchpad RAM locations can only be accessed indirectly. Thus, a direct reference to one of the upper 128 locations must be an SFR access. Direct RAM is reached at locations 0 to 7F_H (0 to 127).

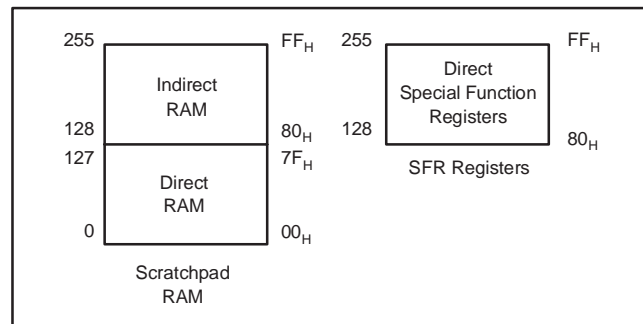


Figure 20. Register Map

SFRs are accessed directly between 80_H and FF_H (128 to 255). The RAM locations between 128 and 255 can be reached through an indirect reference to those locations. Scratchpad RAM is available for general-purpose data storage. It is commonly used in place of off-chip RAM when the total data contents are small. When off-chip RAM is needed, the Scratchpad area will still provide the fastest general-purpose access. Within the 256 bytes of RAM, there are several special-purpose areas.

Bit Addressable Locations

In addition to direct register access, some individual bits are also accessible. These are individually addressable bits in both the RAM and SFR area. In the Scratchpad RAM area, registers 20_H to 2F_H are bit addressable. This provides 128 (16 • 8) individual bits available to software. A bit access is distinguished from a full-register access by the type of instruction. In the SFR area, any register location ending in a 0 or 8 is bit addressable. Figure 19 shows details of the on-chip RAM addressing including the locations of individual RAM bits.

Working Registers

As part of the lower 128 bytes of RAM, there are four banks of Working Registers, as shown in Figure 21. The Working Registers are general-purpose RAM locations that can be addressed in a special way. They are designated R0 through R7. Since there are four banks, the currently selected bank will be used by any instruction using R0—R7. This allows software to change context by simply switching banks. This is controlled via the Program Status Word register (PSW; 0D0_H) in the SFR area described below. Registers R0 and R1 also allow their contents to be used for indirect addressing of the upper 128 bytes of RAM.

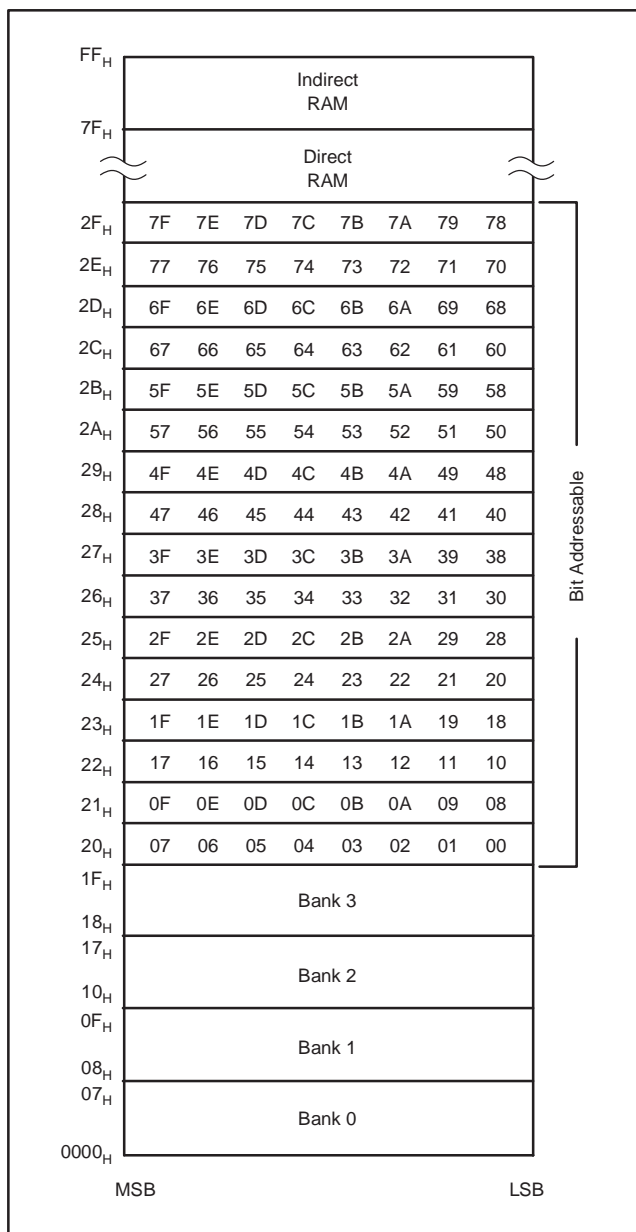


Figure 21. Scratchpad Register Addressing

Thus, an instruction can designate the value stored in R0 (for example) to address the upper RAM. The 16 bytes immediately above these registers are bit addressable. So any of the 128 bits in this area can be directly accessed using bit addressable instructions.

Stack

Another use of the Scratchpad area is for the programmer's stack. This area is selected using the Stack Pointer (SP; 81_H) SFR. Whenever a call or interrupt is invoked, the return address is placed on the Stack. It also is available to the programmer for variables, etc., since the Stack can be moved and there is no fixed location within the RAM designated as Stack. The Stack Pointer will default to 07_H on reset. The user can then move it as needed. A convenient location would be the upper RAM area (> 7F_H) since this is only available indirectly. The SP will point to the last used value. Therefore, the next value placed on the Stack is put at SP + 1. Each PUSH or CALL will increment the SP by the appropriate value. Each POP or RET will decrement as well.

Program Memory

After reset, the CPU begins execution from Program Memory location 0000_H. The selection of where Program Memory execution begins is made by tying the $\bar{E}A$ pin to DV_{DD} for internal access, or DGND for external access. When $\bar{E}A$ is tied to DV_{DD}, any PC fetches outside the internal Program Memory address occur from external memory. If $\bar{E}A$ is tied to DGND, then all PC fetches address external memory. The standard internal Program Memory size for MSC1213/14 family members is shown in Table 8. If enabled the Boot ROM will appear from address F800_H to FFFF_H.

Table 8. MSC1213/14 Maximum Internal Program Memory Sizes

MODEL NUMBER	STANDARD INTERNAL PROGRAM MEMORY SIZE (BYTES)
MSC1213Y5/14Y5	32k
MSC1213Y4/14Y4	16k
MSC1213Y3/14Y3	8k
MSC1213Y2/14Y2	4k

ACCESSING EXTERNAL MEMORY

If external memory is used, P0 and P2 can be configured as address and data lines. If external memory is not used, P0 and P2 can be configured as general-purpose I/O lines through the Hardware Configuration Register.

To enable access to external memory bits 0 and 1 of the HCR1 register must be set to 0. When these bits are enabled all memory accesses for both internal and external memory will appear on ports 0 and 2. During the data portion of the cycle for internal memory, Port 0 will be zero for security purposes.

Accesses to external memory are of two types: accesses to external Program Memory and accesses to external Data Memory. Accesses to external Program Memory use signal $\overline{\text{PSEN}}$ (program store enable) as the read strobe. Accesses to external Data Memory use $\overline{\text{RD}}$ or $\overline{\text{WR}}$ (alternate functions of P3.7 and P3.6) to strobe the memory.

External Program Memory and external Data Memory may be combined if desired by applying the $\overline{\text{RD}}$ and $\overline{\text{PSEN}}$ signals to the inputs of an AND gate and using the output of the gate as the read strobe to the external Program/Data Memory.

A program fetch from external Program Memory uses a 16-bit address. Accesses to external Data Memory can use either a 16-bit address (MOVX @DPTR) or an 8-bit address (MOVX @R_i).

If Port 2 is selected for external memory use (HCR1, bit 0), it cannot be used as general-purpose I/O. This bit (or Bit 1 of HCR1) also forces bits P3.6 and P3.7 to be used for $\overline{\text{WR}}$ and $\overline{\text{RD}}$ instead of I/O. Port 2, P3.6, and P3.7 should all be written to '1.'

If an 8-bit address is being used (MOVX @R_i), the contents of the MPAGE (92H) SFR remain at the Port 2 pins throughout the external memory cycle. This will facilitate paging.

In any case, the low byte of the address is time-multiplexed with the data byte on Port 0. The ADDR/DATA signals use CMOS drivers in the Port 0, Port 2, $\overline{\text{WR}}$, and $\overline{\text{RD}}$ output buffers. Thus, in this application the Port 0 pins are not open-drain outputs, and do not require external pull-ups for high-speed access. Signal ALE (Address Latch Enable) should be used to capture the address byte into an external latch. The address byte is valid at the negative transition of ALE. Then, in a write cycle, the data byte to be written appears on Port 0 just before $\overline{\text{WR}}$ is activated, and remains there until after $\overline{\text{WR}}$ is deactivated. In a read cycle, the incoming byte is accepted at Port 0 just before the read strobe is deactivated.

The functions of Port 0 and Port 2 are selected in Hardware Configuration Register 1. This can only be changed during the Flash Program mode. There is no conflict in the use of these registers; they will either be used as general-purpose I/O or for external memory access. The default state is for Port 0 and Port 2 to be used as general-purpose I/O. If an external memory access is attempted when they are configured as general-purpose I/O, the values of Port 0 and Port 2 will not be affected.

External Program Memory is accessed under two conditions:

1. Whenever signal $\overline{\text{EA}}$ is LOW during reset, then all future accesses are external, or
2. Whenever the Program Counter (PC) contains a number that is outside of the internal Program Memory address range, if the ports are enabled.

If Port 0 and Port 2 are selected for external memory, all 8 bits of Port 0 and Port 2, as well as P3.6 and P3.7, are dedicated to an output function and may not be used for general-purpose I/O. During external program fetches, Port 2 outputs the high byte of the PC.

Programming Flash Memory

There are four sections of Flash Memory for programming.

1. 128 configuration bytes.
2. Reset sector (4kB) (not to be confused with the 2kB Boot ROM).
3. Program Memory.
4. Data Memory.

Boot ROM

There is a 2kB Boot ROM that controls operation during serial or parallel programming. Additionally, the Boot ROM routines can be accessed during the user mode if it is enabled. When enabled, the Boot ROM routines will be located at memory addresses F800_H–FFFF_H during user mode. In program mode the Boot ROM is located in the first 2kB of Program Memory. For additional information, refer to the Application Note SBAA085, available for download from the TI web site (www.ti.com).

The MSC1213/14 are shipped with Flash Memory erased (all 1s). Parallel programming methods typically involve a third-party programmer. Serial programming methods typically involve in-system programming. User Application mode allows Code Program and Data Memory programming. The actual code for Flash programming cannot execute from Flash. That code must execute from the Boot ROM or internal (von Neumann) RAM.

Flash Programming Mode

There are two programming modes: parallel and serial. The programming mode is selected by the state of the ALE and $\overline{\text{PSEN}}$ signals during reset (BOR, WDT, software, or POR). Serial programming mode is selected with $\overline{\text{PSEN}} = 0$ and $\text{ALE} = 1$. Parallel programming mode is selected with $\overline{\text{PSEN}} = 1$ and $\text{ALE} = 0$ (see Figure 22). If they are both HIGH, the MSC1213/14 will operate in User Application mode. For both signals, LOW is a reserved mode and is not defined. Programming mode is exited with a reset and the normal mode selected.

Serial programming mode works through USART0, and has special protocols. Table 9 describes these protocols, which are discussed at length in Application Note SBAA076 (available for download at www.ti.com). The serial programming mode works at a maximum baud rate determined by f_{OSC} .

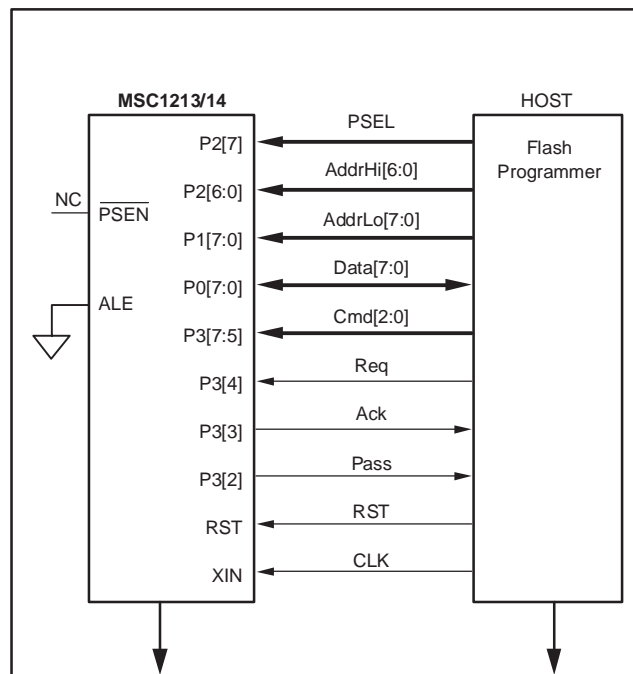


Figure 22. Parallel Programming Configuration

HARDWARE CONFIGURATION MEMORY

The 128 configuration bytes can only be written during the program mode. The bytes are accessed through SFR registers CADDR (SFR 93_H) and CDATA (SFR 94_H). Two of the configuration bytes control Flash partitioning and system control. If the security bit is set, these bits can not be changed except with a Mass Erase command that erases all of the Flash Memory including the 128 configuration bytes.

INTERRUPTS

The MSC1213/14 use a three-priority interrupt system. As shown in Table 10, each interrupt source has an independent priority bit, flag, interrupt vector, and enable (except that nine interrupts share the Auxiliary Interrupt (AI) at the highest priority). In addition, interrupts can be globally enabled or disabled. The interrupt structure is compatible with the original 8051 family. All of the standard interrupts are available.

Table 9. ROM Routines

ADDRESS	ROUTINE	C DECLARATIONS	DESCRIPTION
FFD5	put_string	void put_string (char code *string);	Output string
FFD7	page_erase	char page_erase (int faddr, char fdata, char fdm);	Erase flash page
FFD9	write_flash	Assembly only; DPTR = address, R5 = data	Fast flash write
FFDB	write_flash_chk	char write_flash_chk (int faddr, char fdata, char fdm);	Write flash byte, verify
FFDD	write_flash_byte	char write_flash_byte (int faddr, char fdata, char fdm);	Write flash byte
FFDF	faddr_data_read	char faddr_data_read (char faddr);	Read HW config byte from addr
FFE1	data_x_c_read	char data_x_c_read (int faddr, char fdm);	Read xdata or code byte
FFE3	tx_byte	void tx_byte (char);	Send byte to USART0
FFE5	tx_hex	void tx_hex (char);	Send hex value to USART0
FFE7	putok	void putok (void);	Send "OK" to USART0
FFE9	rx_byte	char rx_byte (void);	Read byte from USART0
FFEB	rx_byte_echo	char rx_byte_echo (void);	Read and echo byte on USART0
FFED	rx_hex_echo	int rx_hex_echo (void);	Read and echo hex on USART0
FFEF	rx_hex_int_echo	int rx_hex_int_echo (void);	Read int as hex and echo: USART0
FFF1	rx_hex_rev_echo	int rx_hex_rev_echo (void);	Read int reversed as hex and echo: USART0
FFF3	autobaud	void autobaud (void);	Set baud with received CR
FFF5	putspace4	void putspace4 (void);	Output 4 spaces to USART0
FFF7	putspace3	void putspace3 (void);	Output 3 spaces to USART0
FFF9	putspace2	void putspace2 (void);	Output 2 spaces to USART0
FFFB	putspace1	void putspace1 (void);	Output 1 space to USART0
FFFB	putcr	void putcr (void);	Output CR, LF to USART0
F97D ⁽¹⁾	cmd_parse	void cmd_parser (void);	See SBAA076
FD3B ⁽¹⁾	monitor_isr	void monitor_isr () interrupt 6	Push registers and call cmd_parser

(1) These addresses only relate to version 1.0 of the MSC1213/14 Boot ROM.

