Click here to ask about the production status of specific part numbers.

MAX78000

Ultra-Low-Power Arm Cortex-M4 Processor with FPU-Based Microcontroller with Convolutional Neural Network Accelerator

General Description

Artificial intelligence (AI) requires extreme computational horsepower, but Maxim is cutting the power cord from AI insights. The MAX78000 is a new breed of AI microcontroller built to enable neural networks to execute at ultra-low power and live at the edge of the IoT. This product combines the most energy-efficient AI processing with Maxim's proven ultra-low power microcontrollers. Our hardware-based convolutional neural network (CNN) accelerator enables battery-powered applications to execute AI inferences while spending only microjoules of energy.

The MAX78000 is an advanced system-on-chip featuring an Arm® Cortex®-M4 with FPU CPU for efficient system control with an ultra-low-power deep neural network accelerator. The CNN engine has a weight storage memory of 442KB, and can support 1-, 2-, 4-, and 8-bit weights (supporting networks of up to 3.5 million weights). The CNN weight memory is SRAM-based, so AI network updates can be made on the fly. The CNN engine also has 512KB of data memory. The CNN architecture is highly flexible, allowing networks to be trained in conventional toolsets like PyTorch and TensorFlow®, then converted for execution on the MAX78000 using tools provided by Maxim.

In addition to the memory in the CNN engine, the MAX78000 has large on-chip system memory for the microcontroller core, with 512KB flash and up to 128KB SRAM. Multiple high-speed and low-power communications interfaces are supported, including I^2S and a parallel camera interface (PCIF).

The device is available in 81-pin CTBGA (8mm x 8mm, 0.8mm pitch) and 130-pin WLP (4.6mm x 3.7mm, 0.35mm pitch) packages.

Applications

- Object Detection and Classification
- Audio Processing: Multi-Keyword Recognition, Sound Classification, Noise Cancellation
- Facial Recognition
- Time-Series Data Processing: Heart Rate/Health Signal Analysis, Multi-Sensor Analysis, Predictive Maintenance

Benefits and Features

- Dual Core Ultra-Low-Power Microcontroller
  - Arm Cortex-M4 Processor with FPU Up to 100MHz
  - 512KB Flash and 128KB SRAM
  - Optimized Performance with 16KB Instruction Cache
  - Optional Error Correction Code (ECC-SEC-DED) for SRAM
  - 32-Bit RISC-V Coprocessor up to 60MHz
  - Up to 52 General-Purpose I/O Pins
  - 12-Bit Parallel Camera Interface
  - One I^2S Master/Slave for Digital Audio Interface
- Neural Network Accelerator
  - Highly Optimaized for Deep Convolutional Neural Networks
  - 442k 8bit Weight Capacity with 1,2,4,8-bit Weights
  - Programmable Input Image Size up to 1024 x 1024 pixels
  - Programmable Network Depth up to 64 Layers
  - Programmable per Layer Network Channel Widths up to 1024 Channels
  - 1 and 2 Dimensional Convolution Processing
  - Streaming Mode
  - Flexibility to Support Other Network Types, Including MLP and Recurrent Neural Networks
- Power Management Maximizes Operating Time for Battery Applications
  - Integrated Single-Inductor Multiple-Output (SIMO) Switch-Mode Power Supply (SMPS)
  - 2.0V to 3.6V SIMO Supply Voltage Range
  - Dynamic Voltage Scaling Minimizes Active Core Power Consumption
  - 22.2µA/MHz While Loop Execution at 3.0V from Cache (CM4 only)
  - Selectable SRAM Retention in Low-Power Modes with Real-Time Clock (RTC) Enabled
- Security and Integrity
  - Available Secure Boot
  - AES 128/192/256 Hardware Acceleration Engine
  - True Random Number Generator (TRNG) Seed Generator

***Ordering Information* appears at end of data sheet.**

19-100868; Rev 0; 8/20

Simplified Block Diagram

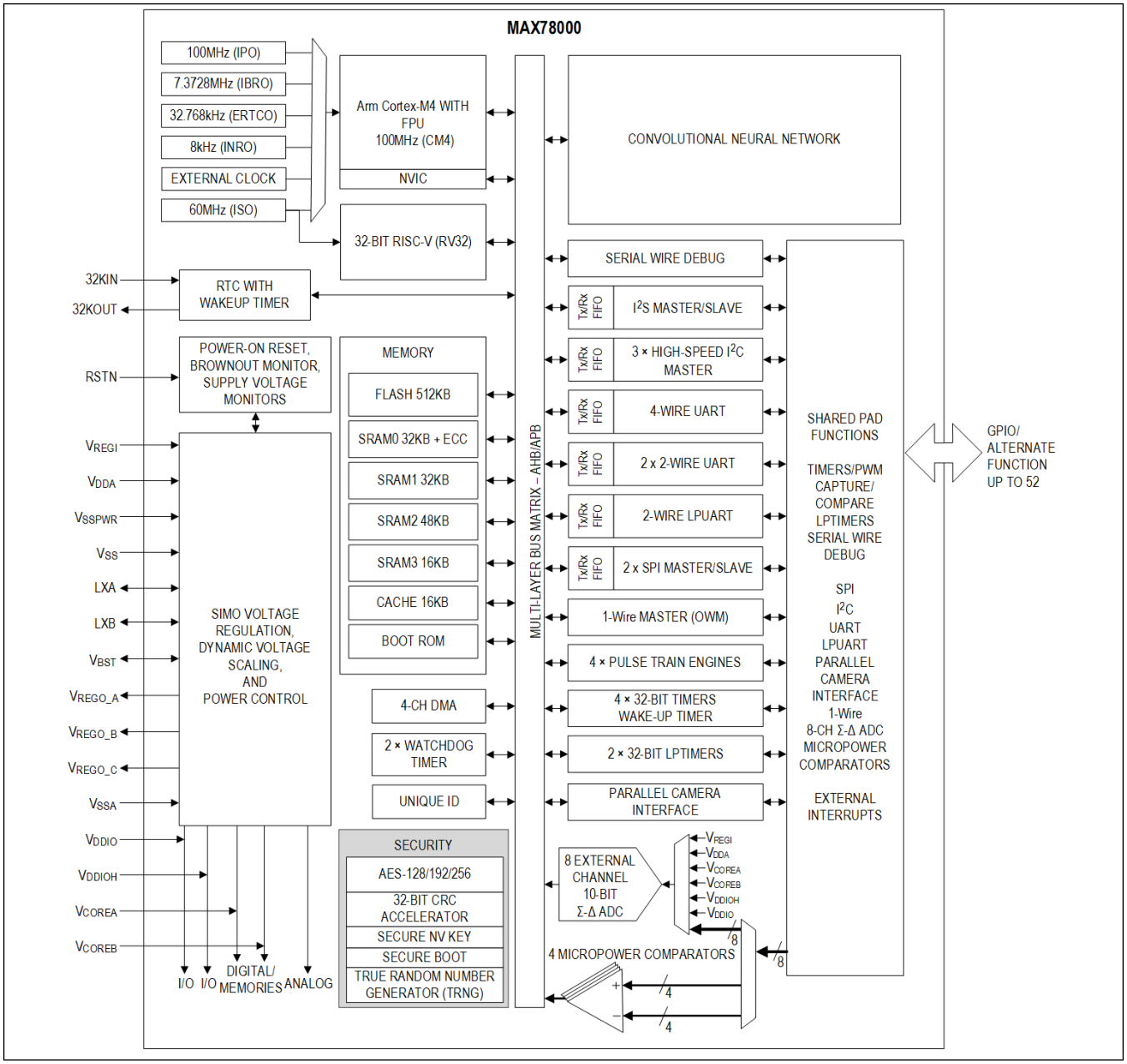


TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

Absolute Maximum Ratings

V_{COREA}, V_{COREB} ..... -0.3V to +1.21V
V_{DDIO} ..... -0.3V to +3.6V
V_{DDIOH} ..... -0.3V to +3.6V
V_{REGI} ..... -0.3V to +3.6V
V_{DDA} ..... -0.3V to +1.89V
GPIO (V_{DDIO}) ..... -0.3V to V_{DDIO} + 0.5V
RSTN, GPIO (V_{DDIOH}) ..... -0.3V to V_{DDIOH} + 0.5V
32KIN, 32KOUT ..... -0.3V to V_{DDA} + 0.2V
V_{DDIO} Combined Pins (sink) 100mA
V_{DDIOH} Combined Pins (sink) 100mA
V_{SSA} 100mA
V_{SS} 200mA
V_{SSPWR} 100mA
Output Current (sink) by any GPIO Pin 25mA
Output Current (source) by any GPIO Pin ..... -25mA
Continuous Package Power Dissipation CTBGA (multilayer board) T_A = +70°C (derate 29.81mW/°C above +70°C) 2384.50mW
Operating Temperature Range ..... -40°C to +105°C
Storage Temperature Range ..... -65°C to +150°C
Soldering Temperature ..... +260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

81-CTBGA

Package Code	X8188+3C
Outline Number	21-0735
Land Pattern Number	90-0460
Thermal Resistance, Four-Layer Board:	
Junction-to-Ambient (θ_{JA})	33.55ºC/W
Junction-to-Case Thermal Resistance (θ_{JC})	6.73ºC/W

For the latest package outline information and land patterns (footprints), go to *www.maximintegrated.com/packages*. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to *www.maximintegrated.com/thermal-tutorial*.