Table 10. Interrupt Summary

INTERRUPT/EVENT	INTERRUPT		PRIORITY	FLAG	ENABLE	PRIORITY CONTROL
	ADDR	NUM				
DV _{DD} Low Voltage/HW Breakpoint	33 _H	6	HIGH	EDLVB (AIE.0) ⁽¹⁾ EBP (BPCON.0) ⁽¹⁾	EDLVB (AIE.0) ⁽¹⁾ EBP (BPCON.0) ⁽¹⁾	N/A
AV _{DD} Low Voltage	33 _H	6	0	EALV (AIE.1) ⁽¹⁾	EALV (AIE.1) ⁽¹⁾	N/A
SPI Receive / I ² C ⁽⁵⁾	33 _H	6	0	ESPIR/EI2C (AIE.2) ⁽¹⁾	ESPIR/EI2C (AIE.2) ⁽¹⁾	N/A
SPI Transmit	33 _H	6	0	ESPIT (AIE.3) ⁽¹⁾	ESPIT (AIE.3) ⁽¹⁾	N/A
Milliseconds Timer	33 _H	6	0	EMSEC (AIE.4) ⁽¹⁾	EMSEC (AIE.4) ⁽¹⁾	N/A
ADC	33 _H	6	0	EADC (AIE.5) ⁽¹⁾	EADC (AIE.5) ⁽¹⁾	N/A
Summation Register	33 _H	6	0	ESUM (AIE.6) ⁽¹⁾	ESUM (AIE.6) ⁽¹⁾	N/A
Seconds Timer	33 _H	6	0	ESEC (AIE.7) ⁽¹⁾	ESEC (AIE.7) ⁽¹⁾	N/A
External Interrupt 0	03 _H	0	1	IE0 (TCON.1) ⁽²⁾	EX0 (IE.0) ⁽⁴⁾	PX0 (IP.0)
Timer 0 Overflow	0B _H	1	2	TF0 (TCON.5) ⁽³⁾	ET1 (IE.1) ⁽⁴⁾	PT0 (IP.1)
External Interrupt 1	13 _H	2	3	IE1 (TCON.3) ⁽²⁾	EX1 (IE.2) ⁽⁴⁾	PX1 (IP.2)
Timer 1 Overflow	0B _H	3	4	TF1 (TCON.7) ⁽³⁾	ET1 (IE.3) ⁽⁴⁾	PT1 (IP.3)
Serial Port 0	23 _H	4	5	RI_0 (SCON0.0) TI_0 (SCON0.1)	ES0 (IE.4) ⁽⁴⁾	PS0 (IP.4)
Timer 2 Overflow	2B _H	5	6	TF2 (T2CON.7)	ET2 (IE.5) ⁽⁴⁾	PT2 (IP.5)
Serial Port 1	3B _H	7	7	RI_1 (SCON1.0) TI_1 (SCON1.1)	ES1 (IE.6) ⁽⁴⁾	PS1 (IP.6)
External Interrupt 2	43 _H	8	8	IE2 (EXIF.4)	EX2 (EIE.0) ⁽⁴⁾	PX2 (IP.0)
External Interrupt 3	4B _H	9	9	IE3 (EXIF.5)	EX3 (EIE.1) ⁽⁴⁾	PX3 (IP.1)
External Interrupt 4	53 _H	10	10	IE4 (EXIF.6)	EX4 (EIE.2) ⁽⁴⁾	PX4 (IP.2)
External Interrupt 5	5B _H	11	11	IE5 (EXIF.7)	EX5 (EIE.3) ⁽⁴⁾	PX5 (IP.3)
Watchdog	63 _H	12	12 LOW	WDTI (EICON.3)	EWDI (EIE.4) ⁽⁴⁾	PWDI (IP.4)

(1) These interrupts set the AI flag (EICON.4) and are enabled by EAI (EICON.5).

(2) If edge-triggered, cleared automatically by hardware when the service routine is vectored to. If level-triggered, the flag follows the state of the pin.

(3) Cleared automatically by hardware when interrupt vector occurs.

(4) Globally enabled by EA (IE.7).

(5) I²C is only available on the MSC1213.

Hardware Configuration Register 0 (HCR0)—Accessed Using SFR Registers CADDR and CDATA.

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
CADDR 7FH	EPMA	PML	RSL	EBR	EWDR	DFSEL2	DFSEL1	DFSEL0

For access to this register during normal operation, refer to the register descriptions for CADDR and CDATA.

EPMA Enable Programming Memory Access (Security Bit).

- bit 7 0: After reset in programming modes, Flash Memory can only be accessed in UAM mode until a mass erase is done.
- 1: Fully Accessible (default)

PML Program Memory Lock (PML has Priority Over RSL).

- bit 6 0: Enable writing to program memory in UAM mode.
- 1: Disable writing to program memory in UAM mode (default).

RSL Reset Sector Lock.

- bit 5 0: Enable Reset Sector Writing
- 1: Enable Read-Only Mode for Reset Sector (4kB) (default)

The reset sector can be used to provide another method of Flash Memory programming. This will allow Program Memory updates without changing the jumpers for in-circuit code updates or program development. The code in this boot sector would then provide the monitor and programming routines with the ability to jump into the main Flash code when programming is finished.

EBR Enable Boot ROM. Boot ROM is 2kB of code located in ROM, not to be confused with the 4kB Boot Sector located in Flash Memory.

- bit 4 0: Disable Internal Boot ROM
- 1: Enable Internal Boot ROM (default)

EWDR Enable Watchdog Reset.

- bit 3 0: Disable Watchdog Reset
- 1: Enable Watchdog Reset (default)

DFSEL Data Flash Memory Size. (See Table 3.)

- bits 2–0 000: Reserved
- 001: 32kB, 16kB, 8kB, or 4kB Data Flash Memory
- 010: 16kB, 8kB, or 4kB Data Flash Memory
- 011: 8kB or 4kB Data Flash Memory
- 100: 4kB Data Flash Memory
- 101: 2kB Data Flash Memory
- 110: 1kB Data Flash Memory
- 111: No Data Flash Memory (default)

Hardware Configuration Register 1 (HCR1)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
CADDR 7E _H	DBLSEL1	DBLSEL0	ABLSEL1	ABLSEL0	DAB	DDB	EGP0	EGP23

For access to this register during normal operation, refer to the register descriptions for CADDR and CDATA.

DBLSEL Digital Supply Brownout Level Select

bits 7–6 00: 4.5V
01: 4.2V
10: 2.7V
11: 2.5V (default)

ABLSEL Analog Supply Brownout Level Select

bits 5–4 00: 4.5V
01: 4.2V
10: 2.7V
11: 2.5V (default)

DAB Disable Analog Power-Supply Brownout Reset

bit 3 0: Enable Analog Brownout Reset
1: Disable Analog Brownout Reset (default)

DDB Disable Digital Power-Supply Brownout Reset

bit 2 0: Enable Digital Brownout Reset
1: Disable Digital Brownout Reset (default)

EGP0 Enable General-Purpose I/O for Port 0

bit 1 0: Port 0 is Used for External Memory, P3.6 and P3.7 Used for \overline{WR} and \overline{RD} .
1: Port 0 is Used as General-Purpose I/O (default)

EGP23 Enable General-Purpose I/O for Ports 2 and 3

bit 0 0: Port 2 is Used for External Memory, P3.6 and P3.7. Used for \overline{WR} and \overline{RD} .
1: Port 2 and Port3 are Used as General-Purpose I/O (default)

Configuration Memory Programming

Hardware configuration memory can be changed only in SPM or PPM mode.

SFR Definitions (Boldface indicates that the register is unique to the MSC1213Yx/MSC1214Yx)

ADDRESS	REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	RESET VALUES	
80 _H	P0	P0.7	P0.6	P0.5	P0.4	P0.3	P0.2	P0.1	P0.0	FF _H	
81 _H	SP									07 _H	
82 _H	DPL0									00 _H	
83 _H	DPH0									00 _H	
84 _H	DPL1									00 _H	
85 _H	DPH1									00 _H	
86 _H	DPS	0	0	0	0	0	0	0	SEL	00 _H	
87 _H	PCON	SMOD	0	1	1	GF1	GF0	STOP	IDLE	30_H	
88 _H	TCON	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00 _H	
89 _H	TMOD	-----Timer 1-----					-----Timer 0-----				00 _H
		GATE	C/T	M1	M0	GATE	C/T	M1	M0		
8A _H	TL0									00 _H	
8B _H	TL1									00 _H	
8C _H	TH0									00 _H	
8D _H	TH1									00 _H	
8E _H	CKCON	0	0	T2M	T1M	T0M	MD2	MD1	MD0	01 _H	
8F _H	MWS	0	0	0	0	0	0	0	MXWS	00 _H	
90 _H	P1	P1.7 INT5/SCK/SCL	P1.6 INT4/MISO/SDA	P1.5 INT3/MOSI	P1.4 INT2/SS	P1.3 TXD1	P1.2 RXD1	P1.1 T2EX	P1.0 T2	FF _H	
91 _H	EXIF	IE5	IE4	IE3	IE2	1	0	0	0	08 _H	
92 _H	MPAGE									08 _H	
93 _{Hv}	CADDR									00 _H	
94 _H	CDATA									00 _H	
95 _H	MCON	BPSEL	0	0					RAMMAP	00 _H	
96 _H										00 _H	
97 _H											
98 _H	SCON0	SM0_0	SM1_0	SM2_0	REN_0	TB8_0	RB8_0	TI_0	RI_0	00 _H	
99 _H	SBUF0									00 _H	
9A _H	SPICON I2CCON(1)	SCK2 START	SCK1 STOP	SCK0 ACK	FIFO 0	ORDER FAST	MSTR MSTR	CPHA SCLA	CPOL FILEN	00 _H	
9B _H	SPIDATA I2CDATA(1)									00 _H	
9C _H	SPIRCON I2CGM(1)	RXCNT7 RXFLUSH GCMEN	RXCNT6	RXCNT5	RXCNT4	RXCNT3	RXCNT2 RXIRQ2	RXCNT1 RXIRQ1	RXCNT0 RXIRQ0	00 _H	
9D _H	SPITCON I2CSTAT(1)	TXCNT7 TXFLUSH STAT7 SCKD7/SAE	TXCNT6 STAT5 SCKD6/SA6	TXCNT5 CLK_EN STAT5 SCKD5/SA5	TXCNT4 DRV_DLY STAT4 SCKD4/SA4	TXCNT3 DRV_EN STAT3 SCKD3/SA3	TXCNT2 TXIRQ2 0 SCKD2/SA2	TXCNT1 TXIRQ1 0 SCKD1/SA1	TXCNT0 TXIRQ0 0 SCKD0/SA0	00 _H	
9E _H	SPISTART I2CSTART(1)	1								80 _H	
9F _H	SPIEND	1								80 _H	
A0 _H	P2	P2.7	P2.6	P2.5	P2.4	P2.3	P2.2	P2.1	P2.0	FF _H	
A1 _H	PWMCON			PPOL	PWMSEL	SPDSEL	TPCNTL2	TPCNTL1	TPCNTL0	00 _H	
A2 _H	PWMLOW TONELOW	PWM7 TDIV7	PWM6 TDIV6	PWM5 TDIV5	PWM4 TDIV4	PWM3 TDIV3	PWM2 TDIV2	PWM1 TDIV1	PWM0 TDIV0	00 _H	
A3 _H	PWMHI TONEHI	PWM15 TDIV15	PWM14 TDIV14	PWM13 TDIV13	PWM12 TDIV12	PWM11 TDIV11	PWM10 TDIV10	PWM9 TDIV9	PWM8 TDIV8	00 _H	
A4 _H	AIPOL	ESEC	ESUM	EADC	EMSEC	ESPIT	ESPIR/EI2C	EALV	EDLVB	00 _H	
A5 _H	PAI	0	0	0	0	PAI3	PAI2	PAI1	PAI0	00 _H	
A6 _H	AIE	ESEC	ESUM	EADC	EMSEC	ESPIT	ESPIR/EI2C	EALV	EDLVB	00 _H	
A7 _H	AISTAT	SEC	SUM	ADC	MSEC	SPIT	SPIR/I2CSI	ALVD	DLVD	00 _H	
A8 _H	IE	EA	ES1	ET2	ES0	ET1	EX1	ET0	EX0	00 _H	
A9 _H	BPCON	BP	0	0	0	0	0	PMSEL	EBP	00 _H	
AA _H	BPL										
AB _H	BPH										
AC _H	P0DDRL	P03H	P03L	P02H	P02L	P01H	P01L	P00H	P00L	00 _H	
AD _H	P0DDRH	P07H	P07L	P06H	P06L	P05H	P05L	P04H	P04L	00 _H	
AE _H	P1DDRL	P13H	P13L	P12H	P12L	P11H	P11L	P10H	P10L	00 _H	
AF _H	P1DDRH	P17H	P17L	P16H	P16L	P15H	P15L	P14H	P14L	00 _H	

(1) I2C is only available on the MSC1213.

(2) Applies to MSC1213 only. See HWPC0 (page 76) for MSC1214.

SFR Definitions (Continued)

ADDRESS	REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	RESET VALUES
B0H	P3	P3.7 RD	P3.6 WR	P3.5 T1	P3.4 T0	P3.3 INT1	P3.2 INT0	P3.1 TXD0	P3.0 RXD0	FFH
B1H	P2DDR1	P23H	P23L	P22H	P22L	P21H	P21L	P20H	P20L	00H
B2H	P2DDR2	P27H	P27L	P26H	P26L	P25H	P25L	P24H	P24L	00H
B3H	P3DDR1	P33H	P33L	P32H	P32L	P31H	P31L	P30H	P30L	00H
B4H	P3DDR2	P37H	P33L	P32H	P32L	P31H	P31L	P30H	P30L	00H
B5H	DACL									
B6H	DACH									
B7H	DACSEL	DSEL7	DSEL6	DSEL5	DSEL4	DSEL3	DSEL2	DSEL1	DSEL0	00H
B8H	IP	1	PS1	PT2	PS0	PT1	PX1	PT0	PX0	80H
B9H										
BAH										
BBH										
BCH										
BDH										
BEH										
BFH										
C0H	SCON1	SM0_1	SM1_1	SM2_1	REN_1	TB8_1	RB8_1	TI_1	RI_1	00H
C1H	SBUF1									00H
C2H										
C3H										
C4H										
C5H										
C6H	EWU						EWUWDT	EWUEX1	EWUEX0	00H
C7H	SYSC1K	0	0	DIVMOD1	DIVMOD0	0	DIV2	DIV1	DIV0	00H
C8H	T2CON	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	00H
C9H										
CAH	RCAP2L									00H
CBH	RCAP2H									00H
CCH	TL2									00H
CDH	TH2									00H
CEH										
CFH										
D0H	PSW	CY	AC	F0	RS1	RS0	OV	F1	P	00H
D1H	OCL								LSB	00H
D2H	OCM									00H
D3H	OCH	MSB								00H
D4H	GCL								LSB	54H
D5H	GCM									EC
D6H	GCH	MSB								5FH
D7H	ADMUX	INP3	INP2	INP1	INP0	INN3	INN2	INN1	INN0	01H
D8H	EICON	SMOD1	1	EAI	AI	WDTI	0	0	0	40H
D9H	ADRESL								LSB	00H
DAH	ADRESM									00H
DBH	ADRESH	MSB								00H
DCH	ADCON0	REFCLK	BOD	EVREF	VREFH	EBUF	PGA2	PGA1	PGA0	30H
DDH	ADCON1	OF_UF	POL	SM1	SM0	—	CAL2	CAL1	CAL0	0000_0000 ⁽²⁾
DEH	ADCON2	DR7	DR6	DR5	DR4	DR3	DR2	DR1	DR0	1BH
DFH	ADCON3	0	0	0	0	0	DR10	DR9	DR8	06H
E0H	ACC									00H
E1H	SSCON	SSCON1	SSCON0	SCNT2	SCNT1	SCNT0	SHF2	SHF1	SHF0	00H
E2H	SUMR0									00H
E3H	SUMR1									00H
E4H	SUMR2									00H
E5H	SUMR3									00H
E6H	ODAC									00H
E7H	LVDCON	ALVDIS	ALVD2	ALVD1	ALVD0	DLVDIS	DLVD2	DLVD1	DLVD0	00H
E8H	EIE	1	1	1	EWDI	EX5	EX4	EX3	EX2	E0H
E9H	HWPC0	0	0	0	0	0	1	MEMORY SIZE		0000_01xx ⁽²⁾

PRODUCT PREVIEW

(1) I²C is only available on the MSC1213.

(2) Applies to MSC1213 only. See HWPC0 (page 76) for MSC1214.

SFR Definitions (Continued)

ADDRESS	REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	RESET VALUES
EA _H	HWPC1	0	0	0	1	1	0	0	0	18 _H
EB _H	HWVER	1	0	0	0	0	0	0	0	80 _H
EC _H	Reserved									00 _H
ED _H	Reserved									00 _H
EE _H	FMCON	0	PGERA	0	FRCM	0	BUSY	1	0	02 _H
EF _H	FTCON	FER3	FER2	FER1	FER0	FWR3	FWR2	FWR1	FWR0	A5 _H
F0 _H	B	B.7	B.6	B.5	B.4	B.3	B.2	B.1	B.0	00 _H
F1 _H	PDCON	0	PDDAC	PDI2C	PDPWM	PDADC	PDWDT	PDST	PDSP1	7F _H
F2 _H	PASEL	0	0	PSEN2	PSEN1	PSEN0	0	ALE1	ALE0	00 _H
F3 _H										
F4 _H										
F5 _H										
F6 _H	ACLK	0	FREQ6	FREQ5	FREQ4	FREQ3	FREQ2	FREQ1	FREQ0	03 _H
F7 _H	SRST	0	0	0	0	0	0	0	RSTREQ	00 _H
F8 _H	EIP	1	1	1	PWDI	PX5	PX4	PX3	PX2	E0 _H
F9 _H	SECINT	WRT	SECINT6	SECINT5	SECINT4	SECINT3	SECINT2	SECINT1	SECINT0	7F _H
FA _H	MSINT	WRT	MSINT6	MSINT5	MSINT4	MSINT3	MSINT2	MSINT1	MSINT0	7F _H
FB _H	USEC	0	0	FREQ5	FREQ4	FREQ3	FREQ2	FREQ1	FREQ0	03 _H
FC _H	MSECL									9F _H
FD _H	MSECH									0F _H
FE _H	HMSEC									63 _H
FF _H	WDTCON	EWDT	DWDT	RWDT	WDCNT4	WDCNT3	WDCNT2	WDCNT1	WDCNT0	00 _H

(1) I²C is only available on the MSC1213.

(2) Applies to MSC1213 only. See HWPC0 (page 76) for MSC1214.