Electrical Characteristics

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLIES						
Core Input Supply Voltage A	V_{COREA}	Falling	V_{COREA} V_{RST}	1.1	1.21	V
		Rising	0.9	1.1	1.21	
Core Input Supply Voltage B	V_{COREB}	Falling	V_{COREB} V_{RST}	1.1	1.21	V
		Rising	0.9	1.1	1.21	

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply Voltage, Battery	V_{REGI}	Falling	V_{REGI} V_{RST}	3.0	3.6	V
		Rising	2.45	3.0	3.6	
Input Supply Voltage, Analog	V_{DDA}		1.71	1.8	1.89	V
Input Supply Voltage, GPIO	V_{DDIO}		1.71	1.8	1.89	V
Input Supply Voltage, GPIO (High)	V_{DDIOH}		1.71	3.0	3.6	V
Power-Fail Reset Voltage	V_{RST}	Monitors V_{COREA}		0.76		V
		Monitors V_{COREB}	0.72	0.77		
		Monitors V_{DDA}	1.58	1.64	1.69	
		Monitors V_{DDIO}	1.58	1.64	1.69	
		Monitors V_{DDIOH}	1.58	1.64	1.69	
		Monitors V_{REGI}	1.91	1.98	2.08	
Power-On Reset Voltage	V_{POR}	Monitors V_{COREA}		0.63		V
		Monitors V_{DDA}		1.25		

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V_{REGI} Current, ACTIVE Mode	I_{REGI_DACT}	Dynamic, IPO enabled, $f_{SYS\_CLK(MAX)}$ = 100MHz, total current into V_{REGI} pin, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in Active mode executing CoreMark®, RV32 in ACTIVE mode executing While(1), ECC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		41.9		µA/MHz
		Dynamic, IPO enabled, $f_{SYS\_CLK(MAX)}$ = 100MHz, total current into V_{REGI} pin, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 and RV32 in ACTIVE mode executing While(1), ECC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		38		
		Dynamic, IPO enabled, $f_{SYS\_CLK(MAX)}$ = 100MHz, total current into V_{REGI} pin, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in ACTIVE mode executing While(1), RV32 in SLEEP mode, ECC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		22.2		
		Dynamic, total current into V_{REGI} pin, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in SLEEP mode, RV32 in ACTIVE mode running from ISO, ECC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		22.9		
	I_{REGI_FACT}	Fixed, IPO enabled, ISO enabled, total current into V_{REGI}, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in ACTIVE mode 0MHz, RV32 in ACTIVE mode 0MHz, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		744		µA

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V_{REGI} Current, SLEEP Mode	I_{REGI_DSLP}	Dynamic, IPO enabled, $f_{SYS\_CLK(MAX)}$ = 100MHz, ISO enabled, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in SLEEP mode, RV32 in SLEEP mode, ECC disabled, all CNN quadrants disabled, all CNN memory disabled, standard DMA with 2 channels active; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		22.5		µA/MHz
	I_{REGI_FSLP}	Fixed, IPO enabled, ISO enabled, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 in SLEEP mode, RV32 in SLEEP mode, ECC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		1.5		mA
V_{REGI} Current, LOW POWER Mode	I_{REGI_DLP}	Dynamic, ISO enabled, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 powered off, RV32 in ACTIVE mode, $f_{SYS\_CLK(MAX)}$ = 60MHz, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		18.3		µA/MHz
	I_{REGI_FLP}	Fixed, ISO enabled, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, CM4 powered off, RV32 in ACTIVE mode 0MHz, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		0.64		mA
V_{REGI} Current, MICRO POWER Mode	I_{REGI_DMP}	Dynamic, ERTCO enabled, IBRO enabled, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, LPUART active, f_{LPUART} = 32.768kHz, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		230		µA
V_{REGI} Current, STANDBY Mode	I_{REGI_STBY}	Fixed, total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA		11.3		µA

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
V_{REGI} Current, BACKUP Mode	I_{REGI_BK}	Total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V, RTC disabled, all CNN quadrants disabled, all CNN memory disabled; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA	All SRAM retained		11.1		µA
			No SRAM retention		9		
			SRAM0 retained		9.6		
			SRAM0 and SRAM1 retained		10.1		
			SRAM0, SRAM1, and SRAM2 retained		10.6		
V_{REGI} Current, POWER DOWN Mode	I_{REGI_PDM}	Total current into V_{REGI} pins, V_{REGI} = 3.0V, V_{COREA} = V_{COREB} = 1.1V; inputs tied to V_{SS}, V_{DDIO}, or V_{DDIOH}; outputs source/sink 0mA			0.17		µA
V_{REGO_X} Output Current	$V_{REGO\_A\_IOUT}$	V_{REGO_A} output current			5	50	mA
	$V_{REGO\_B\_IOUT}$	V_{REGO_B} output current			5	50	
	$V_{REGO\_C\_IOUT}$	V_{REGO_C} output current			10	100	
V_{REGO_X} Output Current Combined	$V_{REGO\_X\_IOUT\_TOT}$	All three V_{REGO_X} outputs combined			20	100	mA
V_{REGO_X} Output Voltage Range	$V_{REGO\_X\_RANGE}$	$V_{REGI} \geq V_{REGO\_X}$ + 200mV		0.5	1.0	1.85	V
V_{REGO_X} Efficiency	$V_{REGO\_X\_EFF}$	V_{REGI} = 2.7V, V_{REGO_X} = 1.1 V, load = 30mA			90		%
SLEEP Mode Resume Time	t_{SLP_ON}	Time from power mode exit to execution of first user instruction			0.67		µs
LOW-POWER Mode Resume Time	t_{LP_ON}	Time from power mode exit to execution of first user instruction			9.5		µs
MICROPOWER Mode Resume Time	t_{MP_ON}	Time from power mode exit to execution of first user instruction			31		us
STANDBY Mode Resume Time	t_{STBY_ON}	Time from power mode exit to execution of first user instruction			35		µs
BACKUP Mode Resume Time	t_{BKU_ON}	Time from power mode exit to execution of first user instruction			0.14		ms
POWER-DOWN Mode Resume Time	t_{PDM_ON}	Time from power mode exit to execution of first user instruction. Includes bootloader execution time.			5		ms
CLOCKS							
System Clock Frequency	f_{SYS_CLK}			0.0625		100,000	kHz

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
System Clock Period	t_{SYS_CLK}				1/ f_{SYS_CLK}		ns
Internal Primary Oscillator (IPO)	f_{IPO}				100		MHz
Internal Secondary Oscillator (ISO)	f_{ISO}				60		MHz
Internal Baud Rate Oscillator (IBRO)	f_{IBRO}				7.3728		MHz
Internal Nano-Ring Oscillator (INRO)	f_{INRO}	8kHz selected			8		kHz
		16kHz selected			16		
		30kHz selected			32		
External RTC Oscillator (ERTCO)	f_{ERTCO}	32kHz watch crystal, C_L = 6pF, ESR < 90kΩ, C_0 ≤ 2pF			32.768		kHz
RTC Operating Current	I_{RTC}	All power modes, RTC enabled			0.3		µA
RTC Power-Up Time	t_{RTC_ON}				250		ms
External I^2S Clock Input Frequency	$f_{EXT\_I2S\_CLK}$	I2S_CLKEXT selected				25	MHz
External System Clock Input Frequency	f_{EXT_CLK}	EXT_CLK selected				80	MHz
External Low Power Timer 1 Clock Input Frequency	$f_{EXT\_LPTMR1\_CLK}$	LPTMR1_CLK selected				8	MHz
External Low Power Timer 2 Clock Input Frequency	$f_{EXT\_LPTMR2\_CLK}$	LPTMR2_CLK selected				8	MHz
CONVOLUTIONAL NEURAL NETWORK							
CNN Active Energy	E_{J_CNN}	Max power network, random data, and random mask configuration	x16 Quadrant 0, 1, 2, and 3 enabled		4.02		pJ/MAC

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
V_{COREA} CNN Active Current	$I_{COREA\_CNN\_MNISTA}$	MNIST Standard dataset, optimized network	x16 Quadrant 0 enabled; x16 Quadrant 1, 2, and 3 powered down and isolated		10.1		mA
	$I_{COREA\_CNN\_MNISTB}$		x16 Quadrant 0, 1, 2, and 3 enabled		29		
	$I_{COREA\_CNNMPRA}$	Max power network, random data, and random mask configuration	x16 Quadrant 0 enabled; x16 Quadrant 1, 2, and 3 powered down and isolated		31.7		
	$I_{COREA\_CNNMPRB}$		x16 Quadrant 0, 1, 2, and 3 enabled. External power supply must be used for V_{COREA} since the on-board SIMO will not supply above 100mA.		118		
	I_{COREA_CNNMPA}	Max power network, data, mask configuration	x16 Quadrant 0 enabled; x16 Quadrant 1, 2, and 3 powered down and isolated		38.5		
	I_{COREA_CNNMPB}		x16 Quadrant 0, 1, 2, and 3 enabled. External power supply must be used for VCOREA since the on-board SIMO will not supply above 100mA.		146		
V_{REGI} Mask Memory Retention Current	I_{REGI_CNNMR}	V_{COREB} = 1.0V	x16 Quadrant 0 only; x16 Quadrant 1, 2, and 3 powered down and isolated		6.625		µA
			x16 Quadrant 0, 1, 2, and 3 enabled		26.5		

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
V_{REGI} CNN Inactive Current	I_{REGI_CNNIA}	CNN enabled/ inactive, clocks disabled	x16 Quadrant 0 enabled; x16 Quadrant 1, 2, and 3 powered down and isolated		264		µA
			x16 Quadrant 0, 1, 2, and 3 enabled		790.4		
GENERAL-PURPOSE I/O							
Input Low Voltage for All GPIO Except P3.0 and P3.1	V_{IL_VDDIO}	P3.0 and P3.1 can only use V_{DDIOH} as I/O supply and cannot use V_{DDIO} as I/O supply	V_{DDIO} selected as I/O supply			0.3 × V_{DDIO}	V
Input Low Voltage for All GPIO	V_{IL_VDDIOH}	V_{DDIOH} selected as I/O supply				0.3 × V_{DDIOH}	V
Input Low Voltage for RSTN	V_{IL_RSTN}				0.5 x V_{DDIOH}		V
Input High Voltage for All GPIO Except P3.0 and P3.1	V_{IH_VDDIO}	P3.0 and P3.1 can only use V_{DDIOH} as I/O supply and cannot use V_{DDIO} as I/O supply	V_{DDIO} selected as I/O supply	0.7 × V_{DDIO}			V
Input High Voltage for All GPIO	V_{IH_VDDIOH}	V_{DDIOH} selected as I/O supply		0.7 × V_{DDIOH}			V
Input High Voltage for RSTN	V_{IH_RSTN}				0.5 x V_{DDIOH}		V

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Low Voltage for All GPIO Except P3.0 and P3.1	V_{OL_VDDIO}	P3.0 and P3.1 can only use V_{DDIOH} as I/O supply and cannot use V_{DDIO} as I/O supply	V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 00, I_{OL} = 1mA		0.2	0.4	V
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 01, I_{OL} = 2mA		0.2	0.4	
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 10, I_{OL} = 4mA		0.2	0.4	
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 11, I_{OL} = 8mA		0.2	0.4	
Output Low Voltage for All GPIO	V_{OL_VDDIOH}	V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 00, I_{OL} = 1mA			0.2	0.4	V
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 01, I_{OL} = 2mA			0.2	0.4	
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 10, I_{OL} = 4mA			0.2	0.4	
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 11, I_{OL} = 8mA			0.2	0.4	
Combined I_{OL}, All GPIO	I_{OL_TOTAL}					48	mA

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output High Voltage for All GPIO Except P3.0 and P3.1	V_{OH_VDDIO}	P3.0 and P3.1 can only use V_{DDIOH} as I/O supply and cannot use V_{DDIO} as I/O supply	V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 00, I_{OL} = -1mA	V_{DDIO} - 0.4			V
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 01, I_{OL} = -2mA	V_{DDIO} - 0.4			
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 10, I_{OL} = -4mA	V_{DDIO} - 0.4			
			V_{DDIO} selected as I/O supply, V_{DDIO} = 1.71V, GPIOn_DS_SEL[1:0] = 11, I_{OL} = -8mA	V_{DDIO} - 0.4			
Output High Voltage for All GPIO Except P3.0 and P3.1	V_{OH_VDDIOH}	V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 00, I_{OL} = -1mA		V_{DDIOH} - 0.4			V
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 01, I_{OL} = -2mA		V_{DDIOH} - 0.4			
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 10, I_{OL} = -4mA		V_{DDIOH} - 0.4			
		V_{DDIOH} selected as I/O supply, V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] = 11, I_{OL} = -8mA		V_{DDIOH} - 0.4			
Output High Voltage for P3.0 and P3.1	V_{OH_VDDIOH}	V_{DDIOH} = 1.71V, GPIOn_DS_SEL[1:0] fixed at 00, I_{OL} = -1mA		V_{DDIOH} - 0.4			V
Combined I_{OH}, All GPIO	I_{OH_TOTAL}					-48	mA
Input Hysteresis (Schmitt)	V_{IHYS}				300		mV
Input Leakage Current Low	I_{IL}	V_{DDIO} = 1.89V, V_{DDIOH} = 3.6V, V_{DDIOH} selected as I/O supply, V_{IN} = 0V, internal pullup disabled		-100		+100	nA

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Leakage Current High	I_{IH}	V_{DDIO} = 1.89V, V_{DDIOH} = 3.6V, V_{DDIOH} selected as I/O supply, V_{IN} = 3.6V, internal pulldown disabled		-800		+800	nA
	I_{OFF}	V_{DDIO} = 0V, V_{DDIOH} = 0V, V_{DDIO} selected as I/O supply, V_{IN} < 1.89V		-1		+1	µA
	I_{IH3V}	V_{DDIO} = V_{DDIOH} = 1.71V, V_{DDIO} selected as I/O supply, V_{IN} = 3.6V		-2		+2	
Input Pullup Resistor RSTN	R_{PU_R}	Pullup to V_{DDIOH}			25		kΩ
Input Pullup/Pulldown Resistor for All GPIO	R_{PU1}	Normal resistance, P1M = 0			25		kΩ
	R_{PU2}	Highest resistance, P1M = 1			1		MΩ
ADC (SIGMA-DELTA)							
Resolution					10		Bits
ADC Clock Rate	f_{ACLK}			0.1		8	MHz
ADC Clock Period	t_{ACLK}				$1/f_{ACLK}$		µs
Input Voltage Range	V_{AIN}	AIN[7:0], ADC_DIVSEL = [00], ADC_CH_SEL = [7:0]	REF_SEL = 0, INPUT_SCALE = 0	V_{SSA} + 0.05		V_{BG}	V
		AIN[7:0], ADC_DIVSEL = [01], ADC_CH_SEL = [7:0]	REF_SCALE = 0, INPUT_SCALE = 0	V_{SSA} + 0.05		2 x V_{BG}	
		AIN[7:0], ADC_DIVSEL = [10], ADC_CH_SEL = [7:0]	REF_SCALE = 0, INPUT_SCALE = 0, V_{DDIOH} selected as the I/O supply	V_{SSA} + 0.05		V_{DDIOH}	
		AIN[7:0], ADC_DIVSEL = [11], ADC_CH_SEL = [7:0]	REF_SEL = 0, INPUT_SCALE = 0, V_{DDIOH} selected as the I/O supply	V_{SSA} + 0.05		V_{DDIOH}	
Input Impedance	R_{AIN}				30		kΩ
Analog Input Capacitance	C_{AIN}	Fixed capacitance to V_{SSA}			1		pF
		Dynamically switched capacitance			250		fF
Integral Nonlinearity	INL	Measured at +25°C				±2	LSb
Differential Nonlinearity	DNL	Measured at +25°C				±1	LSb
Offset Error	V_{OS}				±1		LSb

Electrical Characteristics (continued)

(Limits are 100% tested at T_A = +25°C and T_A = +105°C. TYP specifications are provided for T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at T_A = +105°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ADC Active Current	I_{ADC}	ADC active, reference buffer enabled, input buffer disabled		102		µA
ADC Setup Time	t_{ADC_SU}	Any power-up of ADC clock or ADC bias to CpuAdcStart			10	µs
ADC Output Latency	t_{ADC}			1067		t_{ACLK}
ADC Sample Rate	f_{ADC}				7.8	ksps
ADC Input Leakage	I_{ADC_LEAK}	ADC inactive or channel not selected		10		nA
Full-Scale Voltage	V_{FS}	ADC code = 0x3FF		1.2		V
Bandgap Temperature Coefficient	V_{TEMPCO}	Box method		30		ppm
COMPARATORS						
Input Offset Voltage	V_{OFFSET}			±1		mV
Input Hysteresis	V_{HYST}	AINCOMPHYST[1:0] = 00		±23		mV
		AINCOMPHYST[1:0] = 01		±50		
		AINCOMPHYST[1:0] = 10		±2		
		AINCOMPHYST[1:0] = 11		±7		
Input Voltage Range	V_{IN_CMP}	Common-mode range	0.6		1.35	V
FLASH MEMORY						
Flash Erase Time	t_{M_ERASE}	Mass erase		20		ms
	t_{P_ERASE}	Page erase		20		
Flash Programming Time per Word	t_{PROG}	32-bit programming mode, f_{FLC_CLK} = 1MHz		42		µs
Flash Endurance			10			kcycles
Data Retention	t_{RET}	T_A = +105°C	10			years

Electrical Characteristics—SPI

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MASTER MODE						
SPI Master Operating Frequency for SPI0	f_{MCK0}	f_{SYS_CLK} = 100MHz, $f_{MCK0(MAX)}$ = f_{SYS_CLK}/2			50	MHz
SPI Master Operating Frequency for SPI1	f_{MCK1}	f_{SYS_CLK} = 100MHz, $f_{MCK1(MAX)}$ = f_{SYS_CLK}/4			25	MHz
SPI Master SCK Period	t_{MCKX}			$1/f_{MCKX}$		ns
SCK Output Pulse-Width High/Low	t_{MCH}, t_{MCL}		$t_{MCKX}/2$			ns
MOSI Output Hold Time After SCK Sample Edge	t_{MOH}		$t_{MCX}/2$			ns

Electrical Characteristics—SPI (continued)

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MOSI Output Valid to Sample Edge	t_{MOV}		$t_{MCKX}/2$			ns
MOSI Output Hold Time After SCK Low Idle	t_{MLH}			$t_{MCKX}/2$		ns
MISO Input Valid to SCK Sample Edge Setup	t_{MIS}			5		ns
MISO Input to SCK Sample Edge Hold	t_{MIH}			$t_{MCKX}/2$		ns
SLAVE MODE						
SPI Slave Operating Frequency	f_{SCK}				50	MHz
SPI Slave SCK Period	t_{SCK}			$1/f_{SCK}$		ns
SCK Input Pulse-Width High/Low	t_{SCH}, t_{SCL}			$t_{SCK}/2$		
SSx Active to First Shift Edge	t_{SSE}			10		ns
MOSI Input to SCK Sample Edge Rise/Fall Setup	t_{SIS}			5		ns
MOSI Input from SCK Sample Edge Transition Hold	t_{SIH}			1		ns
MISO Output Valid After SCLK Shift Edge Transition	t_{SOV}			5		ns
SCK Inactive to SSx Inactive	t_{SSD}			10		ns
SSx Inactive Time	t_{SSH}			$1/f_{SCK}$		µs
MISO Hold Time After SSx Deassertion	t_{SLH}			10		ns

Electrical Characteristics—I^2C

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
STANDARD MODE						
Output Fall Time	t_{OF}	Standard mode, from $V_{IH(MIN)}$ to $V_{IL(MAX)}$		150		ns
SCL Clock Frequency	f_{SCL}		0		100	kHz
Low Period SCL Clock	t_{LOW}		4.7			µs
High Time SCL Clock	t_{HIGH}		4.0			µs

Electrical Characteristics—I²C (continued)

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Setup Time for Repeated Start Condition	$t_{SU;STA}$		4.7			µs
Hold Time for Repeated Start Condition	$t_{HD;STA}$		4.0			µs
Data Setup Time	$t_{SU;DAT}$			300		ns
Data Hold Time	$t_{HD;DAT}$			10		ns
Rise Time for SDA and SCL	t_R			800		ns
Fall Time for SDA and SCL	t_F			200		ns
Setup Time for a Stop Condition	$t_{SU;STO}$		4.0			µs
Bus Free Time Between a Stop and Start Condition	t_{BUS}		4.7			µs
Data Valid Time	$t_{VD;DAT}$		3.45			µs
Data Valid Acknowledge Time	$t_{VD;ACK}$		3.45			µs
FAST MODE						
Output Fall Time	t_{OF}	From $V_{IH(MIN)}$ to $V_{IL(MAX)}$		150		ns
Pulse Width Suppressed by Input Filter	t_{SP}			75		ns
SCL Clock Frequency	f_{SCL}		0		400	kHz
Low Period SCL Clock	t_{LOW}		1.3			µs
High Time SCL Clock	t_{HIGH}		0.6			µs
Setup Time for Repeated Start Condition	$t_{SU;STA}$		0.6			µs
Hold Time for Repeated Start Condition	$t_{HD;STA}$		0.6			µs
Data Setup Time	$t_{SU;DAT}$			125		ns
Data Hold Time	$t_{HD;DAT}$			10		ns
Rise Time for SDA and SCL	t_R			30		ns
Fall Time for SDA and SCL	t_F			30		ns
Setup Time for a Stop Condition	$t_{SU;STO}$		0.6			µs
Bus Free Time Between a Stop and Start Condition	t_{BUS}		1.3			µs
Data Valid Time	$t_{VD;DAT}$		0.9			µs

Electrical Characteristics—I²C (continued)

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Data Valid Acknowledge Time	$t_{VD;ACK}$		0.9			µs
FAST MODE PLUS						
Output Fall Time	t_{OF}	From $V_{IH(MIN)}$ to $V_{IL(MAX)}$		80		ns
Pulse Width Suppressed by Input Filter	t_{SP}			75		ns
SCL Clock Frequency	f_{SCL}		0		1000	kHz
Low Period SCL Clock	t_{LOW}		0.5			µs
High Time SCL clock	t_{HIGH}		0.26			µs
Setup Time for Repeated Start Condition	$t_{SU;STA}$		0.26			µs
Hold Time for Repeated Start Condition	$t_{HD;STA}$		0.26			µs
Data Setup Time	$t_{SU;DAT}$			50		ns
Data Hold Time	$t_{HD;DAT}$			10		ns
Rise Time for SDA and SCL	t_R			50		ns
Fall Time for SDA and SCL	t_F			30		ns
Setup Time for a Stop Condition	$t_{SU;STO}$		0.26			µs
Bus Free Time Between a Stop and Start Condition	t_{BUS}		0.5			µs
Data Valid Time	$t_{VD;DAT}$		0.45			µs
Data Valid Acknowledge Time	$t_{VD;ACK}$		0.45			µs

Electrical Characteristics—I²S

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Bit Clock Frequency	f_{BCLK}				25	MHz
BCLK High Time	t_{WBCLKH}			0.5		$1/f_{BCLK}$
BCLK Low Time				0.5		$1/f_{BCLK}$
LRCLK Setup Time	t_{LRCLK_BLCK}			25		ns
Delay Time, BCLK to SD (Output) Valid	t_{BCLK_SDO}			12		ns
Setup Time for SD (Input)	t_{SU_SDI}			6		ns
Hold Time SD (Input)	t_{HD_SDI}			3		ns