Port 0 (P0)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 80 _H	P0.7	P0.6	P0.5	P0.4	P0.3	P0.2	P0.1	P0.0	FF _H

P0.7–0 Port 0. This port functions as a multiplexed address/data bus during external memory access, and as a general-purpose I/O port when external memory access is not needed. During external memory cycles, this port will contain the LSB of the address when ALE is HIGH, and Data when ALE is LOW. When used as a general-purpose I/O, this port drive is selected by P0DDR1 and P0DDR0 (AC_H, AD_H). Whether Port 0 is used as general-purpose I/O or for external memory access is determined by the Flash Configuration Register (HCR1.1) (See SFR CADDR 93_H).

Stack Pointer (SP)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 81 _H	SP.7	SP.6	SP.5	SP.4	SP.3	SP.2	SP.1	SP.0	07 _H

SP.7–0 Stack Pointer. The stack pointer identifies the location where the stack will begin. The stack pointer is incremented before every PUSH or CALL operation and decremented after each POP or RET/RETI. This register defaults to 07_H after reset.

Data Pointer Low 0 (DPL0)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 82 _H	DPL0.7	DPL0.6	DPL0.5	DPL0.4	DPL0.3	DPL0.2	DPL0.1	DPL0.0	00 _H

DPL0.7–0 Data Pointer Low 0. This register is the low byte of the standard 8051 16-bit data pointer. DPL0 and DPH0 are used to point to non-scratchpad data RAM. The current data pointer is selected by DPS (SFR 86_H).

Data Pointer High 0 (DPH0)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 83 _H	DPH0.7	DPH0.6	DPH0.5	DPH0.4	DPH0.3	DPH0.2	DPH0.1	DPH0.0	00 _H

DPH0.7–0 Data Pointer High 0. This register is the high byte of the standard 8051 16-bit data pointer. DPL0 and DPH0 are used to point to non-scratchpad data RAM. The current data pointer is selected by DPS (SFR 86_H).

Data Pointer Low 1 (DPL1)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 84 _H	DPL1.7	DPL1.6	DPL1.5	DPL1.4	DPL1.3	DPL1.2	DPL1.1	DPL1.0	00 _H

DPL1.7–0 Data Pointer Low 1. This register is the low byte of the auxiliary 16-bit data pointer. When the SEL bit (DPS.0) (SFR 86_H) is set, DPL1 and DPH1 are used in place of DPL0 and DPH0 during DPTR operations.

Data Pointer High 1 (DPH1)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 85 _H	DPH1.7	DPH1.6	DPH1.5	DPH1.4	DPH1.3	DPH1.2	DPH1.1	DPH1.0	00 _H

DPH1.7–0 Data Pointer High. This register is the high byte of the auxiliary 16-bit data pointer. When the SEL bit (DPS.0) (SFR 86_H) is set, DPL1 and DPH1 are used in place of DPL0 and DPH0 during DPTR operations.

Data Pointer Select (DPS)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 86 _H	0	0	0	0	0	0	0	SEL	00 _H

SEL Data Pointer Select. This bit selects the active data pointer.

0: Instructions that use the DPTR will use DPL0 and DPH0.
1: Instructions that use the DPTR will use DPL1 and DPH1.

Power Control (PCON)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 87 _H	SMOD	0	1	1	GF1	GF0	STOP	IDLE	30 _H

SMOD **Serial Port 0 Baud Rate Doubler Enable.** The serial baud rate doubling function for Serial Port 0.
bit 7
0: Serial Port 0 baud rate will be a standard baud rate.
1: Serial Port 0 baud rate will be double that defined by baud rate generation equation.

GF1 **General-Purpose User Flag 1.** This is a general-purpose flag for software control.
bit 3

GF0 **General-Purpose User Flag 0.** This is a general-purpose flag for software control.
bit 2

STOP **Stop Mode Select.** Setting this bit will halt the oscillator and block external clocks. This bit will always read as a 0. All digital pins and DACs keep their respective output values. Internal REF dies. Exit with RESET.
bit 1

IDLE **Idle Mode Select.** Setting this bit will freeze the CPU, Timer 0, 1, and 2, and the USARTs; other peripherals remain active. This bit will always be read as a 0. All digital pins and DACs keep their respective output values. Internal REF remains unchanged. Exit with AI (A6_H) and EWU (C6_H) interrupts.
bit 0

Timer/Counter Control (TCON)

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Reset Value
SFR 88 _H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	00 _H

TF1 **Timer 1 Overflow Flag.** This bit indicates when Timer 1 overflows its maximum count as defined by the current mode. This bit can be cleared by software and is automatically cleared when the CPU vectors to the Timer 1 interrupt service routine.
bit 7
0: No Timer 1 overflow has been detected.
1: Timer 1 has overflowed its maximum count.

TR1 **Timer 1 Run Control.** This bit enables/disables the operation of Timer 1. Halting this timer will preserve the current bit 6 count in TH1, TL1.
bit 6
0: Timer is halted.
1: Timer is enabled.

TF0 **Timer 0 Overflow Flag.** This bit indicates when Timer 0 overflows its maximum count as defined by the current mode. This bit can be cleared by software and is automatically cleared when the CPU vectors to the Timer 0 interrupt service routine.
bit 5
0: No Timer 0 overflow has been detected.
1: Timer 0 has overflowed its maximum count.

TR0 **Timer 0 Run Control.** This bit enables/disables the operation of Timer 0. Halting this timer will preserve the current count in TH0, TL0.
bit 4
0: Timer is halted.
1: Timer is enabled.

IE1 **Interrupt 1 Edge Detect.** This bit is set when an edge/level of the type defined by IT1 is detected. If IT1 = 1, this bit will remain set until cleared in software or the start of the External Interrupt 1 service routine. If IT1 = 0, this bit will inversely reflect the state of the INT1 pin.
bit 3

IT1 **Interrupt 1 Type Select.** This bit selects whether the $\overline{\text{INT1}}$ pin will detect edge or level triggered interrupts.
bit 2
0: $\overline{\text{INT1}}$ is level triggered.
1: $\overline{\text{INT1}}$ is edge triggered.

IE0 **Interrupt 0 Edge Detect.** This bit is set when an edge/level of the type defined by IT0 is detected. If IT0 = 1, this bit will remain set until cleared in software or the start of the External Interrupt 0 service routine. If IT0 = 0, this bit will inversely reflect the state of the INT0 pin.
bit 1

IT0 **Interrupt 0 Type Select.** This bit selects whether the $\overline{\text{INT0}}$ pin will detect edge or level triggered interrupts.
bit 0
0: $\overline{\text{INT0}}$ is level triggered.
1: $\overline{\text{INT0}}$ is edge triggered.

Timer Mode Control (TMOD)

SFR 89 _H	7	6	5	4	3	2	1	0	Reset Value 00 _H
	TIMER 1				TIMER 0				
	GATE	C/T	M1	M0	GATE	C/T	M1	M0	

GATE **Timer 1 Gate Control.** This bit enables/disables the ability of Timer 1 to increment.

bit 7 0: Timer 1 will clock when TR1 = 1, regardless of the state of pin $\overline{\text{INT1}}$.

1: Timer 1 will clock only when TR1 = 1 and pin $\overline{\text{INT1}}$ = 1.

C/T **Timer 1 Counter/Timer Select.**

bit 6 0: Timer is incremented by internal clocks.

1: Timer is incremented by pulses on T1 pin when TR1 (TCON.6, SFR 88_H) is 1.

M1, M0 **Timer 1 Mode Select.** These bits select the operating mode of Timer 1.

bits 5–4

M1	M0	MODE
0	0	Mode 0: 8-bit counter with 5-bit prescale.
0	1	Mode 1: 16 bits.
1	0	Mode 2: 8-bit counter with auto reload.
1	1	Mode 3: Timer 1 is halted, but holds its count.

GATE **Timer 0 Gate Control.** This bit enables/disables the ability of Timer 0 to increment.

bit 3 0: Timer 0 will clock when TR0 = 1, regardless of the state of pin $\overline{\text{INT0}}$ (software control).

1: Timer 0 will clock only when TR0 = 1 and pin $\overline{\text{INT0}}$ = 1 (hardware control).

C/T **Timer 0 Counter/Timer Select.**

bit 2 0: Timer is incremented by internal clocks.

1: Timer is incremented by pulses on pin T0 when TR0 (TCON.4, SFR 88_H) is 1.

M1, M0 **Timer 0 Mode Select.** These bits select the operating mode of Timer 0.

bits 1–0

M1	M0	MODE
0	0	Mode 0: 8-bit counter with 5-bit prescale.
0	1	Mode 1: 16 bits.
1	0	Mode 2: 8-bit counter with auto reload.
1	1	Mode 3: Timer 1 is halted, but holds its count.

Timer 0 LSB (TL0)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8A _H	TL0.7	TL0.6	TL0.5	TL0.4	TL0.3	TL0.2	TL0.1	TL0.0	00 _H

TL0.7–0 **Timer 0 LSB.** This register contains the least significant byte of Timer 0.

bits 7–0

Timer 1 LSB (TL1)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8B _H	TL1.7	TL1.6	TL1.5	TL1.4	TL1.3	TL1.2	TL1.1	TL1.0	00 _H

TL1.7–0 **Timer 1 LSB.** This register contains the least significant byte of Timer 1.

bits 7–0

Timer 0 MSB (TH0)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8C _H	TH0.7	TH0.6	TH0.5	TH0.4	TH0.3	TH0.2	TH0.1	TH0.0	00 _H

TH0.7–0 **Timer 0 MSB.** This register contains the most significant byte of Timer 0.

bits 7–0

Timer 1 MSB (TH1)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8D _H	TH1.7	TH1.6	TH1.5	TH1.4	TH1.3	TH1.2	TH1.1	TH1.0	00 _H

TH1.7–0 Timer 1 MSB. This register contains the most significant byte of Timer 1.
bits 7–0

Clock Control (CKCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8E _H	0	0	T2M	T1M	T0M	MD2	MD1	MD0	01 _H

T2M **Timer 2 Clock Select.** This bit controls the division of the system clock that drives Timer 2. This bit has no effect when the timer is in baud rate generator or clock output modes. Clearing this bit to 0 maintains 8051 compatibility. This bit has no effect on instruction cycle timing.

- 0: Timer 2 uses a divide by 12 of the crystal frequency.
- 1: Timer 2 uses a divide by 4 of the crystal frequency.

T1M **Timer 1 Clock Select.** This bit controls the division of the system clock that drives Timer 1. Clearing this bit to 0 maintains 8051 compatibility. This bit has no effect on instruction cycle timing.

- 0: Timer 1 uses a divide by 12 of the crystal frequency.
- 1: Timer 1 uses a divide by 4 of the crystal frequency.

T0M **Timer 0 Clock Select.** This bit controls the division of the system clock that drives Timer 0. Clearing this bit to 0 maintains 8051 compatibility. This bit has no effect on instruction cycle timing.

- 0: Timer 0 uses a divide by 12 of the crystal frequency.
- 1: Timer 0 uses a divide by 4 of the crystal frequency.

MD2, MD1, MD0 **Stretch MOVX Select 2–0.** These bits select the time by which external MOVX cycles are to be stretched. This allows slower memory or peripherals to be accessed without using ports or manual software intervention. The width of the RD or WR strobe will be stretched by the specified interval, which will be transparent to the software except for the increased time to execute the MOVX instruction. All internal MOVX instructions on devices containing MOVX SRAM are performed at the 2 instruction cycle rate.

MD2	MD1	MD0	STRETCH VALUE	MOVX DURATION	RD or WR STROBE WIDTH (SYS CLKs)	RD or WR STROBE WIDTH (μs) at 12MHz
0	0	0	0	2 Instruction Cycles	2	0.167
0	0	1	1	3 Instruction Cycles (default)	4	0.333
0	1	0	2	4 Instruction Cycles	8	0.667
0	1	1	3	5 Instruction Cycles	12	1.000
1	0	0	4	6 Instruction Cycles	16	1.333
1	0	1	5	7 Instruction Cycles	20	1.667
1	1	0	6	8 Instruction Cycles	24	2.000
1	1	1	7	9 Instruction Cycles	28	2.333

Memory Write Select (MWS)

	7	6	5	4	3	2	1	0	Reset Value
SFR 8F _H	0	0	0	0	0	0	0	MXWS	00 _H

MXWS **MOVX Write Select.** This allows writing to the internal Flash program memory.

- 0: MOVX operations will access data memory (default).
- 1: MOVX operations will access program memory. Write operations can be inhibited by the PML or RSL bits in HCR0.

Port 1 (P1)

	7	6	5	4	3	2	1	0	Reset Value
SFR 90 _H	P1.7 INT5/SCK/SCL	P1.6 INT4/MISO/SDA	P1.5 INT3/MOSI	P1.4 INT2/SS	P1.3 TXD1	P1.2 RXD1	P1.1 T2EX	P1.0 T2	FF _H

P1.7–0 General-Purpose I/O Port 1. This register functions as a general-purpose I/O port. In addition, all the pins have an alternative function listed below. Each of the functions is controlled by several other SFRs. The associated Port 1 latch bit must contain a logic '1' before the pin can be used in its alternate function capacity. To use the alternate function, set the appropriate mode in P1DDRL (SFR AE_H), P1DDRH (SFR AF_H).

INT5/SCK/SCL External Interrupt 5. A falling edge on this pin will cause an external interrupt 5 if enabled.

bit 7 **SPI Clock.** The master clock for SPI data transfers.

Serial Clock. The serial clock for I²C data transfers (MSC1213 only).

INT4/MISO/SDA External Interrupt 4. A rising edge on this pin will cause an external interrupt 4 if enabled.

bit 6 **Master In Slave Out** For SPI data transfers, this pin receives data for the master and transmits data from the slave.

SDA. For I²C data transfers, this pin is the data line (MSC1213 only).

INT3/MOSI External Interrupt 3. A falling edge on this pin will cause an external interrupt 3 if enabled.

bit 5 **Master Out Slave In.** For SPI data transfers, this pin transmits master data and receives slave data.

INT2/SS External Interrupt 2. A rising edge on this pin will cause an external interrupt 2 if enabled.

bit 4 **Slave Select.** During SPI operation, this pin provides the select signal for the slave device.

TXD1 Serial Port 1 Transmit. This pin transmits the serial Port 1 data in serial port modes 1, 2, 3, and emits the synchronizing clock in serial port mode 0.

RXD1 Serial Port 1 Receive. This pin receives the serial Port 1 data in serial port modes 1, 2, 3, and is a bidirectional data transfer pin in serial port mode 0.

T2EX Timer 2 Capture/Reload Trigger. A 1 to 0 transition on this pin will cause the value in the T2 registers to be transferred into the capture registers if enabled by EXEN2 (T2CON.3, SFR C8_H). When in auto-reload mode, a 1 to 0 transition on this pin will reload the Timer 2 registers with the value in RCAP2L and RCAP2H if enabled by EXEN2 (T2CON.3, SFR C8_H).

T2 Timer 2 External Input. A 1 to 0 transition on this pin will cause Timer 2 to increment or decrement depending on the timer configuration.

External Interrupt Flag (EXIF)

	7	6	5	4	3	2	1	0	Reset Value
SFR 91 _H	IE5	IE4	IE3	IE2	1	0	0	0	08 _H

IE5 External Interrupt 5 Flag. This bit will be set when a falling edge is detected on INT5. This bit must be cleared manually by software. Setting this bit in software will cause an interrupt if enabled.

IE4 External Interrupt 4 Flag. This bit will be set when a rising edge is detected on INT4. This bit must be cleared manually by software. Setting this bit in software will cause an interrupt if enabled.

IE3 External Interrupt 3 Flag. This bit will be set when a falling edge is detected on INT3. This bit must be cleared manually by software. Setting this bit in software will cause an interrupt if enabled.

IE2 External Interrupt 2 Flag. This bit will be set when a rising edge is detected on INT2. This bit must be cleared manually by software. Setting this bit in software will cause an interrupt if enabled.

Memory Page (MPAGE)

	7	6	5	4	3	2	1	0	Reset Value
SFR 92 _H									00 _H

MPAGE The 8051 uses Port 2 for the upper 8 bits of the external data memory access by MOVX A@Ri and MOVX @Ri, A instructions. The MSC1213/14 uses register MPAGE instead of Port 2. To access external data memory using the MOVX A@Ri and MOVX @Ri, A instructions, the user should preload the upper byte of the address into MPAGE (versus preloading into P2 for the standard 8051).

Configuration Address Register (CADDR) (write-only)

	7	6	5	4	3	2	1	0	Reset Value
SFR 93 _H									00 _H

CADDR Configuration Address Register. This register supplies the address for reading bytes in the 128 bytes of Flash Configuration Memory. **WARNING:** If this register is written to while executing from Flash Memory, the CDATA register will be incorrect.

Configuration Data Register (CDATA)

	7	6	5	4	3	2	1	0	Reset Value
SFR 94 _H									00 _H

CDATA Configuration Data Register. This register will contain the data in the 128 bytes of Flash Configuration Memory that is located at the last written address in the CADDR register. This is a read-only register.

Memory Control (MCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR 95 _H	BPSEL	0	0	—	—	—	—	RAMMAP	00 _H

BPSEL Breakpoint Address Selection
bit 7 Write: Select one of two Breakpoint registers: 0 or 1.
0: Select breakpoint register 0.
1: Select breakpoint register 1.
Read: Provides the Breakpoint register that created the last interrupt: 0 or 1.