Electrical Characteristics—PCIF

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
PCIF						
PCIF Operating Frequency	f_{CLK}				10	MHz
PCIF Clock Period	t_{CLK}			$1/f_{CLK}$		ns
PCIF_PCLK Output Pulse-Width High/Low	t_{WCH}, t_{WCL}		$t_{CLK}/2$			ns
PCIF_VSYNC, PCIF_HSYNC Setup Time	t_{SSU}			5		ns
PCIF_VSYNC, PCIF_HSYNC Hold Time	t_{SHLD}			5		ns
PCIF_D0-PCIF_D11 Setup TIme	t_{DSU}			5		ns
PCIF_D0_PCIF_D11 Hold Time	t_{DHLD}			5		ns

Electrical Characteristics—1-Wire Master

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Write 0 Low Time	t_{W0L}	Standard		60		µs
		Overdrive		8		
Write 1 Low Time	t_{W1L}	Standard		6		µs
		Standard, Long Line mode		8		
		Overdrive		1		
Presence Detect Sample	t_{MSP}	Standard		70		µs
		Standard, Long Line mode		85		
		Overdrive		9		
Read Data Value	t_{MSR}	Standard		15		µs
		Standard, Long Line mode		24		
		Overdrive		3		
Recovery Time	t_{REC0}	Standard		10		µs
		Standard, Long Line mode		20		
		Overdrive		4		
Reset Time High	t_{RSTH}	Standard		480		µs
		Overdrive		58		
Reset Time Low	t_{RSTL}	Standard		600		µs
		Overdrive		70		
Time Slot	t_{SLOT}	Standard		70		µs
		Overdrive		12		