RAMMAP Memory Map 1kB extended SRAM.
bit 0 0: Address is: 0000_H—03FF_H (default) (Data Memory)
1: Address is 8400_H—87FF_H (Data and Program Memory)

Serial Port 0 Control (SCON0)

	7	6	5	4	3	2	1	0	Reset Value
SFR 98 _H	SM0_0	SM1_0	SM2_0	REN_0	TB8_0	RB8_0	TI_0	RI_0	00 _H

SM0–2 Serial Port 0 Mode. These bits control the mode of serial Port 0. Modes 1, 2, and 3 have 1 start and 1 stop bit in addition to the 8 or 9 data bits.

MODE	SM0	SM1	SM2	FUNCTION	LENGTH	PERIOD
0	0	0	0	Synchronous	8 bits	12 p _{CLK} ⁽¹⁾
0	0	0	1	Synchronous	8 bits	4 p _{CLK} ⁽¹⁾
1 ⁽²⁾	0	1	0	Asynchronous	10 bits	Timer 1 or 2 Baud Rate Equation
1 ⁽²⁾	0	1	1	Valid Stop Required ⁽³⁾	10 bits	Timer 1 Baud Rate Equation
2	1	0	0	Asynchronous	11 bits	64 p _{CLK} ⁽¹⁾ (SMOD = 0) 32 p _{CLK} ⁽¹⁾ (SMOD = 1)
2	1	0	1	Asynchronous with Multiprocessor Communication ⁽⁴⁾	11 bits	64 p _{CLK} ⁽¹⁾ (SMOD = 0) 32 p _{CLK} ⁽¹⁾ (SMOD = 1)
3 ⁽²⁾	1	1	0	Asynchronous	11 bits	Timer 1 or 2 Baud Rate Equation
3 ⁽²⁾	1	1	1	Asynchronous with Multiprocessor Communication ⁽⁴⁾	11 bits	Timer 1 or 2 Baud Rate Equation

(1) p_{CLK} will be equal to t_{CLK}, except that p_{CLK} will stop for IDLE.
(2) For modes 1 and 3, the selection of Timer 1 or 2 for baud rate is specified via the T2CON (C8_H) register.
(3) RI_0 will only be activated when a valid STOP is received.
(4) RI_0 will not be activated if bit 9 = 0.

REN_0 Receive Enable. This bit enables/disables the serial Port 0 received shift register.
bit 4 0: Serial Port 0 reception disabled.
1: Serial Port 0 received enabled (modes 1, 2, and 3). Initiate synchronous reception (mode 0).

TB8_0 9th Transmission Bit State. This bit defines the state of the 9th transmission bit in serial Port 0 modes 2 and 3.
bit 3

RB8_0 9th Received Bit State. This bit identifies the state of the 9th reception bit of received data in serial Port 0 modes 2 and 3. In serial port mode 1, when SM2_0 = 0, RB8_0 is the state of the stop bit. RB8_0 is not used in mode 0.
bit 2

- TI_0** **Transmitter Interrupt Flag.** This bit indicates that data in the serial Port 0 buffer has been completely shifted out. In serial port mode 0, bit 1 TI_0 is set at the end of the 8th data bit. In all other modes, this bit is set at the end of the last data bit. This bit must be manually cleared by software.
- RI_0** **Receiver Interrupt Flag.** This bit indicates that a byte of data has been received in the serial Port 0 buffer. In serial port mode 0, RI_0 bit 0 is set at the end of the 8th bit. In serial port mode 1, RI_0 is set after the last sample of the incoming stop bit subject to the state of SM2_0. In modes 2 and 3, RI_0 is set after the last sample of RB8_0. This bit must be manually cleared by software.

Serial Data Buffer 0 (SBUF0)

	7	6	5	4	3	2	1	0	Reset Value
SFR 99H									00H

SBUF0 **Serial Data Buffer 0.** Data for Serial Port 0 is read from or written to this location. The serial transmit and receive buffers are separate bits 7–0 registers, but both are addressed at this location.

SPI Control (SPICON). Any change resets the SPI interface, counters, and pointers. PDCON controls which is enabled.

	7	6	5	4	3	2	1	0	Reset Value
SFR 9AH	SCK2	SCK1	SCK0	FIFO	ORDER	MSTR	CPHA	CPOL	00H

SCK **SCK Selection.** Selection of t_{CLK} divider for generation of SCK in Master mode. bits 7–5

SCK2	SCK1	SCK0	SCK PERIOD
0	0	0	$t_{CLK}/2$
0	0	1	$t_{CLK}/4$
0	1	0	$t_{CLK}/8$
0	1	1	$t_{CLK}/16$
1	0	0	$t_{CLK}/32$
1	0	1	$t_{CLK}/64$
1	1	0	$t_{CLK}/128$
1	1	1	$t_{CLK}/256$

FIFO **Enable FIFO in on-chip indirect memory.** bit 4
 0: Both transmit and receive are double buffers
 1: Circular FIFO used for transmit and receive bytes

ORDER **Set Bit Order for Transmit and Receive.** bit 3
 0: Most Significant Bits First
 1: Least Significant Bits First

MSTR **SPI Master Mode.** bit 2
 0: Slave Mode
 1: Master Mode

CPHA **Serial Clock Phase Control.** bit 1
 0: Valid data starting from half SCK period before the first edge of SCK
 1: Valid data starting from the first edge of SCK

CPOL **Serial Clock Polarity.** bit 0
 0: SCK idle at logic LOW
 1: SCK idle at logic HIGH

I²C Control Register (I2CCON) (Available only on the MSC1213)

- START** **Start Condition (Master mode).**
bit 7
Read: Current status of start condition or repeated start condition.
Write: When operating as a master, a start condition is transmitted when the START bit is set to 1. During a data transfer, if the START bit is set, a repeated start is transmitted after the current data transfer is complete. If no transfer is in progress when the START and STOP bits are set simultaneously, a START will be followed by a STOP.
- STOP** **Stop Condition (Master mode).**
bit 6
Read: Current status of stop condition.
Write: Setting STOP to logic 1 causes a stop condition to be transmitted. When a stop condition is received, hardware clears STOP to logic 0. If both START and STOP are set during a transfer, a stop condition is transmitted followed by a start condition.
- ACK** **Acknowledge.** Defines the ACK/NACK generation from the master/slave receiver during the acknowledge cycle.
bit 5
0: A NACK (high level on SDA) is returned during the acknowledge cycle.
1: An ACK (low level on SDA) is returned during the acknowledge cycle.
In slave transmit mode, 0 = Current byte is last byte, 1 = More to follow.
- 0** **Always set this value to zero.**
bit 4
- FAST** **Fast Mode Enable.**
bit 3
0: Standard Mode (100kHz)
1: Fast Mode (400kHz)
- MSTR** **SPI Master Mode.**
bit 2
0: Slave Mode
1: Master Mode
- SCLS** **Clock Stretch.**
bit 1
0: No effect
1: Release the clock line. For the slave mode, the clock is stretched for each data transfer. This bit releases the clock.
- FILEN** **Filter Enable. 50ns glitch filter.**
bit 0
0: Filter disabled
1: Filter enabled

SPI Data Register (SPIDATA) / I²C Data Register (I2CDATA)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9B _H									00 _H

SPIDATA **SPI Data Register.** Data for SPI is read from or written to this location. The SPI transmit and receive buffers are separate registers, bits 7–0 but both are addressed at this location. Read to clear the receive interrupt and write to clear the transmit interrupt.

I2CDATA **I²C Data Register. (MSC1213 only.)** Data for I²C is read from or written to this location. The I²C transmit and receive buffers are separate registers, bits 7–0 but both are addressed at this location. Writing to this register starts transmission. In Master mode, reading this register starts a Master read cycle.

SPI Receive Control Register (SPIRCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9C _H	RXCNT7 RXFLUSH	RXCNT6	RXCNT5	RXCNT4	RXCNT3	RXCNT2 RXIRQ2	RXCNT1 RXIRQ1	RXCNT0 RXIRQ0	00 _H

RXCNT Receive Counter. Read-only bits which read the number of bytes in the receive buffer (0 to 128).
bits 7–0

RXFLUSH Flush Receive FIFO. Write-only.
bit 7 0: No Action
1: SPI Receive Buffer Set to Empty

RXIRQ Read IRQ Level. Write-only.
bits 2–0

000	Generate IRQ when Receive Count = 1 or more.
001	Generate IRQ when Receive Count = 2 or more.
010	Generate IRQ when Receive Count = 4 or more.
011	Generate IRQ when Receive Count = 8 or more.
100	Generate IRQ when Receive Count = 16 or more.
101	Generate IRQ when Receive Count = 32 or more.
110	Generate IRQ when Receive Count = 64 or more.
111	Generate IRQ when Receive Count = 128 or more.

I²C GM Register (I2CGM) (Available only on the MSC1213)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9C _H	GCMEN								00 _H

GCMEN General Call/Multiple Master Enable. Write-only.
bit 7 Slave mode: 0 = General call ignored, 1 = General call will be detected
Master mode: 0 = Single master, 1 = Multiple master mode

SPI Transmit Control Register (SPITCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9D _H	TXCNT7 TXFLUSH	TXCNT6	TXCNT5 CLK_EN	TXCNT4 DRV_DLY	TXCNT3 DRV_EN	TXCNT2 TXIRQ2	TXCNT1 TXIRQ1	TXCNT0 TXIRQ0	00 _H

TXCNT Transmit Counter. Read-only bits which read the number of bytes in the transmit buffer (0 to 128).
bits 7–0

TXFLUSH Flush Transmit FIFO. This bit is write-only. When set, the SPI transmit pointer is set equal to the FIFO Output pointer.
bit 7 This bit is 0 for a read operation.

CLK_EN SCLK Driver Enable.
bit 5 0: Disable SCLK Driver (Master Mode)
1: Enable SCLK Driver (Master Mode)

DRV_DLY Drive Delay (refer to DRV_EN bit).
bit 4 0: Drive Output Immediately
1: Drive Output After Current Byte Transfer

DRV_EN Drive Enable.
bit 3

DRV_DLY	DRV_EN	MOSI or MISO OUTPUT CONTROL
0	0	Tristate immediately.
0	1	Drive immediately.
1	0	Tristate after the current byte transfer.
1	1	Drive after the current byte transfer.

TXIRQ Transmit IRQ Level. Write-only bits.
bits 2–0

000	Generate IRQ when Transmit Count = 1 or less.
001	Generate IRQ when Transmit Count = 2 or less.
010	Generate IRQ when Transmit Count = 4 or less.
011	Generate IRQ when Transmit Count = 8 or less.
100	Generate IRQ when Transmit Count = 16 or less.
101	Generate IRQ when Transmit Count = 32 or less.
110	Generate IRQ when Transmit Count = 64 or less.
111	Generate IRQ when Transmit Count = 128 or less.

I²C Status Register (I2CSTAT) (Available only on the MSC1213)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9DH	STAT7 SCKD7/SAE	STAT6 SCKD6/SA6	STAT5 SCKD5/SA5	STAT4 SCKD4/SA4	STAT3 SCKD3/SA3	0 SCKD2/SA2	0 SCKD1/SA1	0 SCKD0/SA0	00H

STAT7–3 Status Code. Read-only. Reading this register clears the status interrupt.
bit 7–3

STATUS CODE	STATUS OF THE HARDWARE	MODE
0x08	START condition transmitted.	Master
0x10	Repeated START condition transmitted.	Master
0x18	Slave address + W transmitted and ACK received.	Master
0x20	Slave address + W transmitted and NACK received.	Master
0x28	Data byte transmitted and ACK received.	Master
0x30	Data byte transmitted and NACK received.	Master
0x38	Arbitration lost.	Master
0x40	Slave address + R transmitted and ACK received.	Master
0x48	Slave address + R transmitted and NACK received.	Master
0x50	Data byte received and ACK transmitted.	Master
0x58	Data byte received and NACK transmitted.	Master
0x60	I2Cs slave address + W received and ACK transmitted.	Slave
0x70	General call received and ACK transmitted.	Slave
0x80	Previously addressed as slave, data byte received and ACK transmitted.	Slave
0x88	Previously addressed as slave, data byte received and NACK transmitted.	Slave
0x90	Previously addressed with GC, data byte received and ACK transmitted.	Slave
0x98	Previously addressed with GC, data byte received and NACK transmitted.	Slave
0xA0	A STOP or repeated START received when addressed as slave or GC.	Slave
0xA8	I2Cs slave address + R received and ACK transmitted.	Slave
0xB8	Previously addressed as slave, data byte transmitted and ACK received.	Slave
0xC0	Previously addressed as slave, data byte transmitted and NACK received.	Slave
0xC8	Previously addressed as slave, last data byte transmitted.	Slave

SCKD7–0 Serial Clock Divisor. Write-only, master mode.
bit 7–0 The frequency of the SCL line is set equal to Sysclk/[2 • (SCKD + 1)]. The minimum value for SCKD is 3.

SAE Slave Address Enable. Write-only, slave mode.
bit 7 In slave mode, if this is set, address recognition is enabled.

SA6–0 Slave Address. Write-only, slave mode.
bit 6–0 The address of this device is used in slave mode for address recognition.

I²C Start Register (I2CSTART) (Available only on the MSC1213)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9EH									80H

I2CSTART I2C Start Address. Write-only. When any value is written to this register, the I2C system is reset; that is, the counters and state machines will go back to the initial state. So, in multi-master mode when arbitration is lost, then the I2C should be reset so that the counters and FSMs are brought back to the idle state.

SPI Buffer Start Address (SPISTART)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9EH	1								80H

SPISTART SPI FIFO Start Address. Write-only. This specifies the start address of the SPI data buffer. This is a circular FIFO that is located in the bits 6–0 128 bytes of indirect RAM. The FIFO starts at this address and ends at the address specified in SPIEND. Must be less than SPIEND. Writing clears SPI transmit and receive counters.

SPI TP SPI Transmit Pointer. Read-only. This is the FIFO address for SPI transmissions. This is where the next byte will be written into the bits 6–0 byte will be written into the SPI FIFO buffer. This pointer increments after each write to the SPI Data register unless that would make it equal to the SPI Receive pointer.

SPI Buffer End Address (SPIEND)

	7	6	5	4	3	2	1	0	Reset Value
SFR 9FH	1								80H

SPIEND SPI FIFO End Address. Write-only. This specifies the end address of the SPI data FIFO. This is a circular buffer that is located in the bits 6–0 128 bytes of indirect RAM. The buffer starts at SPISTART and ends at this address.

SPI RP SPI Receive Pointer. Read-only. This is the FIFO address for SPI received bytes. This is the location of the next byte to be read from bits 6–0 the SPI FIFO. This increments with each read from the SPI Data register until the RxCNT is zero.

Port 2 (P2)

	7	6	5	4	3	2	1	0	Reset Value
SFR A0H									FFH

P2 Port 2. This port functions as an address bus during external memory access, and as a general-purpose I/O port. During external memory cycles, this port will contain the MSB of the address. Whether Port 2 is used as general-purpose I/O or for external memory access is determined by the Flash Configuration Register (HCR1.0).

PWM Control (PWMCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR A1H	—	—	PPOL	PWMSEL	SPDSEL	TPCNTL2	TPCNTL1	TPCNTL0	00H

PPOL Period Polarity. Specifies the starting level of the PWM pulse.
 bit 5 0: ON Period. PWM Duty register programs the ON period.
 1: OFF Period. PWM Duty register programs the OFF period.

PWMSEL PWM Register Select. Select which 16-bit register is accessed by PWMLOW/PWMHIGH.
 bit 4 0: Period (must be 0 for TONE mode)
 1: Duty

SPDSEL Speed Select.
 bit 3 0: 1MHz (the USEC Clock)
 1: SYSCLK

TPCNTL Tone Generator/Pulse Width Modulation Control.
 bits 2–0

TPCNTL2	TPCNTL1	TPCNTL0	MODE
0	0	0	Disable (default)
0	0	1	PWM
0	1	1	TONE—Square
1	1	1	TONE—Staircase

Tone Low (TONELOW) /PWM Low (PWMLOW)

	7	6	5	4	3	2	1	0	Reset Value
SFR A2 _H	PWM7 TDIV7	PWM6 TDIV6	PWM5 TDIV5	PWM4 TDIV4	PWM3 TDIV3	PWM2 TDIV2	PWM1 TDIV1	PWM0 TDIV0	00 _H

PWMLOW Pulse Width Modulator Low Bits. These 8 bits are the least significant 8 bits of the PWM register.
bits 7–0

TDIV7–0 Tone Divisor. The low order bits that define the half-time period. For staircase mode the output is high impedance for the last 1/4 bits 7–0 of this period.

Tone High (TONEHI)/PWM High (PWMHI)

	7	6	5	4	3	2	1	0	Reset Value
SFR A3 _H	PWM15 TDIV15	PWM14 TDIV14	PWM13 TDIV13	PWM12 TDIV12	PWM11 TDIV11	PWM10 TDIV10	PWM9 TDIV9	PWM8 TDIV8	00 _H

PWMHI Pulse Width Modulator High Bits. These 8 bits are the high order bits of the PWM register.
bits 7–0

TDIV15–8 Tone Divisor. The high order bits that define the half time period. For staircase mode the output is high impedance for the last 1/4 bits 7–0 of this period.

Pending Auxiliary Interrupt (PAI)

PAI Pending Auxiliary Interrupt Register. The results of this register can be used as an index to vector to the appropriate interrupt routine.
bits 3–0 All of these interrupts vector through address 0033_H.

PAI3	PAI2	PAI1	PAI0	AUXILIARY INTERRUPT STATUS
0	0	0	0	No Pending Auxiliary IRQ
0	0	0	1	Digital Low Voltage IRQ Pending
0	0	1	0	Analog Low Voltage IRQ Pending
0	0	1	1	SPI Receive IRQ Pending. I ² C Status Pending.
0	1	0	0	SPI Transmit IRQ Pending.
0	1	0	1	One Millisecond System Timer IRQ Pending.
0	1	1	0	Analog-to-Digital Conversion IRQ Pending.
0	1	1	1	Accumulator IRQ Pending.
1	0	0	0	One Second System Timer IRQ Pending.

Auxiliary Interrupt Poll (AIPOL)

		7	6	5	4	3	2	1	0	Reset Value
RD	SFR A4 _H	ESEC	ESUM	EADC	EMSEC	ESPIT	ESPIR/EI2C	EALV	EDLVB	00 _H
WR									RDSEL	00 _H

Interrupts are enabled by EICON.4 (SFR D8_H). The other interrupts are controlled by the IE and EIE registers.

ESEC Enable Seconds Timer Interrupt (lowest priority auxiliary interrupt).
bit 7 Read-only.
AIPOL.RDSEL = 1: Read: Current value of **Seconds Timer Interrupt** before masking.
AIPOL.RDSEL = 0: Read: Value of ESEC bit.

ESUM Enable Summation Interrupt.
bit 6 Read-only.
AIPOL.RDSEL = 1: Read: Current value of **Summation Interrupt** before masking.
AIPOL.RDSEL = 0: Read: Value of ESUM bit.

EADC Enable ADC Interrupt.
bit 5 Read-only.
AIPOL.RDSEL = 1: Read: Current value of **ADC Interrupt** before masking.
AIPOL.RDSEL = 0: Read: Value of EADC bit.

EMSEC Enable Millisecond System Timer Interrupt.
bit 4 Read-only.
AIPOL.RDSEL = 1: Read: Current value of **Millisecond System Timer Interrupt** before masking.
AIPOL.RDSEL = 0: Read: Value of EMSEC bit.

Auxiliary Interrupt Enable (AIE)

	7	6	5	4	3	2	1	0	Reset Value
SFR A6H	ESEC	ESUM	EADC	EMSEC	ESPIT	ESPIR/EI2C	EALV	EDLVB	00H

Interrupts are enabled by EICON.4 (SFR D8H). The other interrupts are controlled by the IE and EIE registers.

ESEC Enable Seconds Timer Interrupt (lowest priority auxiliary interrupt).

bit 7 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **Seconds Timer Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **ESEC** bit.

ESUM Enable Summation Interrupt.

bit 6 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **Summation Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **ESUM** bit.

EADC Enable ADC Interrupt.

bit 5 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **ADC Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **EADC** bit.

EMSEC Enable Millisecond System Timer Interrupt.

bit 4 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **Millisecond System Timer Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **EMSEC** bit.

ESPIT Enable SPI Transmit Interrupt.

bit 3 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **SPI Transmit Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **ESPIT** bit.

ESPIR/EI2C Enable SPI Receive Interrupt. Enable I2C Status Interrupt. (I2C available only on the MSC1213.)

bit 2 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **SPI Receive Interrupt** or **I2C Status Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **ESPIR/EI2C** bit.

EALV Enable Analog Low Voltage Interrupt.

bit 1 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **Analog Low Voltage Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **EALV** bit.

EDLVB Enable Digital Low Voltage or Breakpoint Interrupt (highest priority auxiliary interrupt).

bit 0 Write: Set mask bit for this interrupt; 0 = masked, 1 = enabled.
Read: When AIPOL.RDSEL = 0: Current value of **Digital Low Voltage** or **Breakpoint Interrupt** before masking.
Read: When AIPOL.RDSEL = 1: Value of **EDLVB** bit.

Auxiliary Interrupt Status Register (AISTAT)

	7	6	5	4	3	2	1	0	Reset Value
SFR A7 _H	SEC	SUM	ADC	MSEC	SPIT	SPIR/I2CSI	ALVD	DLVD	00 _H

SEC Second System Timer Interrupt Status Flag (lowest priority AI).

bit 7
0: SEC interrupt inactive or masked.
1: SEC Interrupt active.

SUM Summation Register Interrupt Status Flag.

bit 6
0: SUM interrupt inactive or masked (if active, it is set inactive by reading the lowest byte of the Summation register).
1: SUM interrupt active.

ADC ADC Interrupt Status Flag.

bit 5
0: ADC interrupt inactive or masked (If active, it is set inactive by reading the lowest byte of the Data Output Register).
1: ADC interrupt active (If active no new data will be written to the Data Output Register).

MSEC Millisecond System Timer Interrupt Status Flag.

bit 4
0: MSEC interrupt inactive or masked.
1: MSEC interrupt active.

SPIT SPI Transmit Interrupt Status Flag.

bit 3
0: SPI transmit interrupt inactive or masked.
1: SPI transmit interrupt active.

SPIR/I2CSI SPI Receive Interrupt Status Flag. I2C Status Interrupt. (I2C available only on the MSC1213.)

bit 2
0: SPI receive or I2CSI interrupt inactive or masked.
1: SPI receive or I2CSI interrupt active.

ALVD Analog Low Voltage Detect Interrupt Status Flag.

bit 1
0: ALVD interrupt inactive or masked.
1: ALVD interrupt active.

DLVD Digital Low Voltage Detect or Breakpoint Interrupt Status Flag (highest priority AI).

bit 0
0: DLVD interrupt inactive or masked.
1: DLVD interrupt active.

Interrupt Enable (IE)

	7	6	5	4	3	2	1	0	Reset Value
SFR A8 _H	EA	ES1	ET2	ES0	ET1	EX1	ET0	EX0	00 _H

EA Global Interrupt Enable. This bit controls the global masking of all interrupts except those in AIE (SFR A6_H).

bit 7
0: Disable interrupt sources. This bit overrides individual interrupt mask settings for this register.
1: Enable all individual interrupt masks. Individual interrupts in this register will occur if enabled.

ES1 Enable Serial Port 1 Interrupt. This bit controls the masking of the serial Port 1 interrupt.

bit 6
0: Disable all serial Port 1 interrupts.
1: Enable interrupt requests generated by the RI_1 (SCON1.0, SFR C0_H) or TI_1 (SCON1.1, SFR C0_H) flags.

ET2 Enable Timer 2 Interrupt. This bit controls the masking of the Timer 2 interrupt.

bit 5
0: Disable all Timer 2 interrupts.
1: Enable interrupt requests generated by the TF2 flag (T2CON.7, SFR C8_H).

ES0 Enable Serial port 0 interrupt. This bit controls the masking of the serial Port 0 interrupt.

bit 4
0: Disable all serial Port 0 interrupts.
1: Enable interrupt requests generated by the RI_0 (SCON0.0, SFR 98_H) or TI_0 (SCON0.1, SFR 98_H) flags.

ET1 Enable Timer 1 Interrupt. This bit controls the masking of the Timer 1 interrupt.

bit 3
0: Disable Timer 1 interrupt.
1: Enable interrupt requests generated by the TF1 flag (TCON.7, SFR 88_H).

EX1 Enable External Interrupt 1. This bit controls the masking of external interrupt 1.

bit 2
0: Disable external interrupt 1.
1: Enable interrupt requests generated by the $\overline{\text{INT1}}$ pin.

ET0 Enable Timer 0 Interrupt. This bit controls the masking of the Timer 0 interrupt.

bit 1
0: Disable all Timer 0 interrupts.
1: Enable interrupt requests generated by the TF0 flag (TCON.5, SFR 88_H).

EX0 Enable External Interrupt 0. This bit controls the masking of external interrupt 0.
 bit 0 0: Disable external interrupt 0.
 1: Enable interrupt requests generated by the $\overline{\text{INT0}}$ pin.

Breakpoint Control (BPCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR A9 _H	BP	0	0	0	0	0	PMSEL	EBP	00 _H

Writing to register sets the breakpoint condition specified by MCON, BPL, and BPH.

BP Breakpoint Interrupt. This bit indicates that a break condition has been recognized by a hardware breakpoint register(s).
 bit 7 Read: Status of Breakpoint Interrupt. Will indicate a breakpoint match for any of the breakpoint registers.
 Write: 0: No effect.
 1: Clear Breakpoint 1 for breakpoint register selected by MCON (SFR 95_H).

PMSEL Program Memory Select. Write this bit to select memory for address breakpoints of register selected in
 bit 1 MCON (SFR 95_H).
 0: Break on address in data memory.
 1: Break on address in program memory.

EBP Enable Breakpoint. This bit enables this breakpoint register. Address of breakpoint register selected by
 bit 0 MCON (SFR 95_H).
 0: Breakpoint disabled.
 1: Breakpoint enabled.

Breakpoint Low (BPL) Address for BP Register Selected in MCON (95_H)

	7	6	5	4	3	2	1	0	Reset Value
SFR AA _H	BPL.7	BPL.6	BPL.5	BPL.4	BPL.3	BPL.2	BPL.1	BPL.0	00 _H

BPL.7–0 Breakpoint Low Address. The low 8 bits of the 16-bit breakpoint address.
 bits 7–0

Breakpoint High Address (BPH) Address for BP Register Selected in MCON (95_H)

	7	6	5	4	3	2	1	0	Reset Value
SFR AB _H	BPH.7	BPH.6	BPH.5	BPH.4	BPH.3	BPH.2	BPH.1	BPH.0	00 _H

BPH.7–0 Breakpoint High Address. The high 8 bits of the 16-bit breakpoint address.
 bits 7–0

Port 0 Data Direction Low Register (P0DDRL)

	7	6	5	4	3	2	1	0	Reset Value
SFR AC _H	P03H	P03L	P02H	P02L	P01H	P01L	P00H	P00L	00 _H

P0.3 Port 0 bit 3 control.

bits 7–6

P03H	P03L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.2 Port 0 bit 2 control.

bits 5–4

P02H	P02L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.1 Port 0 bit 1 control.

bits 3–2

P01H	P01L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.0 Port 0 bit 0 control.

bits 1–0

P00H	P00L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 0 also controlled by \overline{EA} and Memory Access Control HCR1.1.

Port 0 Data Direction High Register (P0DDRH)

	7	6	5	4	3	2	1	0	Reset Value
SFR AD _H	P07H	P07L	P06H	P06L	P05H	P05L	P04H	P04L	00 _H

P0.7 Port 0 bit 7 control.

bits 7–6

P07H	P07L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.6 Port 0 bit 6 control.

bits 5–4

P06H	P06L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.5 Port 0 bit 5 control.

bits 3–2

P05H	P05L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P0.4 Port 0 bit 4 control.

bits 1–0

P04H	P04L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 0 also controlled by \overline{EA} and Memory Access Control HCR1.1.

Port 1 Data Direction Low Register (P1DDRL)

	7	6	5	4	3	2	1	0	Reset Value
SFR AE _H	P13H	P13L	P12H	P12L	P11H	P11L	P10H	P10L	00 _H

P1.3 Port 1 bit 3 control.

bits 7–6

P13H	P13L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.2 Port 1 bit 2 control.

bits 5–4

P12H	P12L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.1 Port 1 bit 1 control.

bits 3–2

P11H	P11L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.0 Port 1 bit 0 control.

bits 1–0

P10H	P10L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

Port 1 Data Direction High Register (P1DDRH)

	7	6	5	4	3	2	1	0	Reset Value
SFR AF _H	P17H	P17L	P16H	P16L	P15H	P15L	P14H	P14L	00 _H

P1.7 Port 1 bit 7 control.

bits 7–6

P17H	P17L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.6 Port 1 bit 6 control.

bits 5–4

P16H	P16L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.5 Port 1 bit 5 control.

bits 3–2

P15H	P15L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P1.4 Port 1 bit 4 control.

bits 1–0

P14H	P14L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

Port 3 (P3)

	7	6	5	4	3	2	1	0	Reset Value
SFR B0 _H	$\overline{P3.7}$ RD	$\overline{P3.6}$ WR	P3.5 T1	P3.4 T0	$\overline{P3.3}$ INT1	$\overline{P3.2}$ INT0	P3.1 TXD0	P3.0 RXD0	FF _H

P3.7–0 **General-Purpose I/O Port 3.** This register functions as a general-purpose I/O port. In addition, all the pins have an alternative function listed below. Each of the functions is controlled by several other SFRs. The associated Port 3 latch bit must contain a logic '1' before the pin can be used in its alternate function capacity.

\overline{RD} **External Data Memory Read Strobe.** This pin provides an active low read strobe to an external memory device. If Port 0 or Port 2 is selected for external memory in the HCR1 register, this function will be enabled even if a 1 is not written to this latch bit. When external memory is selected, the settings of P3DRRH are ignored.

\overline{WR} **External Data Memory Write Strobe.** This pin provides an active low write strobe to an external memory device. If Port 0 or Port 2 is selected for external memory in the HCR1 register, this function will be enabled even if a 1 is not written to this latch bit. When external memory is selected, the settings of P3DRRH are ignored.

T1 **Timer/Counter 1 External Input.** A 1 to 0 transition on this pin will increment Timer 1.

bit 5

T0 **Timer/Counter 0 External Input.** A 1 to 0 transition on this pin will increment Timer 0.

bit 4

$\overline{INT1}$ **External Interrupt 1.** A falling edge/low level on this pin will cause an external interrupt 1 if enabled.

bit 3

$\overline{INT0}$ **External Interrupt 0.** A falling edge/low level on this pin will cause an external interrupt 0 if enabled.

bit 2

TXD0 **Serial Port 0 Transmit.** This pin transmits the serial Port 0 data in serial port modes 1, 2, 3, and emits the synchronizing clock in serial port mode 0.

bit 1

RXD0 **Serial Port 0 Receive.** This pin receives the serial Port 0 data in serial port modes 1, 2, 3, and is a bidirectional data transfer pin in serial port mode 0.

bit 0

Port 2 Data Direction Low Register (P2DDRL)

	7	6	5	4	3	2	1	0	Reset Value
SFR B1 _H	P23H	P23L	P22H	P22L	P21H	P21L	P20H	P20L	00 _H

P2.3 Port 2 bit 3 control.
bits 7–6

P23H	P23L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.2 Port 2 bit 2 control.
bits 5–4

P22H	P22L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.1 Port 2 bit 1 control.
bits 3–2

P21H	P21L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.0 Port 2 bit 0 control.
bits 1–0

P20H	P20L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 2 also controlled by \overline{EA} and Memory Access Control HCR1.1.

Port 2 Data Direction High Register (P2DDRH)

	7	6	5	4	3	2	1	0	Reset Value
SFR B2 _H	P27H	P27L	P26H	P26L	P25H	P25L	P24H	P24L	00 _H

P2.7 Port 2 bit 7 control.
bits 7–6

P27H	P27L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.6 Port 2 bit 6 control.
bits 5–4

P26H	P26L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.5 Port 2 bit 5 control.

bits 3–2

P25H	P25L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P2.4 Port 2 bit 4 control.

bits 1–0

P24H	P24L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 2 also controlled by \overline{EA} and Memory Access Control HCR1.1.

Port 3 Data Direction Low Register (P3DDRL)

	7	6	5	4	3	2	1	0	Reset Value
SFR B3 _H	P33H	P33L	P32H	P32L	P31H	P31L	P30H	P30L	00 _H

P3.3 Port 3 bit 3 control.

bits 7–6

P33H	P33L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P3.2 Port 3 bit 2 control.

bits 5–4

P32H	P32L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P3.1 Port 3 bit 1 control.

bits 3–2

P31H	P31L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P3.0 Port 3 bit 0 control.

bits 1–0

P30H	P30L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

Port 3 Data Direction High Register (P3DDRH)

	7	6	5	4	3	2	1	0	Reset Value
SFR B4 _H	P37H	P37L	P36H	P36L	P35H	P35L	P34H	P34L	00 _H

P3.7 Port 3 bit 7 control.
bits 7–6

P37H	P37L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 3.7 also controlled by \overline{EA} and Memory Access Control HCR1.1.

P3.6 Port 3 bit 6 control.
bits 5–4

P36H	P36L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

NOTE: Port 3.6 also controlled by \overline{EA} and Memory Access Control HCR1.1.

P3.5 Port 3 bit 5 control.
bits 3–2

P35H	P35L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

P3.4 Port 3 bit 4 control.
bits 1–0

P34H	P34L	
0	0	Standard 8051 (Pull-Up)
0	1	CMOS Output
1	0	Open Drain Output
1	1	Input

DAC Low Byte (DACL)

	7	6	5	4	3	2	1	0	Reset Value
SFR B5 _H									00 _H

DACL7–0 Least Significant Bit Register for DAC0 and DAC1 Control.
bits 7–0

DAC High Byte (DACH)

	7	6	5	4	3	2	1	0	Reset Value
SFR B6 _H									00 _H

DACH7–0 Most Significant Byte Register for DAC0 and DAC1 Control.
bits 7–0

DAC Select Register (DACSEL)

	7	6	5	4	3	2	1	0	Reset Value
SFR B7 _H	DSEL7	DSEL6	DSEL5	DSEL4	DSEL3	DSEL2	DSEL1	DSEL0	00 _H

DSEL7–0 DAC and DAC Control Select. The DACSEL register selects which DAC output register or which DAC control register is accessed by bits 7–0 the DACL and DACH registers.