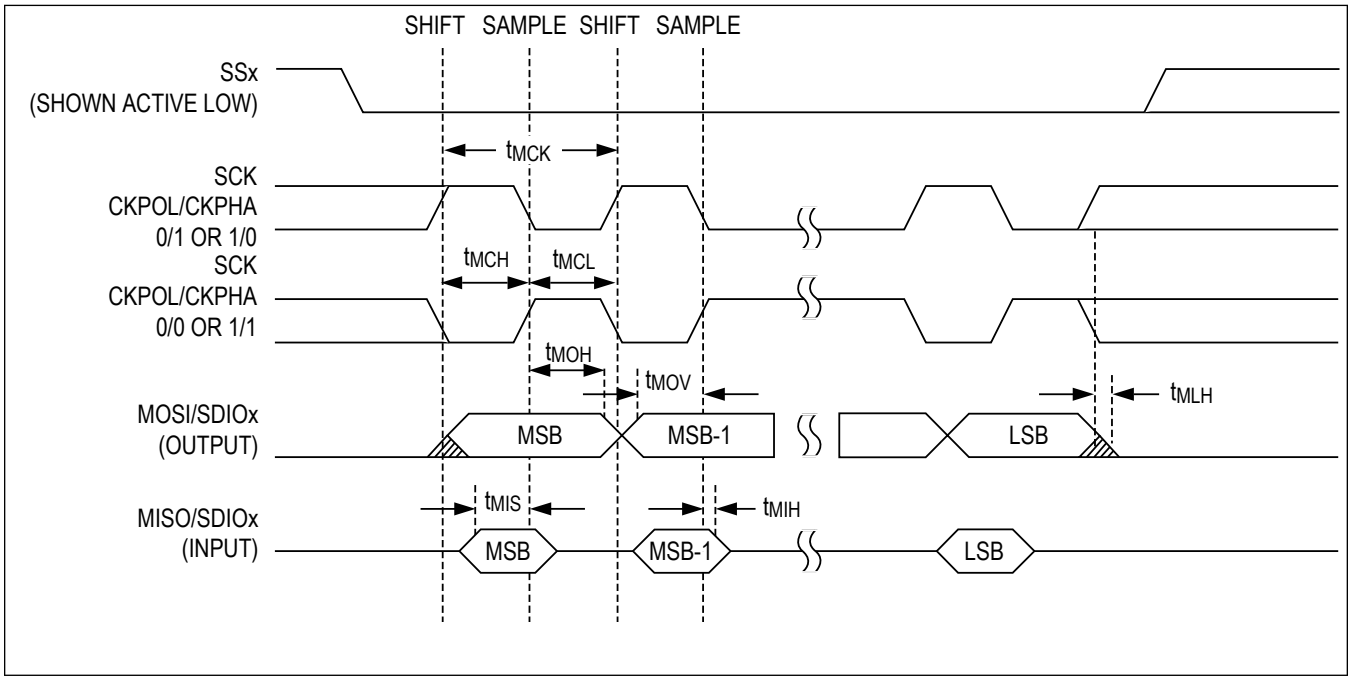


Figure 1. SPI Master Mode Timing Diagram

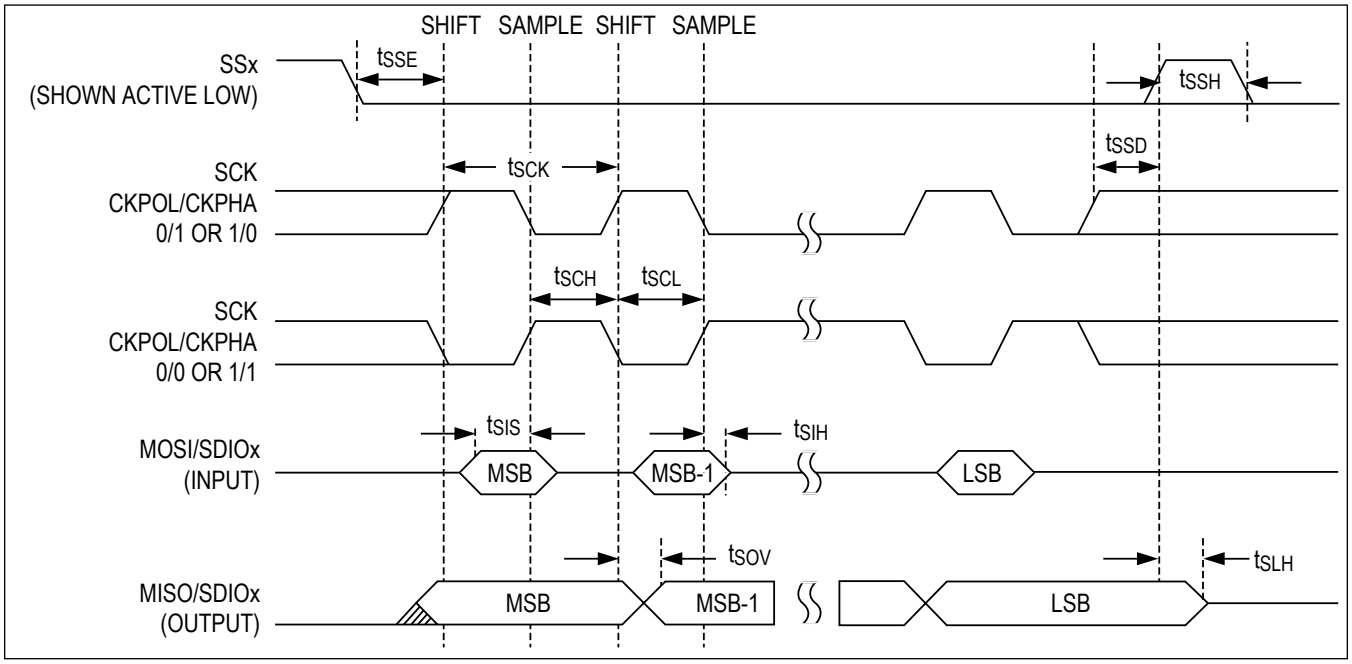


Figure 2. SPI Slave Mode Timing Diagram

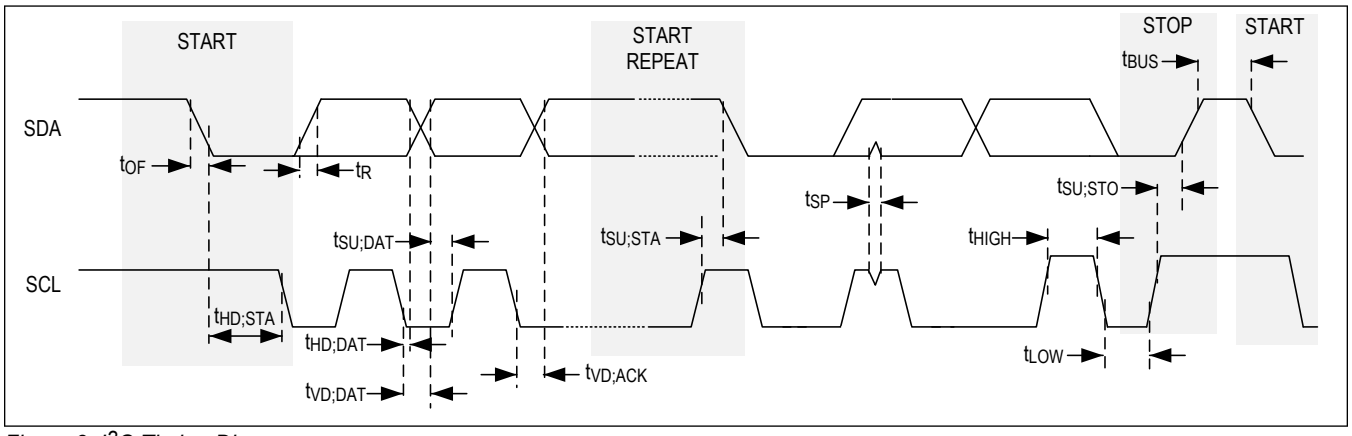


Figure 3. I²C Timing Diagram

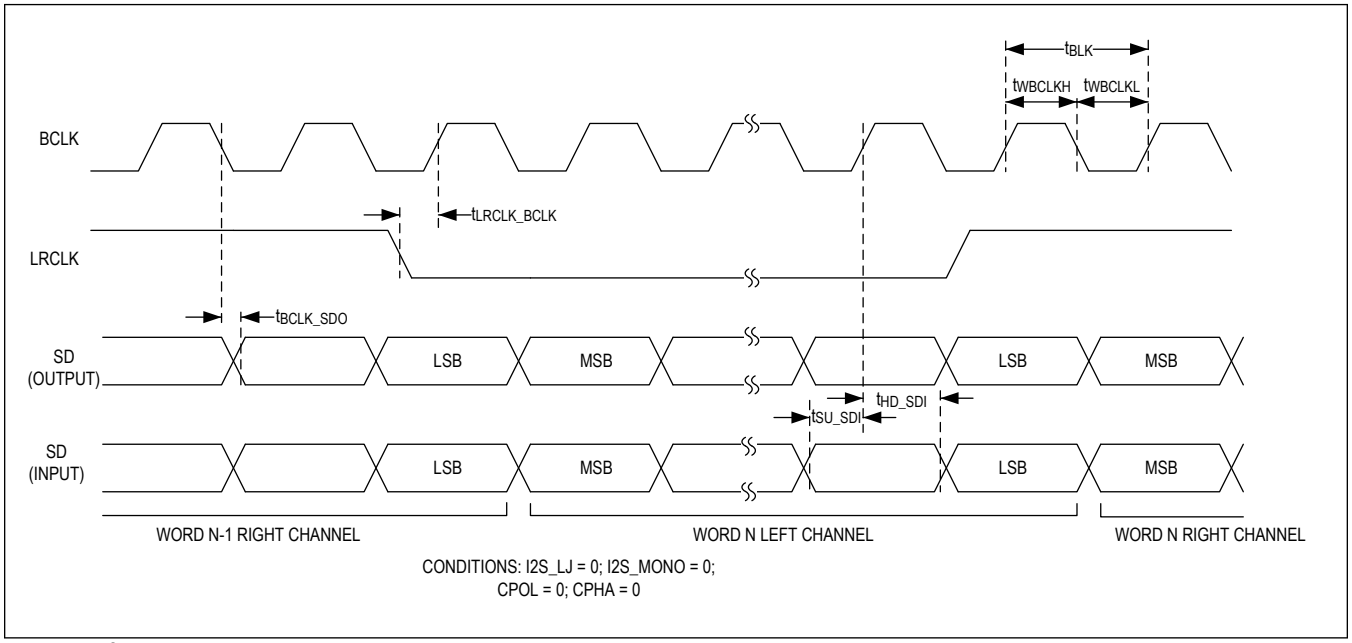


Figure 4. I²S Timing Diagram

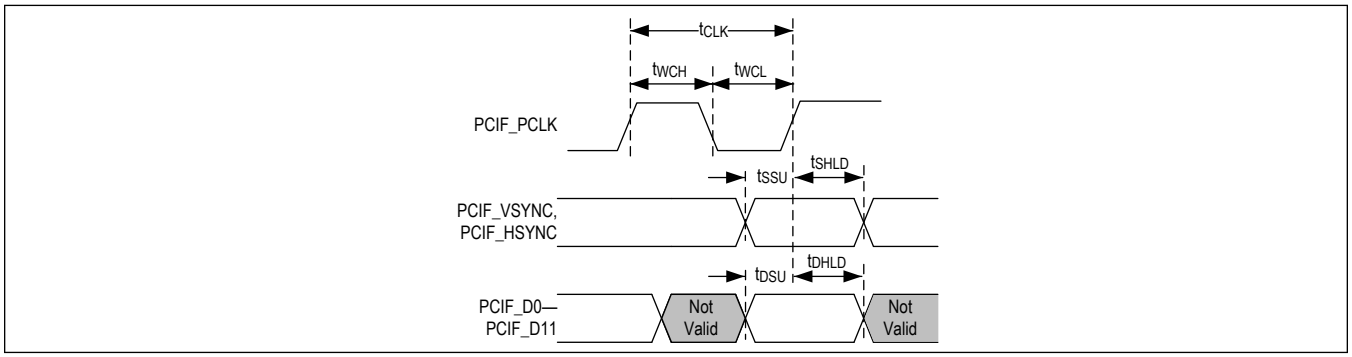


Figure 5. Parallel Camera Interface Timing Diagram

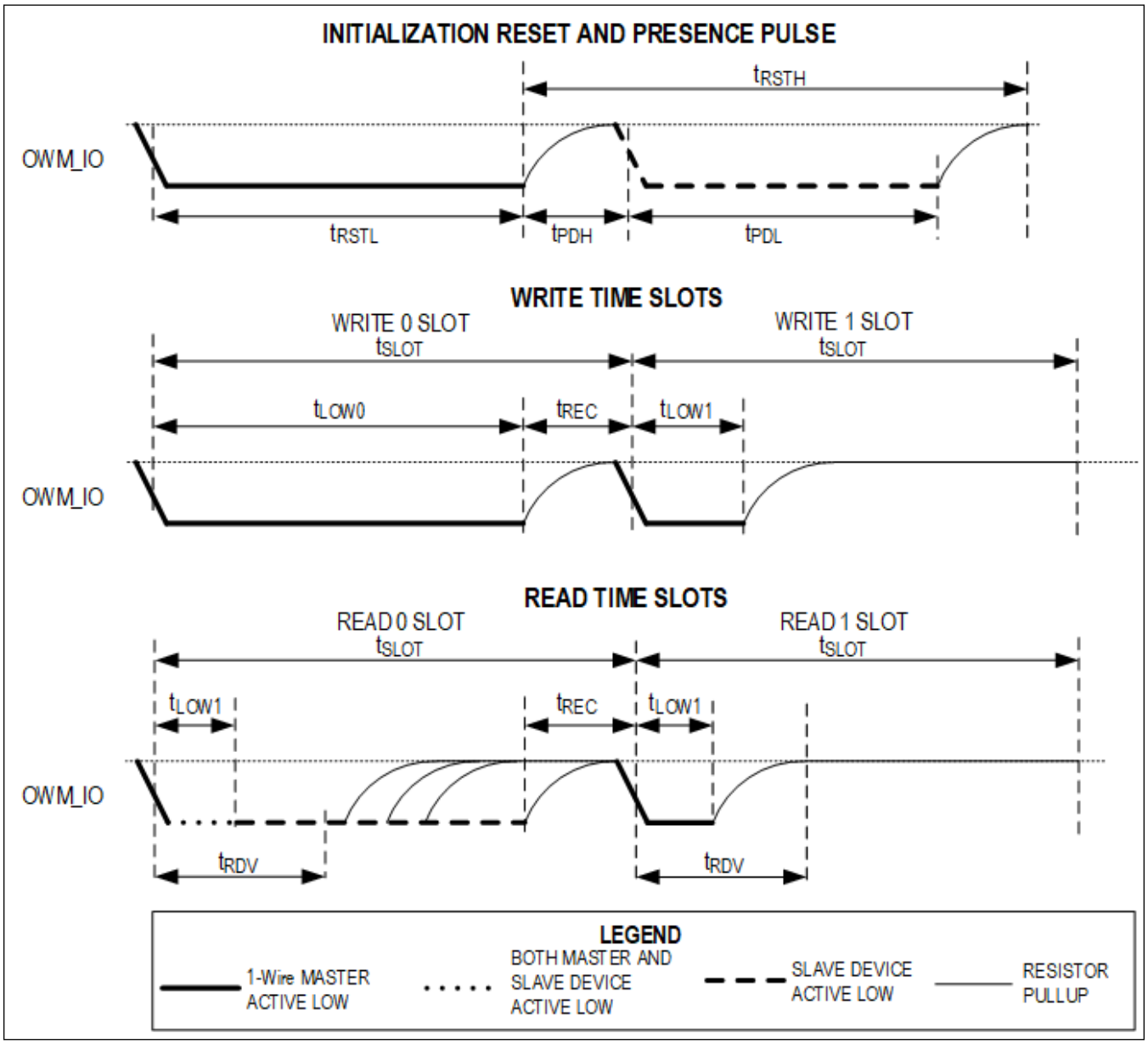
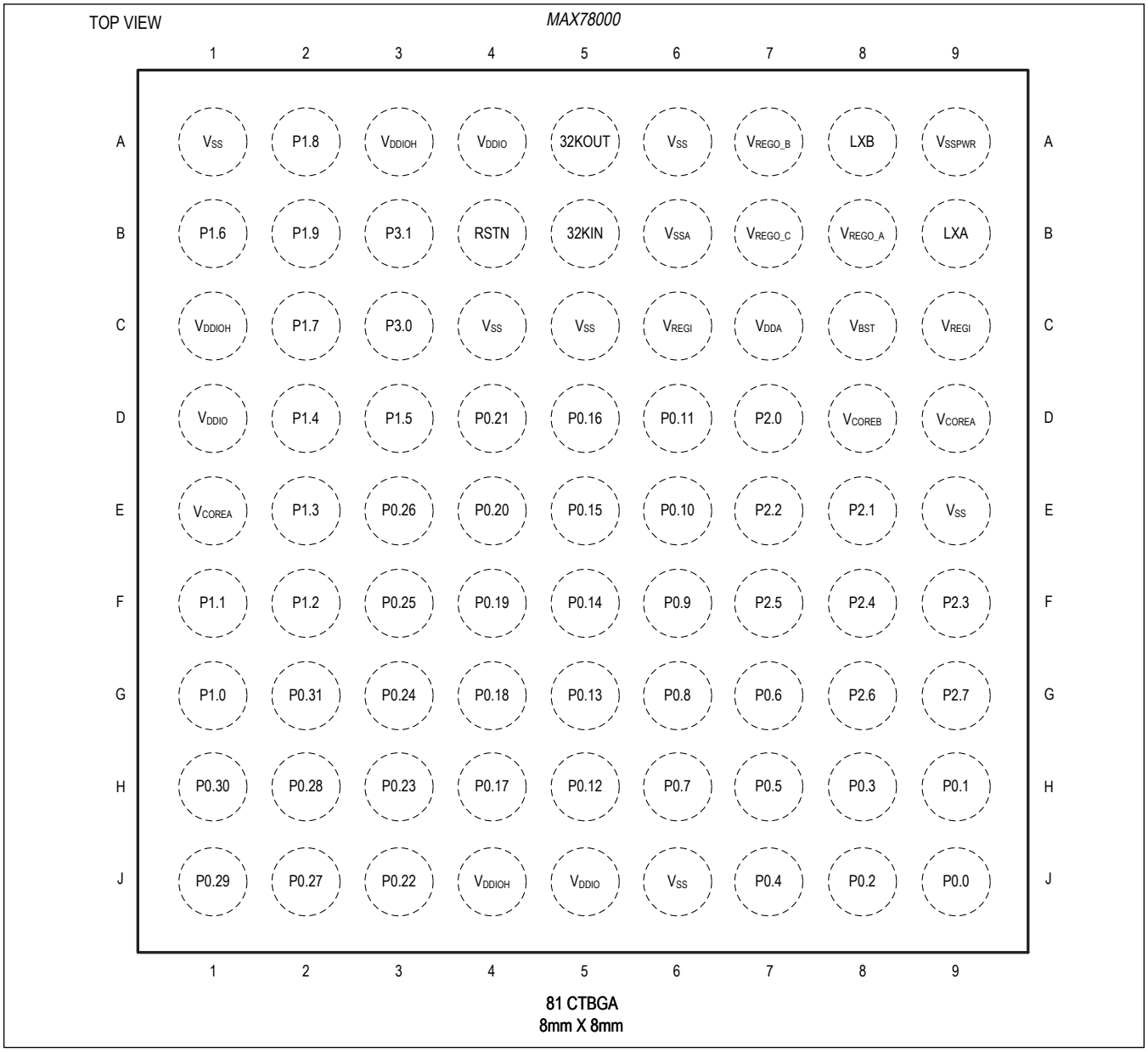