DACSEL (B7 _H)	DACH (B6 _H)	DACL (B5 _H)	RESET VALUE
00 _H	DAC0 (high)	DAC0 (low)	0000 _H
01 _H	DAC1 (high)	DAC1 (low)	0000 _H
02 _H	—	—	0000 _H
03 _H	—	—	0000 _H
04 _H	DACCON1	DACCON0	6363 _H
05 _H	—	—	0303 _H
06 _H	—	LOADCON	--00 _H
07 _H	—	—	—

DAC0 Control Register (DACCON0)

DACSEL = 04 _H	7	6	5	4	3	2	1	0	Reset Value
SFR B5 _H	COR0	EOD0	IDAC0DIS	IDAC0SINK	0	SELREF0	DOM0_1	DOM0_0	63 _H

COR0 Current Over Range on DAC0

bit 7 Write: 0 = Clear to release from high-impedance state back to normal mode unless an over-range condition exists.
1 = NOP

Read: 0 = No current over range for DAC0.

0 = NOP

1 = IDAC overcurrent for 3 consecutive ticks on ms clock USEC (EOD0 = 1) or Current Over Range raw signal (EOD0 = 0).

EOD0 Enable Over-Current Detection

bit 6 0 = Disable over-current detection.

1 = Enable over-current detection (default). After 3 consecutive ticks on MSEC clock of overcurrent, the DAC is disabled; however, the register values are preserved. Writing to COR0 releases the high-impedance state.

IDAC0DIS IDAC0 Disable (for DOM0 = 00)

bit 5 0 = IDAC on mode for DAC0.

1 = IDAC off mode for DAC0 (default).

IDAC0SINK ENABLE CURRENT SINK

bit 4 0 = DAC0 is sourcing current.

1 = DAC0 is sinking current using external device.

Not Used

bit 3

SELREF0 Select the Reference Voltage for DAC0 Voltage Reference.

bit 2 0 = DAC0 $V_{REF} = AV_{DD}$ (default).

1 = DAC0 $V_{REF} =$ voltage on REFIN+/REFOUT pin.

DOM0_1–0 DAC Output Mode DAC0.

bits 1–0

DOM0	OUTPUT MODE for DAC0
00	Normal VDAC output, IDAC controlled by IDAC0DIS bit.
01	Power-Down mode—VDAC output off 1k Ω to AGND, IDAC off.
10	Power-Down mode—VDAC output off 100k Ω to AGND, IDAC off.
11	Power-Down mode—VDAC output off high impedance, IDAC off (default).

DAC1 Control Register (DACCON1)

DACSEL = 04H	7	6	5	4	3	2	1	0	Reset Value
SFR B6H	COR1	EOD1	IDAC1DIS	IDAC1SINK	0	SELREF1	DOM1_1	DOM1_0	63H

COR1 Current Over Range on DAC1

bit 7 Write: 0 = Clear to release from high-impedance state back to normal mode unless an over-range condition exists.
1 = NOP
Read: 0 = No current over range for DAC1.
0 = NOP
1 = IDAC overcurrent for 3 consecutive ticks on ms clock USEC (EOD1 = 1) or Current Over Range raw signal (EOD1 = 0).

EOD1 Enable Over-Current Detection

bit 6 0 = Disable over-current detection.
1 = Enable over-current detection (default). After 3 consecutive ticks on MSEC clock of overcurrent, the DAC is disabled; however, the register values are preserved. Writing to COR1 releases the high-impedance state.

IDAC1DIS IDAC1 Disable (for DOM1 = 00)

bit 5 0 = IDAC on mode for DAC1.
1 = IDAC off mode for DAC1 (default).

IDAC1SINK ENABLE CURRENT SINK

bit 4 0 = DAC1 is sourcing current.
1 = DAC1 is sinking current using external device.

Not Used

bit 3

SELREF1 Select the Reference Voltage for DAC1 Voltage Reference.

bit 2 0 = DAC1 $V_{REF} = AV_{DD}$ (default).
1 = DAC1 $V_{REF} =$ voltage on V_{REF} IN pins.

DOM1_1-0 DAC Output Mode DAC1.

bits 1-0

DOM1	OUTPUT MODE for DAC1
00	Normal VDAC output, IDAC controlled by IDAC1DIS bit.
01	Power-Down mode—VDAC output off 1k Ω to AGND, IDAC off.
10	Power-Down mode—VDAC output off 100k Ω to AGND, IDAC off.
11	Power-Down mode—VDAC output off high impedance, IDAC off (default).

DAC Load Control Register (LOADCON)

DACSEL = 06H	7	6	5	4	3	2	1	0	Reset Value
SFR B5H					D1LOAD1	D1LOAD0	D0LOAD1	D0LOAD0	00H

D3LOAD1-0 DAC Load Options.

bit 7-6

DxLOAD	OUTPUT MODE for
00	Direct load: write to DACxL directly loads the DAC buffer and the DAC output (write to DACxH does not load DAC output).
01	Delay load: the values last written to DACxL/DACxH will be transferred to the DAC output on the next MSEC timer tick.
10	Delay load: the values last written to DACxL/DACxH will be transferred to the DAC output on the next HMSEC timer tick.
11	Sync load: the values contained in the DACxL/DACxH registers will be transferred to the DAC output immediately after 11B is written to this register.

D2LOAD1-0

bit 5-4

D1LOAD1-0

bit 3-2

D0LOAD1-0

bit 1-0

Interrupt Priority (IP)

	7	6	5	4	3	2	1	0	Reset Value
SFR B8 _H	1	PS1	PT2	PS0	PT1	PX1	PT0	PX0	80 _H

PS1 **Serial Port 1 Interrupt.** This bit controls the priority of the serial Port 1 interrupt.
bit 6 0 = Serial Port 1 priority is determined by the natural priority order.
1 = Serial Port 1 is a high priority interrupt.

PT2 **Timer 2 Interrupt.** This bit controls the priority of the Timer 2 interrupt.
bit 5 0 = Timer 2 priority is determined by the natural priority order.
1 = Timer 2 priority is a high priority interrupt.

PS0 **Serial Port 0 Interrupt.** This bit controls the priority of the serial Port 0 interrupt.
bit 4 0 = Serial Port 0 priority is determined by the natural priority order.
1 = Serial Port 0 is a high priority interrupt.

PT1 **Timer 1 Interrupt.** This bit controls the priority of the Timer 1 interrupt.
bit 3 0 = Timer 1 priority is determined by the natural priority order.
1 = Timer 1 priority is a high priority interrupt.

PX1 **External Interrupt 1.** This bit controls the priority of external interrupt 1.
bit 2 0 = External interrupt 1 priority is determined by the natural priority order.
1 = External interrupt 1 is a high priority interrupt.

PT0 **Timer 0 Interrupt.** This bit controls the priority of the Timer 0 interrupt.
bit 1 0 = Timer 0 priority is determined by the natural priority order.
1 = Timer 0 priority is a high priority interrupt.

PX0 **External Interrupt 0.** This bit controls the priority of external interrupt 0.
bit 0 0 = External interrupt 0 priority is determined by the natural priority order.
1 = External interrupt 0 is a high priority interrupt.

Serial Port 1 Control (SCON1)

	7	6	5	4	3	2	1	0	Reset Value
SFR C0 _H	SM0_1	SM1_1	SM2_1	REN_1	TB8_1	RB8_1	TI_1	RI_1	00 _H

SM0–2 **Serial Port 1 Mode.** These bits control the mode of serial Port 1. Modes 1, 2, and 3 have 1 start and 1 stop bit in addition to the 8 or 9 data bits.

MODE	SM0	SM1	SM2	FUNCTION	LENGTH	PERIOD
0	0	0	0	Synchronous	8 bits	12 p _{CLK} ⁽¹⁾
0	0	0	1	Synchronous	8 bits	4 p _{CLK} ⁽¹⁾
1 ⁽²⁾	0	1	0	Asynchronous	10 bits	Timer 1 Baud Rate Equation
1 ⁽²⁾	0	1	1	Valid Stop Required ⁽³⁾	10 bits	Timer 1 Baud Rate Equation
2	1	0	0	Asynchronous	11 bits	64 p _{CLK} ⁽¹⁾ (SMOD = 0) 32 p _{CLK} ⁽¹⁾ (SMOD = 1)
2	1	0	1	Asynchronous with Multiprocessor Communication ⁽⁴⁾	11 bits	64 p _{CLK} ⁽¹⁾ (SMOD = 0) 32 p _{CLK} ⁽¹⁾ (SMOD = 1)
3 ⁽²⁾	1	1	0	Asynchronous	11 bits	Timer 1 Baud Rate Equation
3 ⁽²⁾	1	1	1	Asynchronous with Multiprocessor Communication ⁽⁴⁾	11 bits	Timer 1 Baud Rate Equation

(1) p_{CLK} will be equal to t_{CLK}, except that p_{CLK} will stop for IDLE.
(2) For modes 1 and 3, the selection of Timer 1 for baud rate is specified via the T2CON (C8_H) register.
(3) RI_0 will only be activated when a valid STOP is received.
(4) RI_0 will not be activated if bit 9 = 0.

REN_1 **Receive Enable.** This bit enables/disables the serial Port 1 received shift register.
bit 4 0 = Serial Port 1 reception disabled.
1 = Serial Port 1 received enabled (modes 1, 2, and 3). Initiate synchronous reception (mode 0).

TB8_1 **9th Transmission Bit State.** This bit defines the state of the 9th transmission bit in serial Port 1 modes 2 and 3.
bit 3

RB8_1 **9th Received Bit State.** This bit identifies the state of the 9th reception bit of received data in serial Port 1 modes 2 and 3. In serial port mode 1, when SM2_1 = 0, RB8_1 is the state of the stop bit. RB8_1 is not used in mode 0.
bit 2

TI_1 **Transmitter Interrupt Flag.** This bit indicates that data in the serial Port 1 buffer has been completely shifted out. In serial port mode 0, TI_1 is set at the end of the 8th data bit. In all other modes, this bit is set at the end of the last data bit. This bit must be cleared by software to transmit the next byte.
bit 1

RI_1 **Receiver Interrupt Flag.** This bit indicates that a byte of data has been received in the serial Port 1 buffer. In serial port mode 0, RI_1 is set at the end of the 8th bit. In serial port mode 1, RI_1 is set after the last sample of the incoming stop bit subject to the state of SM2_1. In modes 2 and 3, RI_1 is set after the last sample of RB8_1. This bit must be cleared by software to receive the next byte.
bit 0

Serial Data Buffer 1 (SBUF1)

	7	6	5	4	3	2	1	0	Reset Value
SFR C1 _H									00 _H

SBUF1.7–0 **Serial Data Buffer 1.** Data for serial Port 1 is read from or written to this location. The serial transmit and receive buffers are separate registers, but both are addressed at this location.
bits 7–0

Enable Wake Up (EWU) Waking Up from IDLE Mode

	7	6	5	4	3	2	1	0	Reset Value
SFR C6 _H	—	—	—	—	—	EWUWDT	EWUEX1	EWUEX0	00 _H

Auxiliary interrupts will wake up from IDLE. They are enabled with EAI (EICON.5).

EWUWDT **Enable Wake Up Watchdog Timer.** Wake using watchdog timer interrupt.
bit 2 0 = Don't wake up on watchdog timer interrupt.
1 = Wake up on watchdog timer interrupt.

EWUEX1 **Enable Wake Up External 1.** Wake using external interrupt source 1.
bit 1 0 = Don't wake up on external interrupt source 1.
1 = Wake up on external interrupt source 1.

EWUEX0 **Enable Wake Up External 0.** Wake using external interrupt source 0.
bit 0 0 = Don't wake up on external interrupt source 0.
1 = Wake up on external interrupt source 0.

System Clock Divider Register (SYSCLK)

	7	6	5	4	3	2	1	0	Reset Value
SFR C7 _H	0	0	DIVMOD1	DIVMOD0	0	DIV2	DIV1	DIV0	00 _H

DIVMOD1–0
bits 5–4

Clock Divide Mode
Write:

DIVMOD	DIVIDE MODE
00	Normal mode (default, no divide).
01	Immediate mode: start divide immediately, return to Normal mode on IDLE wakeup condition or directly writing to SFR.
10	Delay mode: same as Immediate mode, except that the mode changes with the millisecond interrupt (MSINT). If MSINT is enable, the divide will start on the next MSINT and return to normal mode on the following MSINT. If MSINT is not enable, the divide will start on the next MSINT condition (even if masked) but will not leave the divide mode until the MSINT counter overflows, which follows a wakeup condition.
11	Medium mode. Same as immediate mode but cannot return to Normal mode on IDLE wakeup condition. Must write directly to SFR.

Read:

DIVMOD	DIVISION MODE STATUS
00	No divide
01	Divider is in Immediate mode
10	Divider is in Delay mode
11	Medium mode

DIV2–0 **Divide Mode**

bit 2–0

DIV	DIVISOR
000	Divide by 2 (default)
001	Divide by 4
010	Divide by 8
011	Divide by 16
100	Divide by 32
101	Divide by 1024
110	Divide by 2048
111	Divide by 4096

$$f_{\text{CLK}} = \frac{f_{\text{OSC}}}{\text{Divisor}}$$

Timer 2 Control (T2CON)

	7	6	5	4	3	2	1	0	Reset Value
SFR C8 _H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	00 _H

TF2 bit 7 **Timer 2 Overflow Flag.** This flag will be set when Timer 2 overflows from FFFF_H. It must be cleared by software. TF2 will only be set if RCLK and TCLK are both cleared to 0. Writing a 1 to TF2 forces a Timer 2 interrupt if enabled.

EXF2 bit 6 **Timer 2 External Flag.** A negative transition on the T2EX pin (P1.1) will cause this flag to be set based on the EXEN2 (T2CON.3) bit. If set by a negative transition, this flag must be cleared to 0 by software. Setting this bit in software will force a timer interrupt if enabled.

RCLK bit 5 **Receive Clock Flag.** This bit determines the serial Port 0 timebase when receiving data in serial modes 1 or 3.
0 = Timer 1 overflow is used to determine receiver baud rate for USART0.
1 = Timer 2 overflow is used to determine receiver baud rate for USART0.
Setting this bit will force Timer 2 into baud rate generation mode. The timer will operate from a divide by 2 of the external clock.

TCLK bit 4 **Transmit Clock Flag.** This bit determines the serial Port 0 timebase when transmitting data in serial modes 1 or 3.
0 = Timer 1 overflow is used to determine transmitter baud rate for USART0.
1 = Timer 2 overflow is used to determine transmitter baud rate for USART0.
Setting this bit will force Timer 2 into baud rate generation mode. The timer will operate from a divide by 2 of the external clock.

EXEN2 bit 3 **Timer 2 External Enable.** This bit enables the capture/reload function on the T2EX pin if Timer 2 is not generating baud rates for the serial port.
0 = Timer 2 will ignore all external events at T2EX.
1 = Timer 2 will capture or reload a value if a negative transition is detected on the T2EX pin.

TR2 bit 2 **Timer 2 Run Control.** This bit enables/disables the operation of Timer 2. Halting this timer will preserve the current count in TH2, TL2.
0 = Timer 2 is halted.
1 = Timer 2 is enabled.

C/T2 bit 1 **Counter/Timer Select.** This bit determines whether Timer 2 will function as a timer or counter. Independent of this bit, Timer 2 runs at 2 clocks per tick when used in baud rate generator mode.
0 = Timer 2 functions as a timer. The speed of Timer 2 is determined by the T2M bit (CKCON.5).
1 = Timer 2 will count negative transitions on the T2 pin (P1.0).

CP/RL2 bit 0 **Capture/Reload Select.** This bit determines whether the capture or reload function will be used for Timer 2. If either RCLK or TCLK is set, this bit will not function and the timer will function in an auto-reload mode following each overflow.
0 = Auto-reloads will occur when Timer 2 overflows or a falling edge is detected on T2EX if EXEN2 = 1.
1 = Timer 2 captures will occur when a falling edge is detected on T2EX if EXEN2 = 1.

Timer 2 Capture LSB (RCAP2L)

	7	6	5	4	3	2	1	0	Reset Value
SFR CA _H									00 _H

RCAP2L bits 7–0 **Timer 2 Capture LSB.** This register is used to capture the TL2 value when Timer 2 is configured in capture mode. RCAP2L is also used as the LSB of a 16-bit reload value when Timer 2 is configured in auto-reload mode.

Timer 2 Capture MSB (RCAP2H)

	7	6	5	4	3	2	1	0	Reset Value
SFR CB _H									00 _H

RCAP2H bits 7–0 **Timer 2 Capture MSB.** This register is used to capture the TH2 value when Timer 2 is configured in capture mode. RCAP2H is also used as the MSB of a 16-bit reload value when Timer 2 is configured in auto-reload mode.

Timer 2 LSB (TL2)

	7	6	5	4	3	2	1	0	Reset Value
SFR CC _H									00 _H

TL2 bits 7–0 **Timer 2 LSB.** This register contains the least significant byte of Timer 2.

Timer 2 MSB (TH2)

	7	6	5	4	3	2	1	0	Reset Value
SFR CD _H									00 _H

TH2 **Timer 2 MSB.** This register contains the most significant byte of Timer 2.
bits 7–0

Program Status Word (PSW)

	7	6	5	4	3	2	1	0	Reset Value
SFR D0 _H	CY	AC	F0	RS1	RS0	OV	F1	P	00 _H

CY **Carry Flag.** This bit is set when the last arithmetic operation resulted in a carry (during addition) or a borrow (during subtraction).
bit 7 Otherwise it is cleared to 0 by all arithmetic operations.

AC **Auxiliary Carry Flag.** This bit is set to 1 if the last arithmetic operation resulted in a carry into (during addition), or a borrow (during subtraction) from the high order nibble. Otherwise it is cleared to 0 by all arithmetic operations.
bit 6

F0 **User Flag 0.** This is a bit-addressable, general-purpose flag for software control.
bit 5

RS1, RS0 **Register Bank Select 1–0.** These bits select which register bank is addressed during register accesses.
bits 4–3

RS1	RS0	REGISTER BANK	ADDRESS
0	0	0	00 _H – 07 _H
0	1	1	08 _H – 0F _H
1	0	2	10 _H – 17 _H
1	1	3	18 _H – 1F _H

OV **Overflow Flag.** This bit is set to 1 if the last arithmetic operation resulted in a carry (addition), borrow (subtraction), or overflow (multiply or divide). Otherwise it is cleared to 0 by all arithmetic operations.
bit 2

F1 **User Flag 1.** This is a bit-addressable, general-purpose flag for software control.
bit 1

P **Parity Flag.** This bit is set to 1 if the modulo-2 sum of the 8 bits of the accumulator is 1 (odd parity); and cleared to 0 on even parity.
bit 0

ADC Offset Calibration Register Low Byte (OCL)

	7	6	5	4	3	2	1	0	Reset Value
SFR D1 _H									00 _H

OCL **ADC Offset Calibration Register Low Byte.** This is the low byte of the 24-bit word that contains the ADC offset calibration. A value which is written to this location will set the ADC offset calibration value.
bits 7–0

ADC Offset Calibration Register Middle Byte (OCM)

	7	6	5	4	3	2	1	0	Reset Value
SFR D2 _H									00 _H

OCM **ADC Offset Calibration Register Middle Byte.** This is the middle byte of the 24-bit word that contains the ADC offset calibration. A value which is written to this location will set the ADC offset calibration value.
bits 7–0

ADC Offset Calibration Register High Byte (OCH)

	7	6	5	4	3	2	1	0	Reset Value
SFR D3 _H									00 _H

OCH **ADC Offset Calibration Register High Byte.** This is the high byte of the 24-bit word that contains the ADC offset calibration. A value which is written to this location will set the ADC offset calibration value.
bits 7–0

ADC Gain Calibration Register Low Byte (GCL)

	7	6	5	4	3	2	1	0	Reset Value
SFR D4 _H									5A _H

GCL **ADC Gain Calibration Register Low Byte.** This is the low byte of the 24-bit word that contains the ADC gain calibration. A value which bits 7–0 is written to this location will set the ADC gain calibration value.

ADC Gain Calibration Register Middle Byte (GCM)

	7	6	5	4	3	2	1	0	Reset Value
SFR D5 _H									EC _H

GCM **ADC Gain Calibration Register Middle Byte.** This is the middle byte of the 24-bit word that contains the ADC gain calibration. bits 7–0 A value which is written to this location will set the ADC gain calibration value.

ADC Gain Calibration Register High Byte (GCH)

	7	6	5	4	3	2	1	0	Reset Value
SFR D6 _H									5F _H

GCH **ADC Gain Calibration Register High Byte.** This is the high byte of the 24-bit word that contains the ADC gain calibration. bits 7–0 A value which is written to this location will set the ADC gain calibration value.

ADC Input Multiplexer Register (ADMUX)

	7	6	5	4	3	2	1	0	Reset Value
SFR D7 _H	INP3	INP2	INP1	INP0	INN3	INN2	INN1	INN0	01 _H

INP3–0 **Input Multiplexer Positive Input.** This selects the positive signal input.
bits 7–4

INP3	INP2	INP1	INP0	POSITIVE INPUT
0	0	0	0	AIN0 (default)
0	0	0	1	AIN1
0	0	1	0	AIN2
0	0	1	1	AIN3
0	1	0	0	AIN4
0	1	0	1	AIN5
0	1	1	0	AIN6
0	1	1	1	AIN7
1	0	0	0	AINCOM
1	1	1	1	Temperature Sensor (requires ADMUX = FF _H)

INN3–0 **Input Multiplexer Negative Input.** This selects the negative signal input.
bits 3–0

INN3	INN2	INN1	INN0	NEGATIVE INPUT
0	0	0	0	AIN0
0	0	0	1	AIN1 (default)
0	0	1	0	AIN2
0	0	1	1	AIN3
0	1	0	0	AIN4
0	1	0	1	AIN5
0	1	1	0	AIN6
0	1	1	1	AIN7
1	0	0	0	AINCOM
1	1	1	1	Temperature Sensor (requires ADMUX = FF _H)

Enable Interrupt Control (EICON)

	7	6	5	4	3	2	1	0	Reset Value
SFR D8 _H	SMOD1	1	EAI	AI	WDTI	0	0	0	40 _H

SMOD1 **Serial Port 1 Mode.** When this bit is set the serial baud rate for Port 1 will be doubled.
bit 7 0 = Standard baud rate for Port 1 (default).
1 = Double baud rate for Port 1.

EAI **Enable Auxiliary Interrupt.** The Auxiliary Interrupt accesses nine different interrupts which are masked and identified by SFR registers PAI (SFR A5_H), AIE (SFR A6_H), and AISTAT (SFR A7_H).
bit 5 0 = Auxiliary Interrupt disabled (default).
1 = Auxiliary Interrupt enabled.

AI **Auxiliary Interrupt Flag.** AI must be cleared by software before exiting the interrupt service routine, after the source of the interrupt is cleared. Otherwise, the interrupt occurs again. Setting AI in software generates an Auxiliary Interrupt, if enabled.
bit 4 0 = No Auxiliary Interrupt detected (default).
1 = Auxiliary Interrupt detected.

WDTI **Watchdog Timer Interrupt Flag.** WDTI must be cleared by software before exiting the interrupt service routine.
bit 3 Otherwise, the interrupt occurs again. Setting WDTI in software generates a watchdog time interrupt, if enabled. The Watchdog timer can generate an interrupt or reset. The interrupt is available only if the reset action is disabled in HCR0.
0 = No Watchdog Timer Interrupt Detected (default).
1 = Watchdog Timer Interrupt Detected.

ADC Results Register Low Byte (ADRESL)

	7	6	5	4	3	2	1	0	Reset Value
SFR D9 _H									00 _H

ADRESL **The ADC Results Low Byte.** This is the low byte of the 24-bit word that contains the ADC results.
bits 7–0 Reading from this register clears the ADC interrupt; however, AI in EICON (SFR D8) must also be cleared.

ADC Results Register Middle Byte (ADRESM)

	7	6	5	4	3	2	1	0	Reset Value
SFR DA _H									00 _H

ADRESM **The ADC Results Middle Byte.** This is the middle byte of the 24-bit word that contains the A/D conversion results.
bits 7–0

ADC Results Register High Byte (ADRESH)

	7	6	5	4	3	2	1	0	Reset Value
SFR DB _H									00 _H

ADRESH **The ADC Results High Byte.** This is the high byte of the 24-bit word that contains the A/D conversion results.
bits 7–0

ADC Control Register 0 (ADCON0)

	7	6	5	4	3	2	1	0	Reset Value
SFR DC _H	REFCLK	BOD	EVREF	VREFH	EBUF	PGA2	PGA1	PGA0	30 _H

REFCLK **Reference Clock.** The reference is specified with a 250kHz clock. The REFCLK should be selected by choosing the appropriate source so that it does not exceed 250kHz.

$$0 = \frac{t_{\text{CLK}}}{(\text{ACLK} + 1) * 4}$$

$$1 = \frac{\text{USEC}}{4}$$

BOD **Burnout Detect.** When enabled this connects a positive current source to the positive channel and a negative current source to the negative channel. If the channel is open circuit then the ADC results will be full-scale. Used with Buffer ON.
bit 6 0 = Burnout Current Sources Off (default).
1 = Burnout Current Sources On.

EVREF **Enable Internal Voltage Reference.** If the internal voltage reference is not used, it should be turned off to save power and reduce noise.
bit 5 0 = Internal Voltage Reference Off.
1 = Internal Voltage Reference On (default). REFIN– should be connected to AGND in this mode. REFIN+ should have a 0.1μF capacitor.

VREFH Voltage Reference High Select. The internal voltage reference can be selected to be 2.5V or 1.25V.
bit 4 0 = REFOUT/REF IN+ is 1.25V.
1 = REFOUT/REF IN+ is 2.5V (default).

EBUF Enable Buffer. Enable the input buffer to provide higher input impedance but limits the input voltage range and dissipates more power.
bit 3 0 = Buffer disabled (default).
1 = Buffer enabled.

PGA2–0 Programmable Gain Amplifier. Sets the gain for the PGA from 1 to 128.
bits 2–0

PGA2	PGA1	PGA0	GAIN
0	0	0	1 (default)
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

ADC Control Register 1 (ADCON1)

	7	6	5	4	3	2	1	0	Reset Value
SFR DD _H	OF_UF	POL	SM1	SM0	—	CAL2	CAL1	CAL0	0000 0000 _B

OF_UF Overflow/Underflow. If this bit is set, the data in the summation register is invalid. Either an overflow or underflow occurred. The bit is cleared by writing a 0 to it.
bit 7

POL Polarity. Polarity of the ADC result and Summation register.
bit 6 0 = Bipolar.
1 = Unipolar. The LSB size is 1/2 the size of bipolar (twice the resolution).

POL	ANALOG INPUT	DIGITAL OUTPUT
0	+FSR	0x7FFFFFFF
	ZERO	0x000000
	–FSR	0x800000
1	+FSR	0xFFFFFFFF
	ZERO	0x000000
	–FSR	0x000000

SM1–0 Settling Mode. Selects the type of filter or auto select which defines the digital filter settling characteristics.
bits 5–4

SM1	SM0	SETTLING MODE
0	0	Auto
0	1	Fast Settling Filter
1	0	Sinc ² Filter
1	1	Sinc ³ Filter

CAL2–0 Calibration Mode Control Bits.
bits 2–0 Writing to these bits initiates the ADC calibration.

CAL2	CAL1	CAL0	CALIBRATION MODE
0	0	0	No Calibration (default)
0	0	1	Self-Calibration, Offset and Gain
0	1	0	Self-Calibration, Offset only
0	1	1	Self-Calibration, Gain only
1	0	0	System Calibration, Offset only
1	0	1	System Calibration, Gain only
1	1	0	Reserved
1	1	1	Reserved

Read Value—000_B.

ADC Control Register 2 (ADCON2)

	7	6	5	4	3	2	1	0	Reset Value
SFR DE _H	DR7	DR6	DR5	DR4	DR3	DR2	DR1	DR0	1B _H

DR7–0 Decimation Ratio LSB.
bits 7–0

ADC Control Register 3 (ADCON3)

	7	6	5	4	3	2	1	0	Reset Value
SFR DF _H	—	—	—	—	—	DR10	DR9	DR8	06 _H

DR10–8 Decimation Ratio Most Significant 3 Bits. The ADC output data rate = (ACLK + 1)/64/Decimation Ratio.
bits 2–0

Accumulator (A or ACC)

	7	6	5	4	3	2	1	0	Reset Value
SFR E0 _H	ACC.7	ACC.6	ACC.5	ACC.4	ACC.3	ACC.2	ACC.1	ACC.0	00 _H

ACC.7–0 Accumulator. This register serves as the accumulator for arithmetic and logic operations.
bits 7–0

Summation/Shifter Control (SSCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR E1 _H	SSCON1	SSCON0	SCNT2	SCNT1	SCNT0	SHF2	SHF1	SHF0	00 _H

The Summation register is powered down when the ADC is powered down. If all zeroes are written to this register the 32-bit SUMR3–0 registers will be cleared. The Summation registers will do sign extend if Bipolar Mode is selected in ADCON1.

SSCON1–0 Summation/Shift Count.
bits 7–6

SSCON1	SSCON0	SCNT2	SCNT1	SCNT0	SHF2	SHF1	SHF0	DESCRIPTION
0	0	0	0	0	0	0	0	Clear Summation Register
0	0	0	1	0	0	0	0	CPU Summation on Write to SUMR0 (sum count/shift ignored)
0	0	1	0	0	0	0	0	CPU Subtraction on Write to SUMR0 (sum count/shift ignored)
1	0	x	x	x	Note (1)	Note (1)	Note (1)	CPU Shift only
0	1	Note (1)	Note (1)	Note (1)	x	x	x	ADC Summation only
1	1	Note (1)	Note (1)	Note (1)	Note (1)	Note (1)	Note (1)	ADC Summation completes then shift completes

(1): Refer to register bit definition.

SCNT2–0 Summation Count. When the summation is complete an interrupt will be generated unless masked. Reading the SUMR0 register clears bits 5–3 the interrupt.

SCNT2	SCNT1	SCNT0	SUMMATION COUNT
0	0	0	2
0	0	1	4
0	1	0	8
0	1	1	16
1	0	0	32
1	0	1	64
1	1	0	128
1	1	1	256

SHF2–0 Shift Count.

bits 2–0

SHF2	SHF1	SHF0	SHIFT	DIVIDE
0	0	0	1	2
0	0	1	2	4
0	1	0	3	8
0	1	1	4	16
1	0	0	5	32
1	0	1	6	64
1	1	0	7	128
1	1	1	8	256

Summation Register 0 (SUMR0)

	7	6	5	4	3	2	1	0	Reset Value
SFR E2 _H									00 _H

SUMR0 Summation Register 0. This is the least significant byte of the 32-bit summation register or bits 0 to 7.

bits 7–0 Write: Will cause values in SUMR3–0 to be added to the summation register.

Read: Will clear the Summation Count Interrupt; however, AI in EICON (SFR D8) must also be cleared.

Summation Register 1 (SUMR1)

	7	6	5	4	3	2	1	0	Reset Value
SFR E3 _H									00 _H

SUMR1 Summation Register 1. This is the most significant byte of the lowest 16 bits of the summation register or bits 8–15.

bits 7–0

Summation Register 2 (SUMR2)

	7	6	5	4	3	2	1	0	Reset Value
SFR E4 _H									00 _H

SUMR2 Summation Register 2. This is the most significant byte of the lowest 24 bits of the summation register or bits 16–23.

bits 7–0

Summation Register 3 (SUMR3)

	7	6	5	4	3	2	1	0	Reset Value
SFR E5 _H									00 _H

SUMR3 Summation Register 3. This is the most significant byte of the 32-bit summation register or bits 24–31.

bits 7–0

Offset DAC Register (ODAC)

	7	6	5	4	3	2	1	0	Reset Value
SFR E6 _H									00 _H

ODAC Offset DAC Register. This register will shift the input by up to half of the ADC full-scale input range. The Offset DAC value is summed into the ADC prior to conversion. Writing 00_H or 80_H to ODAC turns off the Offset DAC.

$$\text{Offset} = \frac{-V_{\text{REF}}}{2 \cdot \text{PGA}} \cdot \left(\frac{\text{ODAC [6 : 0]}}{127} \right) \cdot (-1)^{\text{bit7}}$$

ODAC CODES AND VOLTAGES

ODAC CODE	ODAC VOLTAGE (UNIPOLAR/BIPOLAR MODE)
1111 1111	+0.5 * V _{REF}
1000 0000	0V
0000 0000	0V
0111 1111	-0.5 * V _{REF}

NOTE: ODAC cannot be used to offset the input so that the buffer can be used for AGND signals.

Low Voltage Detect Control (LVDCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR E7 _H	ALVDIS	ALVD2	ALVD1	ALVD0	DLVDIS	DLVD2	DLVD1	DLVD0	00 _H

ALVDIS Analog Low Voltage Detect Disable.

bit 7 0 = Enable Detection of Low Analog Supply Voltage.
 1 = Disable Detection of Low Analog Supply Voltage.

ALVD2–0 Analog Voltage Detection Level.

bits 6–4

ALVD2	ALVD1	ALVD0	VOLTAGE LEVEL
0	0	0	AV _{DD} 2.7V (default)
0	0	1	AV _{DD} 3.0V
0	1	0	AV _{DD} 3.3V
0	1	1	AV _{DD} 4.0V
1	0	0	AV _{DD} 4.2V
1	0	1	AV _{DD} 4.5V
1	1	0	AV _{DD} 4.7V
1	1	1	External Voltage AIN7 compared to 1.2V

DLVDIS Digital Low Voltage Detect Disable.

bit 3 0 = Enable Detection of Low Digital Supply Voltage.
 1 = Disable Detection of Low Digital Supply Voltage.