Figure 6. 1-Wire Master Data Timing Diagram

Pin Configuration

81 CTBGA



Pin Description

PIN	NAME	FUNCTION MODE			FUNCTION
		Primary Signal (Default)	Alternate Function 1	Alternate Function 2	
POWER (See the Applications Information section for bypass capacitor recommendations.)					
C9, C6	V_{REGI}	—	—	—	Battery Power Supply for the SIMO Switchmode Power Supply (SMPS). Bypass device pin C9 with 2 x 47µF capacitors placed as close as possible to the device pin C9 and V_{SSPWR} pins for applications using a coin cell as the battery. See Bypass Capacitors for more information. If power to the device is cycled, the voltage applied to this device pin must reach V_{REGI_POR}.
C7	V_{DDA}	—	—	—	1.8V Analog Power Supply
D9, E1	V_{COREA}	—	—	—	Digital Core Supply Voltage A
D8	V_{COREB}	—	—	—	Digital Core Supply Voltage B
C8	V_{BST}	—	—	—	Boosted Supply Voltage for the Gate Drive of High-Side Switches. Bypass V_{BST} to LXB with a 3.3nF capacitor.
B8	V_{REGO_A}	—	—	—	Buck Converter A Voltage Output. Bypass V_{REGO_A} with a 22µF capacitor to V_{SS} placed as close as possible to the V_{DDA} device pin.
A7	V_{REGO_B}	—	—	—	Buck Converter B Voltage Output. Bypass V_{REGO_B} with a 22µF capacitor to V_{SS} placed as close as possible to the closest V_{COREB} device pin.
B7	V_{REGO_C}	—	—	—	Buck Converter C Voltage Output. Bypass V_{REGO_C} with a 22µF capacitor to V_{SS} placed as close as possible to the closest V_{COREA} device pin.
A4, D1, J5	V_{DDIO}	—	—	—	GPIO Supply Voltage. Bypass this pin to V_{SS} with a 1.0µF capacitor placed as close as possible to the package.
A3, C1, J4	V_{DDIOH}	—	—	—	GPIO Supply Voltage, High. $V_{DDIOH} \geq V_{DDIO}$. Bypass this pin to V_{SS} with a 1.0µF capacitor placed as close as possible to the package.
A1, A6, C4, C5, E9, J6	V_{SS}	—	—	—	Digital Ground
B6	V_{SSA}	—	—	—	Analog Ground
A9	V_{SSPWR}	—	—	—	Ground for the SIMO Switchmode Power Supply (SMPS). This device pin is the return path for the V_{REGI} device pins C6 and C9.
B9	LXA	—	—	—	Switching Inductor Input A. Connect a 2.2µH inductor between LXA and LXB.
A8	LXB	—	—	—	Switching Inductor Input B. Connect a 2.2µH inductor between LXA and LXB.

81 CTBGA

PIN	NAME	FUNCTION MODE			FUNCTION
		Primary Signal (Default)	Alternate Function 1	Alternate Function 2	
RESET AND CONTROL					
B4	RSTN	—	—	—	Active-Low, External System Reset Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a POR reset (resetting all logic on all supplies except for RTC circuitry) and begins execution. This pin has an internal pullup to the V_{DDIOH} supply.
CLOCK					
A5	32KOUT	—	—	—	32kHz Crystal Oscillator Output
B5	32KIN	—	—	—	32kHz Crystal Oscillator Input. Connect a 32kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, this pin can be configured as the input for an external CMOS-level clock source.
GPIO AND ALTERNATE FUNCTION (See the Applications Information section for GPIO and Alternate Function Matrices.)					
J9	P0.0	P0.0	UART0A_RX	—	UART0 Receive Port Map A
H9	P0.1	P0.1	UART0A_TX	—	UART0 Transmit Port Map A
J8	P0.2	P0.2	TMR0A__IOA	UART0B_CTS	Timer 0 I/O 32 Bits or Lower 16 Bits Port Map A; UART0 Clear to Send Port Map B
H8	P0.3	P0.3	EXT_CLK/ TMR0A_IOB	UART0B_RTS	External Clock for Use as SYS_OSC/Timer 0 I/O Upper 16 Bits Port Map A; UART0 Request to Send Port Map B
J7	P0.4	P0.4	SPI0_SS0	TMR0B_IOAN	SPI0 Slave Select 0; Timer 0 Inverted Output Port Map B
H7	P0.5	P0.5	SPI0_MOSI	TMR0B_IOBN	SP0 Master-Out Slave-In Serial Data 0; Timer 0 Inverted Output Upper 16 Bits Port Map B
G7	P0.6	P0.6	SPI0_MISO	OWM_IO	SPI0 Master-In Slave-Out Serial Data 1; 1-Wire Master Data I/O
H6	P0.7	P0.7	SPI0_SCK	OWM_PE	SPI0 Clock; 1-Wire Master Pullup Enable Output
G6	P0.8	P0.8	SPI0_SDIO2	TMR0B_IOA	SPI0 Data 2 I/O; Timer 0 I/O 32 Bits or Lower 16 Bits Port Map B
F6	P0.9	P0.9	SPI0_SDIO3	TMR0B_IOB	SPI0 Data 3 I/O; Timer 0 I/O Upper 16 Bits Port Map B
E6	P0.10	P0.10	I2C0_SCL	SPI0_SS2	I2C0 Clock; SPI0 Slave Select 2
D6	P0.11	P0.11	I2C0_SDA	SPI0_SS1	I2C0 Serial Data; SPI0 Slave Select 1
H5	P0.12	P0.12	UART1A_RX	TMR1B_IOAN	UART1 Receive Port Map A; Timer 1 Inverted Output Port Map B
G5	P0.13	P0.13	UART1A_TX	TMR1B_IOBN	UART1 Transmit Port Map A; Timer 1 Inverted Output Upper 16 Bits Port Map B
F5	P0.14	P0.14	TMR1A_IOA	I2S_CLKEXT	Timer 1 I/O 32 Bits or Lower 16 Bits Port Map A; I2S External Clock Input

81 CTBGA

PIN	NAME	FUNCTION MODE			FUNCTION
		Primary Signal (Default)	Alternate Function 1	Alternate Function 2	
E5	P0.15	P0.15	TMR1A_IOB	PCIF_VSYNC	Timer 1 I/O Upper 16 Bits Port Map A; Parallel Camera Interface Vertical Sync
D5	P0.16	P0.16	I2C1_SCL	PT2	I2C1 Clock; Pulse Train 2
H4	P0.17	P0.17	I2C1_SDA	PT3	I2C1 Serial Data; Pulse Train 3
G4	P0.18	P0.18	PT0	OWM_IO	Pule Train 0; 1-Wire Master Data I/O
F4	P0.19	P0.19	PT1	OWM_PE	Pulse Train 1; 1-Wire Master Pullup Enable Output
E4	P0.20	P0.20	SPI1_SS0	PCIF_D0	SPI1 Slave Select 0; Parallel Camera Interface Data 0
D4	P0.21	P0.21	SPI1_MOSI	PCIF_D1	SPI1_Master Out Slave In Serial Data 0; Parallel Camera Interface Data 1
J3	P0.22	P0.22	SPI1_MISO	PCIF_D2	SPI1 Master In Slave Out Serial Data 1; Parallel Camera Interface Data 2
H3	P0.23	P0.23	SPI1_SCK	PCIF_D3	SPI1 Clock; Parallel Camera Interface Data 3
G3	P0.24	P0.24	SPI1_SDIO2	PCIF_D4	SPI1 Data 2; Parallel Camera Interface Data 4
F3	P0.25	P0.25	SPI1_SDIO3	PCIF_D5	SPI1 Data 3; Parallel Camera Interface Data 5
E3	P0.26	P0.26	TMR2A_IOA	PCIF_D6	Timer 2 I/O 32 Bits or Lower 16 Bits Port Map A; Parallel Camera Interface Data 6
J2	P0.27	P0.27	TMR2A_IOB	PCIF_D7	Timer 2 I/O Upper 16 Bits Port Map A; Parallel Camera Interface Data 7
H2	P0.28	P0.28	SWDIO	—	Serial Wire Debug Data I/O
J1	P0.29	P0.29	SWCLK	—	Serial Wire Debug Clock
H1	P0.30	P0.30	I2C2_SCL	PCIF_D8	I2C2 Clock; Parallel Camera Interface Data 8
G2	P0.31	P0.31	I2C2_SDA	PCIF_D9	I2C2 Serial Data; Parallel Camera Interface Data 9
G1	P1.0	P1.0	UART2A_RX	RV_TCK	UART2 Receive Port Map A; 32-bit RISC-V Test Port Clock
F1	P1.1	P1.1	UART2A_TX	RV_TMS	UART2 Transmit Port Map A; 32-bit RISC-V Test Port Select
F2	P1.2	P1.2	I2S_SCK	RV_TDI	I2S Bit Clock; 32-bit RISC-V Test Port Data Input
E2	P1.3	P1.3	I2S_WS	RV_TDO	I2S Left/Right Clock; 32-bit RISC-V Test Port Data Output
D2	P1.4	P1.4	I2S_SDI	TMR3B_IOA	I2S Serial Data Input; Timer 3 I/O 32 Bits or Lower 16 Bits Port Map B
D3	P1.5	P1.5	I2S_SDO	TMR3B_IOB	I2S Serial Data Output; Timer 3 I/O Upper 16 Bits Port Map B
B1	P1.6	P1.6	TMR3A_IOA	PCIF_D10	Timer 3 I/O 32 Bits or Lower 16 Bits Port Map A; Parallel Camera Interface Data 10
C2	P1.7	P1.7	TMR3A_IOB	PCIF_D11	Timer 3 I/O Upper 16 Bits Port Map A; Parallel Camera Interface Data 11

81 CTBGA

PIN	NAME	FUNCTION MODE			FUNCTION
		Primary Signal (Default)	Alternate Function 1	Alternate Function 2	
A2	P1.8	P1.8	PCIF_HSYNC	RXEV0	Parallel Camera Interface Horizontal Sync; CM4 RX Event Input
B2	P1.9	P1.9	PCIF_PCLK	TXEV0	Parallel Camera Interface Pixel Clock; CM4 TX Event Output
D7	P2.0	P2.0	AIN0/AINON	—	Analog to Digital Converter Input 0/Comparator 0 Negative Input
E8	P2.1	P2.1	AIN1/AIN0P	—	Analog to Digital Converter Input 1/Comparator 0 Positive Input
E7	P2.2	P2.2	AIN2/AIN1N	—	Analog to Digital Converter Input 2/Comparator 1 Negative Input
F9	P2.3	P2.3	AIN3/AIN1P	—	Analog to Digital Converter Input 3/Comparator 1 Positive Input
F8	P2.4	P2.4	AIN4/AIN2N	LPTMR0B_IOA	Analog to Digital Converter Input 4/Comparator 2 Negative Input; Low-Power Timer 0 I/O Port Map B
F7	P2.5	P2.5	AIN5/AIN2P	LPTMR1_IOA	Analog to Digital Converter Input 5/Comparator 2 Positive Input; Low-Power Timer 1 I/O Port Map B
G8	P2.6	P2.6	LPTMR0_CLK/ AIN6/AIN3N	LPUARTB_RX	Low-Power Timer 0 External Clock Input/Analog to Digital Converter Input 6/Comparator 3 Negative Input; Low-Power UART 0 Receive Port Map B
G9	P2.7	P2.7	LPTMR1_CLK/ AIN7/AIN3P	LPUARTB_TX	Low-Power Timer 1 External Clock Input/Analog to Digital Converter Input 7/Comparator 3 Positive Input; Low-Power UART Transmit Port Map B
C3	P3.0	P3.0	PDOWN	WAKEUP	Power-Down Output; Wakeup Input. This device pin can only be powered by V_{DDIOH}.
B3	P3.1	P3.1	SQWOUT	WAKEUP	Square-Wave Output; Wakeup Input. This device pin can only be powered by V_{DDIOH}.

Detailed Description

The MAX78000 is the first of a new breed of low-power microcontrollers built to thrive in the rapidly evolving AI at the edge market. These products include Maxim's proven ultra-low power MCU IP along with deep neural network AI acceleration.

The MAX78000 is an advanced system-on-chip featuring an Arm® Cortex®-M4 with FPU CPU for efficient computation of complex functions and algorithms with integrated power management. It also includes a 442KB-weight CNN accelerator. The devices offer large on-chip memory with 512KB flash and up to 128KB SRAM. Multiple high-speed and low-power communication interfaces are supported including high-speed SPI, high-speed I^2C serial interface, and LPUART. Additional low-power peripherals include flexible LPTIMER and analog comparators. A PCIF is included for capturing images from an image sensor for processing by the CNN. An I^2S interface is included for interfacing to an audio codec for capturing audio samples also for processing by the CNN.

Arm Cortex-M4 with FPU Processor and RISC-V RV32 Processor

The Arm Cortex-M4 with FPU processor CM4 is ideal for the artificial intelligence system control. The architecture combines high-efficiency signal processing functionality with low power, low cost, and ease of use.

The Arm Cortex-M4 with FPU DSP supports single instruction, multiple data (SIMD) path DSP extensions, providing:

- Four parallel 8-bit add/sub
- Floating point single precision
- Two parallel 16-bit add/sub
- Two parallel MACs
- 32- or 64-bit accumulate
- Signed, unsigned, data with or without saturation

The addition of a 32-bit RISC-V coprocessor RV32 provides the system with ultra-low power consumption signal processing.

Convolutional Neural Network Accelerator (CNN)

The CNN accelerator consists of 64 parallel processors with 512KB of SRAM-based storage. Each processor includes a pooling unit and a convolutional engine with dedicated weight memory. Four processors share one data memory. These are further organized into groups of 16 processors that share common controls. A group of 16 processors operates as a slave to another group or independently. Data is read from SRAM associated with each processor and written to any data memory located within the accelerator. Any given processor has visibility of its dedicated weight memory and to the data memory instance it shares with the three others.

The features of the CNN accelerator include:

- 512KB SRAM data storage
  - Configured as 8Kx8-bit integers x64 channels or 32Kx8-bit integers x4 channels for input layers
  - Hardware load and unload assist
- 64 parallel physical channel processors
  - Organized as 4x16 processors
  - 8-bit integer data path with option for 32-bit integers on the output layer
  - Per-channel processor enable/disable
  - Expandable to 1024 parallel logical channel processors
- 1x1 or 3x3 2D kernel sizes
- Configurable 1D kernel size to 1x9
- Full resolution sum-of-product arithmetic for 1024 8-bit integer channels
- Operating frequency up to 50MHz
- Nominal 1 output channel per clock, maximum 4 output channels per clock (passthru)
- Configurable input layer image size

  - 32K pixels, 16 channels, non-streaming
  - 8K pixels, 4 channels, non-streaming
  - 1024 x 1024 pixels, 4 channels, streaming
- Hidden layers
  - Up to 8K 8-bit integer data per channel, x64 channels, non-streaming
  - 8K bytes can be split equally across 1 to 16 logical channels, non-streaming
  - 1M 8-bit integer data per channel, x64 channels, streaming
  - 1M bytes can be split equally across eight layers, streaming
- Optional interrupt on CNN completion
- User-accessible BIST on all SRAM storage
- User-accessible zeroization of all SRAM storage
- Single-step operation with full data SRAM access for CNN operation debug
- Flexible power management
  - Independent x16 processor supply enables
  - Independent x16 processor mask retention enables
  - Independent x16 data path clock enables
  - Active Arm peripheral bus clock gating with per x16 processor override
  - CNN clock frequency scaling (divide by 2, 4, 8, 16)
  - Chip-level voltage control for performance power optimization
- Configurable weight storage
  - SRAM-based weight storage with selectable data retention
  - Configurable from 442K 8-bit integer weights to 3.456M 1-bit logical weights
    - Organized as 768X9X64 8-bit integer weights to 768x72x64 1-bit logical weights
    - Can be configured on a per-layer basis
  - Programmable per x16 processor weight RAM start address, start pointer, and mask count
  - Optional weight load hardware assist for packed weight storage
- 32 independently configurable layer groups
  - Each group can contain element-wise, and/or pooling, and/or convolution operations for a minimum of 32 and a maximum of 96 layers
  - Processor and mask enables (16 channels)
  - Input data format
  - Per-layer data streaming
    - Stream start - relative to prior stream
    - Dual-stream processing delay counters - 1 column, 1 row delta counter
    - Data SRAM circular buffer size
  - Input data size (row, column)
  - Row and column padding 0 to 4 bytes
  - Number of input channels 1 to 1024
  - Kernel bit width size (1, 2, 4, 8)
  - Kernel SRAM start pointer and count
  - Inflight input image pooling
    - Pool mode - none, maximum or average
    - Pool size - 1x1 to 16x16
  - Stride - 1 row, 1 column to 4 rows, 4 columns
  - Data SRAM read pointer base address
  - Data SRAM write pointer configuration
    - Base address
    - Independent offsets for output channel storage in SRAM
    - Programmable stride increment offset
  - Bias - 2048 8-bit integers with option for 512 32-bit integers
  - Pre-activation output scaling from 0 to 8 bits

- Output activation - none, ReLU, absolute value
- Passthru - 8-bit or 32-bit integers
- Element-wise operations (add, subtract, xor, or) with optional convolution - up to 16 elements
- Deconvolution (upscaling)
- Flattening for MLP processing
- 1x1 convolution

Memory

Internal Flash Memory

512KB of internal flash memory provides nonvolatile storage of program and data memory.

Internal SRAM

The internal 128KB SRAM provides low-power retention of application information in all power modes except POWER DOWN. The SRAM is divided into 4 banks. SRAM0 and SRAM1 are both 32KB, SRAM2 is 48KB and SRAM3 is 16KB. SRAM2 and SRAM3 are accessible by the RV-32 in LOW POWER mode. For enhanced system reliability, SRAM0 (32KB) can be configured with error correction coded (ECC) single error correction-double error detection (SED-DED). This data retention feature is optional and configurable. This granularity allows the application to minimize its power consumption by only retaining the most essential data.

Comparators

The eight AIN[7:0] inputs can be configured as four pairs and deployed as four independent comparators with the following features:

- Comparison events can trigger interrupts
- Events can wake the CM4 from SLEEP, LOW POWER, MICRO POWER, STANDBY, or BACKUP operating modes
- Can be active in all power modes

Dynamic Voltage Scaling (DVS) Controller

The DVS controller works using the fixed high-speed oscillator and the V_{COREA} supply voltage to optimally operate the Arm core at the lowest practical voltage. The ability to adaptively adjust the voltage provides a significant reduction in dynamic power consumption.

The DVS controller provides the following features:

- Controls DVS monitoring and adjustment functions
- Continuous monitoring with programmable monitor sample period
- Controlled transition to a programmable operating point
- Independent high and low operating limits for safe, bounded operation
- Independent high, center, and low operating range delay line delay monitors
- Programmable adjustment rate – when an adjustment is required
- Single clock operation
- Arm peripheral bus interface provides control and status access
- Interrupt capability during error

Clocking Scheme

Multiple clock sources can be selected as the system clock:

- Internal primary oscillator (IPO) at a nominal frequency of 100MHz
- Internal secondary oscillator (ISO) at a nominal frequency of 60MHz
- Configurable internal nano-ring oscillator (INRO) at 8kHz, 16kHz, or 30kHz
- External RTC oscillator at 32.768kHz (ERTCO) (external crystal required)
- Internal baud rate oscillator at 7.3728MHz (IBRO)

- External square-wave clock up to 80MHz

There are multiple external clock inputs:

- LPTMR0 and LPTMR1 can be clocked from unique external sources.
- I2S can be be clocked from its own external source.