DLVD2–0 Digital Voltage Detection Level.

bits 2–0

DLVD2	DLVD1	DLVD0	VOLTAGE LEVEL
0	0	0	DV _{DD} 2.7V (default)
0	0	1	DV _{DD} 3.0V
0	1	0	DV _{DD} 3.3V
0	1	1	DV _{DD} 4.0V
1	0	0	DV _{DD} 4.2V
1	0	1	DV _{DD} 4.5V
1	1	0	DV _{DD} 4.7V
1	1	1	External Voltage AIN6 compared to 1.2V

Extended Interrupt Enable (EIE)

	7	6	5	4	3	2	1	0	Reset Value
SFR E8 _H	1	1	1	EWDI	EX5	EX4	EX3	EX2	E0 _H

EWDI Enable Watchdog Interrupt. This bit enables/disables the watchdog interrupt. The Watchdog timer is enabled by (SFR FF_H) and PDCON (SFR F1_H) registers.

bit 4 0 = Disable the Watchdog Interrupt
 1 = Enable Interrupt Request Generated by the Watchdog Timer

EX5 External Interrupt 5 Enable. This bit enables/disables external interrupt 5.

bit 3 0 = Disable External Interrupt 5
 1 = Enable External Interrupt 5

EX4 External Interrupt 4 Enable. This bit enables/disables external interrupt 4.

bit 2 0 = Disable External Interrupt 4
 1 = Enable External Interrupt 4

EX3 External Interrupt 3 Enable. This bit enables/disables external interrupt 3.

bit 1 0 = Disable External Interrupt 3
 1 = Enable External Interrupt 3

EX2 External Interrupt 2 Enable. This bit enables/disables external interrupt 2.

bit 0 0 = Disable External Interrupt 2
 1 = Enable External Interrupt 2

Hardware Product Code Register 0 (HWPC0)

	7	6	5	4	3	2	1	0	Reset Value
SFR E9 _H	0	0	0	0	0	1	MEMORY SIZE		0000_01xx _B ⁽¹⁾

NOTE: (1) Applies to MSC1213 only.
MSC1214: 0000_00xx_B

HWPC0.7–0 **Hardware Product Code LSB.** Read-only.
bits 7–0

MEMORY SIZE	MODEL	FLASH MEMORY
0 0	MSC1213Y2/14Y2	4kB
0 0	MSC1213Y3/14Y3	8kB
1 0	MSC1213Y4/14Y4	16kB
1 1	MSC1213Y5/14Y5	32kB

Hardware Product Code Register 1 (HWPC1)

	7	6	5	4	3	2	1	0	Reset Value
SFR EA _H	0	0	0	1	1	0	0	0	18 _H

HWPC1.7–0 **Hardware Product Code MSB.** Read-only.
bits 7–0

Hardware Version Register (HDWVER)

	7	6	5	4	3	2	1	0	Reset Value
SFR EB _H	1	0	0	0	0	0	0	0	80 _H

Flash Memory Control (FMCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR EE _H	0	PGERA	0	FRCM	0	BUSY	1	0	02 _H

PGERA **Page Erase.** Available in both user and program modes.
bit 6 0 = Disable Page Erase Mode
 1 = Enable Page Erase Mode

FRCM **Frequency Control Mode.** The bypass is only used for slow clocks to save power.
bit 4 0 = Bypass (default)
 1 = Use Delay Line. Saves power (Recommended for all frequencies).

BUSY **Write/Erase BUSY Signal.**
bit 2 0 = Idle or Available
 1 = Busy

Flash Memory Timing Control Register (FTCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR EF _H	FER3	FER2	FER1	FER0	FWR3	FWR2	FWR1	FWR0	A5 _H

Refer to Flash Timing Characteristics

FER3–0 **Set Erase.** Flash Erase Time = (1 + FER) • (MSEC + 1) • t_{CLK}. This can be broken into multiple short erase times.
bits 7–4 10ms industrial temperature range.
 4ms commercial temperature range.

FWR3–0 **Set Flash Write Time** = (1 + FWR) • (USEC + 1) • 5 • t_{CLK}. Total writing time will be longer. (For more information, see Application Report
bits 3–0 SBAA087.) 30–40µs.

B Register (B)

	7	6	5	4	3	2	1	0	Reset Value
SFR F0 _H	B.7	B.6	B.5	B.4	B.3	B.2	B.1	B.0	00 _H

B.7–0 **B Register.** This register serves as a second accumulator for certain arithmetic operations.
bits 7–0

Power-Down Control Register (PDCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR F1 _H	0	PDDAC	PDI2C	PDPWM	PDADC	PDWDT	PDST	PDSPI	7F _H

Turning peripheral modules off puts the MSC1213/14 in the lowest power mode.

PDDAC DAC Module Control.

bit 6
 0 = DACs On
 1 = DACs Power Down

PDI2C I2C Control (MSC1213 only).

bit 5
 0 = I²C On (the state is undefined if PDSPI is also = 0)
 1 = I²C Power Down

PDPWM Pulse Width Module Control.

bit 4
 0 = PWM On
 1 = PWM Power Down

PDADC ADC Control.

bit 3
 0 = ADC On
 1 = ADC, V_{REF}, and Summation registers are powered down.

PDWDT Watchdog Timer Control.

bit 2
 0 = Watchdog Timer On
 1 = Watchdog Timer Power Down

PDST System Timer Control.

bit 1
 0 = System Timer On
 1 = System Timer Power Down

PDSPI SPI System Control.

bit 0
 0 = SPI System On (the state is undefined if PDI2C is also = 0)
 1 = SPI System Power Down

PSEN/ALE Select (PASEL)

	7	6	5	4	3	2	1	0	Reset Value
SFR F2 _H	0	0	PSEN2	PSEN1	PSEN0	0	ALE1	ALE0	00 _H

PSEN2–0 PSEN Mode Select.

bits 5–3

PSEN2	PSEN1	PSEN0	
0	0	x	PSEN
0	1	x	CLK
1	0	x	ADC MODCLK
1	1	0	LOW
1	1	1	HIGH

ALE1–0 ALE Mode Select.

bits 1–0

ALE1	ALE0	
0	x	ALE
1	0	LOW
1	1	HIGH

Analog Clock (ACLK)

	7	6	5	4	3	2	1	0	Reset Value
SFR F6 _H	0	FREQ6	FREQ5	FREQ4	FREQ3	FREQ2	FREQ1	FREQ0	03 _H

FREQ6–0 Clock Frequency Selection. This value + 1 divides the system clock to create the ACLK frequency.

$$\text{bit 6–0} \quad \text{ACLK frequency} = \frac{f_{\text{CLK}}}{\text{FREQ} + 1}$$

$$f_{\text{MOD}} = \frac{f_{\text{CLK}}}{(\text{ACLK} + 1) \cdot 64}$$

$$\text{Data Rate} = \frac{f_{\text{MOD}}}{\text{Decimation}}$$

System Reset Register (SRST)

	7	6	5	4	3	2	1	0	Reset Value
SFR F7 _H	0	0	0	0	0	0	0	RSTREQ	00 _H

RSTREQ Reset Request. Setting this bit to 1 and then clearing to 0 will generate a system reset.

bit 0

Extended Interrupt Priority (EIP)

	7	6	5	4	3	2	1	0	Reset Value
SFR F8 _H	1	1	1	PWDI	PX5	PX4	PX3	PX2	E0 _H

PWDI Watchdog Interrupt Priority. This bit controls the priority of the watchdog interrupt.

bit 4
0 = The watchdog interrupt is low priority.
1 = The watchdog interrupt is high priority.

PX5 External Interrupt 5 Priority. This bit controls the priority of external interrupt 5.

bit 3
0 = External interrupt 5 is low priority.
1 = External interrupt 5 is high priority.

PX4 External Interrupt 4 Priority. This bit controls the priority of external interrupt 4.

bit 2
0 = External interrupt 4 is low priority.
1 = External interrupt 4 is high priority.

PX3 External Interrupt 3 Priority. This bit controls the priority of external interrupt 3.

bit 1
0 = External interrupt 3 is low priority.
1 = External interrupt 3 is high priority.

PX2 External Interrupt 2 Priority. This bit controls the priority of external interrupt 2.

bit 0
0 = External interrupt 2 is low priority.
1 = External interrupt 2 is high priority.

Seconds Timer Interrupt (SECINT)

	7	6	5	4	3	2	1	0	Reset Value
SFR F9 _H	WRT	SECINT6	SECINT5	SECINT4	SECINT3	SECINT2	SECINT1	SECINT0	7F _H

This system clock is divided by the value of the 16-bit register MSEC:HSEC. Then that 1ms timer tick is divided by the register HMSEC which provides the 100ms signal used by this seconds timer. Therefore, this seconds timer can generate an interrupt which occurs from 100ms to 12.8 seconds. Reading this register will clear the Seconds Interrupt; however, AI in EICON (SFR D8) must also be cleared. This Interrupt can be monitored in the AIE register.

WRT Write Control. Determines whether to write the value immediately or wait until the current count is finished.

bit 7
Read = 0.
0 = Delay Write Operation. The SEC value is loaded when the current count expires.
1 = Write Immediately. The counter is loaded once the CPU completes the write operation.

SECINT6–0 Seconds Count. Normal operation would use 100ms as the clock interval.

bits 6–0
Seconds Interrupt = (1 + SEC) • (HMSEC + 1) • (MSEC + 1) • t_{CLK}.

Milliseconds Interrupt (MSINT)

	7	6	5	4	3	2	1	0	Reset Value
SFR FA _H	WRT	MSINT6	MSINT5	MSINT4	MSINT3	MSINT2	MSINT1	MSINT0	7F _H

The clock used for this timer is the 1ms clock which results from dividing the system clock by the values in registers MSECH:MSECL. Reading this register is necessary for clearing the interrupt; however, AI in EICON (SFR D8) must also be cleared.

WRT Write Control. Determines whether to write the value immediately or wait until the current count is finished. Read = 0.
bit 7 0 = Delay Write Operation. The MSINT value is loaded when the current count expires.
1 = Write Immediately. The MSINT counter is loaded once the CPU completes the write operation.

MSINT6–0 Milliseconds Count. Normal operation would use 1ms as the clock interval.

bits 6–0 MS Interrupt Interval = (1 + MSINT) • (MSEC + 1) • t_{CLK}

One Microsecond Register (USEC)

	7	6	5	4	3	2	1	0	Reset Value
SFR FB _H	0	0	FREQ5	FREQ4	FREQ3	FREQ2	FREQ1	FREQ0	03 _H

FREQ5–0 Clock Frequency – 1. This value + 1 divides the system clock to create a 1μs Clock.

bits 5–0 USEC = CLK/(FREQ + 1). This clock is used to set Flash write time. See FTCON (SFR EF_H).

One Millisecond Low Register (MSECL)

	7	6	5	4	3	2	1	0	Reset Value
SFR FC _H	MSECL7	MSECL6	MSECL5	MSECL4	MSECL3	MSECL2	MSECL1	MSECL0	9F _H

MSECL7–0 One Millisecond Low. This value in combination with the next register is used to create a 1ms clock.
bits 7–0 1ms = (MSECH • 256 + MSECL + 1) • t_{CLK}. This clock is used to set Flash erase time. See FTCON (SFR EF_H).

One Millisecond High Register (MSECH)

	7	6	5	4	3	2	1	0	Reset Value
SFR FD _H	MSECH7	MSECH6	MSECH5	MSECH4	MSECH3	MSECH2	MSECH1	MSECH0	0F _H

MSECH7–0 One Millisecond High. This value in combination with the previous register is used to create a 1ms clock.
bits 7–0 1ms = (MSECH • 256 + MSECL + 1) • t_{CLK}.

One Hundred Millisecond Register (HMSEC)

	7	6	5	4	3	2	1	0	Reset Value
SFR FE _H	WRT	HMSEC6	HMSEC5	HMSEC4	HMSEC3	HMSEC2	HMSEC1	HMSEC0	63 _H

WRT Write Control. Determines whether to write the value immediately or wait until the current count is finished. Read = 0.
bit 7 0 = Delay Write Operation. The MSINT value is loaded when the current count expires.
1 = Write Immediately. The MSINT counter is loaded once the CPU completes the write operation.

HMSEC6–0 One Hundred Millisecond. This clock divides the 1ms clock to create a 100ms clock.

bits 6–0 100ms = (MSECH • 256 + MSECL + 1) • (HMSEC + 1) • t_{CLK}.

Watchdog Timer Register (WDTCON)

	7	6	5	4	3	2	1	0	Reset Value
SFR FF _H	EWDT	DWDT	RWDT	WDCNT4	WDCNT3	WDCNT2	WDCNT1	WDCNT0	00 _H

EWDT Enable Watchdog (R/W).
bit 7 Write 1/Write 0 sequence sets the Watchdog Enable Counting bit.

DWDT Disable Watchdog (R/W).
bit 6 Write 1/Write 0 sequence clears the Watchdog Enable Counting bit.

RWDT Reset Watchdog (R/W).
bit 5 Write 1/Write 0 sequence restarts the Watchdog Counter.

WDCNT4–0 Watchdog Count (R/W).
bits 4–0 Watchdog expires in (WDCNT + 1) • HMSEC to (WDCNT + 2) • HMSEC, if the sequence is not asserted. There is an uncertainty of 1 count.

PACKAGING INFORMATION

ORDERABLE DEVICE	STATUS(1)	PACKAGE TYPE	PACKAGE DRAWING	PINS	PACKAGE QTY
MSC1213Y2PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1213Y2PAGT	PREVIEW	TQFP	PAG	64	250
MSC1213Y3PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1213Y3PAGT	PREVIEW	TQFP	PAG	64	250
MSC1213Y4PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1213Y4PAGT	PREVIEW	TQFP	PAG	64	250
MSC1213Y5PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1213Y5PAGT	PREVIEW	TQFP	PAG	64	250
MSC1214Y2PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1214Y2PAGT	PREVIEW	TQFP	PAG	64	250
MSC1214Y3PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1214Y3PAGT	PREVIEW	TQFP	PAG	64	250
MSC1214Y4PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1214Y4PAGT	PREVIEW	TQFP	PAG	64	250
MSC1214Y5PAGR	PREVIEW	TQFP	PAG	64	2000
MSC1214Y5PAGT	PREVIEW	TQFP	PAG	64	250

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

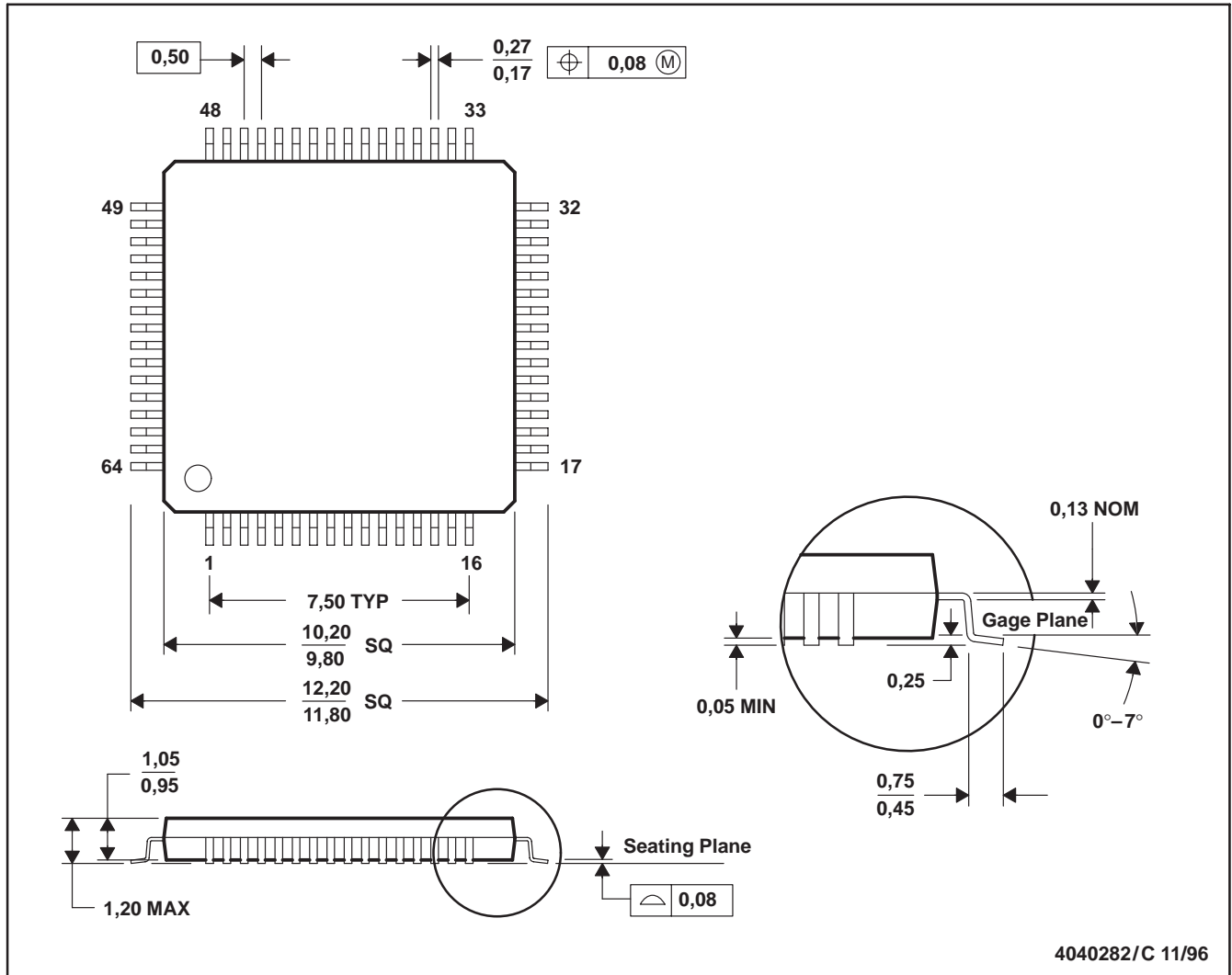
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

PAG (S-PQFP-G64)

PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-026

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