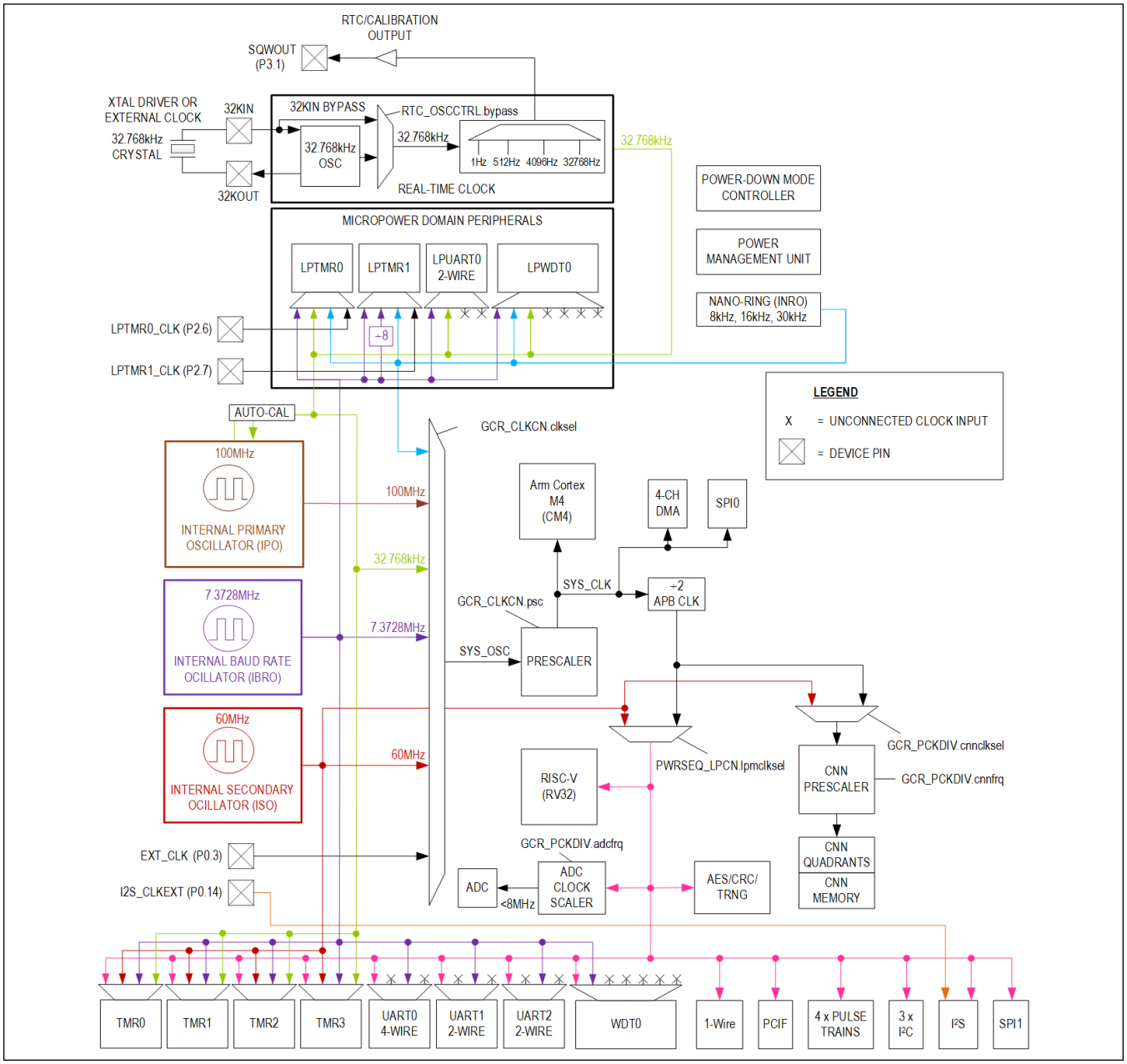


Figure 7. Clocking Scheme Diagram

General-Purpose I/O and Special Function Pins

Most general-purpose I/O (GPIO) pins share both a firmware-controlled I/O function and one or more alternate functions

associated with peripheral modules. Pins can be individually enabled for GPIO or peripheral special function use. Configuring a pin as a special function usually supersedes its use as a firmware-controlled I/O. Although this multiplexing between peripheral and GPIO functions is usually static, it can also be done dynamically. The electrical characteristics of a GPIO pin are identical whether the pin is configured as an I/O or special function, except where explicitly noted in the Electrical Characteristics tables.

In GPIO mode, pins are logically divided into ports of 32 pins. Each pin of a port has an interrupt function that can be independently enabled, and configured as a level- or edge-sensitive interrupt. All GPIOs of a given port share the same interrupt vector.

When configured as GPIO, the following features are provided. The features can be independently enabled or disabled on a per-pin basis.

- Configurable as input, output, bidirectional, or high impedance
- Optional internal pullup resistor or internal pulldown resistor when configured as input
- Exit from low-power modes on rising or falling edge
- Selectable standard- or high-drive modes

The MAX78000 provides up to 52 GPIO pins. Caution is needed since Port 3 (P3.0 and P3.1 device pins) are configured in a different manner from the above description.

Parallel Camera Interface (PCIF)

The PCIF is a low voltage interface suited for CMOS image sensors. It provides up to 12-bits of parallel access capability with single capture and continuous mode operation.

Analog-to-Digital Converter

The 10-bit sigma-delta ADC provides an integrated reference generator and a single-ended input multiplexer. The multiplexer selects an input channel from one of the eight external analog input signals (AIN0–AIN7) or the internal power supply inputs.

The reference for the ADC can be:

- Internal 1.22V bandgap
- V_{SSA} analog supply

An optional feature allows samples captured by the ADC to be automatically compared against user-programmable high and low limits. Up to four channel limit pairs can be configured in this way. The comparison allows the ADC to trigger an interrupt (and potentially wake the CPU from a power mode) when a captured sample goes outside the preprogrammed limit range. Since this comparison is performed directly by the sample limit monitors, it can be performed even while the CPU is in SLEEP, LOW POWER or MICRO POWER mode. The eight AIN[7:0] inputs can be configured as four pairs and deployed as four independent comparators.

The ADC measures the following voltages:

- AIN[7:0] up to 3.3V
- V_{REGI}
- V_{SSA}
- V_{COREA}
- V_{COREB}
- V_{DDIOH}
- V_{DDIO}

Single-Inductor Multiple-Output Switch-Mode Power Supply (SIMO SMPS)

The SIMO SMPS built into the device provides a monolithic power supply architecture for operation from a single lithium cell. The SIMO provides three buck regulator outputs that are voltage programmable. This architecture optimizes power consumption efficiency of the device and minimizes the bill of materials for the circuit design since only a single inductor/capacitor pair is required.

Power Management

Power Management Unit

The power management unit (PMU) provides high-performance operation while minimizing power consumption. It exercises intelligent, precise control of power distribution to the CPUs and peripheral circuitry.

The PMU provides the following features:

- User-configurable system clock
- Automatic enabling and disabling of crystal oscillators based on power mode
- Multiple power domains
- Fast wake-up of powered-down peripherals when activity detected

ACTIVE Mode

In this mode, the CM4 and the RV32 can execute application code and all digital and analog peripherals are available on demand. Dynamic clocking disables peripherals not in use, providing the optimal mix of high performance and low power consumption. The CM4 has access to all system SRAM. The RV32 has access to SRAM2 and SRAM3. Both the CM4 and the RV32 can execute from internal flash simultaneously. SRAM3 can be configured as an instruction cache for the RV32.

SLEEP Mode

This mode consumes less power, but wakes faster because the clocks can optionally be enabled.

The device status is as follows:

- CM4 is asleep.
- RV32 is asleep.
- CNN quadrants and memory are configurable.
- Peripherals are on.
- Standard DMA is available for optional use.

LOW POWER Mode (LPM)

This mode is suitable for running the RV32 processor to collect and move data from enabled peripherals.

The device status is as follows:

- The CM4, SRAM0, SRAM1 are in state retention.
- CNN quadrants and memory are configurable and active.
- The RV32 can access the SPI, all UARTS, all timers, I^2C, 1-Wire, pulse train engines, I^2S, CRC, AES, TRNG, PCIF, and comparators, as well as SRAM2 and SRAM3. SRAM3 can be configured to operate as RV32 instruction cache.
- The transition from LOW POWER mode to ACTIVE mode is faster than the transition from BACKUP mode because system initialization is not required.
- The DMA can access flash.
- IPO can be optionally powered down.
- The following oscillators are enabled:
  - IBRO
  - ERTCO
  - INRO
  - ISO

MICRO POWER Mode (µPM)

This mode is used for extremely low power consumption while using a minimal set of peripherals to provide wakeup capability.

The device status is as follows:

- Both CM4 and RV32 are state retained. System state and all SRAM is retained.

- CNN quadrants are powered off.
- CNN memory provides selectable retention.
- The GPIO pins retain their state.
- All non-MICRO POWER peripherals are state retained.
- The following oscillators are powered down:
  - IPO
  - ISO
- The following oscillators are enabled:
  - IBRO
  - ERTCO
  - INRO
- The following MICRO POWER mode peripherals are available to wake up the device:
  - LPUART0, LPUART1
  - WWDT1
  - All four low-power analog comparators

STANDBY Mode

This mode is used to maintain the system operation while keeping time with the RTC.

The device status is as follows:

- Both CM4 and RV32 are state retained. System state and all SRAM are retained.
- CNN quadrants are powered off.
- CNN memory provides selectable retention.
- GPIO pins retain their state.
- All peripherals are state retained.
- The following oscillators are powered down:
  - IPO
  - ISO
  - IBRO
- The following oscillators are enabled:
  - ERTCO
  - INRO

BACKUP Mode

This mode is used to maintain the system RAM. The device status is as follows:

- CM4 and RV32 are powered off.
- SRAM0, SRAM1, SRAM2, and SRAM3 can be configured to be state retained as per [[Table 0. Backup Mode SRAM Retention]].
- CNN memory provides selectable retention.
- All peripherals are powered off.

The following oscillators are powered down:

- IPO
- ISO
- IBRO

The following oscillators are enabled:

- ERTCO
- INRO

Table 1. BACKUP Mode SRAM Retention

RAM BLOCK	RAM SIZE
SRAM0	32KB + ECC
SRAM1	32KB
SRAM2	48KB
SRAM3	16KB

POWER DOWN Mode (PDM)

This mode is used during product level distribution and storage. The device status is as follows:

- CM4 and RV32 are powered off.
- All peripherals and SRAM are powered down.
- All oscillators are powered down.
- There is no data retention in this mode, but values in flash memory are preserved.
- Voltage monitors are operational.

Wakeup Sources

The sources of wakeup from the SLEEP, LOW POWER, MICRO POWER, STANDBY, BACKUP, and POWER DOWN operating modes are summarized in Table 2.

Table 2. Wakeup Sources

OPERATING MODE	WAKEUP SOURCE
SLEEP	Any enabled peripheral with interrupt capability; RSTN
LOW POWER (LPM)	SPI0, I^2S, I^2C, UARTs, timers, watchdog timers, wakeup timer, all comparators, RTC, GPIOs, RSTN, and RV32
MICRO POWER (µPM)	All comparators, LPUART, LPTMR1, LPTIMER2, LPWDT0, RTC, wakeup timer, GPIOs, RSTN
STANDBY	RTC, wakeup timer, GPIOs, CMP0, RSTN
BACKUP	RTC, wakeup timer, GPIOs, CMP0, RSTN
POWER DOWN (PDM)	P3.0, P3.1, RSTN

Real-Time Clock

An RTC keeps the time of day in absolute seconds. The 32-bit seconds register can count up to approximately 136 years and be translated to calendar format by application software.

The RTC provides a time-of-day alarm that can be programmed to any future value between 1 second and 12 days. When configured for long intervals, the time-of-day alarm can be used as a power-saving timer, allowing the device to remain in an extremely low-power mode, but still awaken periodically to perform assigned tasks. A second independent 32-bit 1/4096 subsecond alarm can be programmed with a tick resolution of 244µs. Both can be configured as recurring alarms. When enabled, either alarm can cause an interrupt or wake the device from most low-power modes.

The time base is generated by a 32.768kHz crystal or an external clock source that must meet the electrical/timing requirements in the *Electrical Characteristics* table.

The RTC calibration feature provides the ability for user software to compensate for minor variations in the RTC oscillator, crystal, temperature, and board layout. Enabling the SQWOUT alternate function outputs a timing signal derived from the RTC. External hardware can measure the frequency and adjust the RTC frequency in increments of ±127ppm with 1ppm resolution. Under most circumstances, the oscillator does not require any calibration.

Programmable Timers

32-Bit Timer/Counter/PWM (TMR, LPTMR)

General-purpose, 32-bit timers provide timing, capture/compare, or generation of pulse-width modulated (PWM) signals with minimal software interaction.

The timer provides the following features:

- 32-bit up/down autoreload
- Programmable prescaler
- PWM output generation
- Capture, compare, and capture/compare capability
- External pin multiplexed with GPIO for timer input, clock gating, or capture
- Timer output pin
- TMR0–TMR3 can be configured as 2 × 16-bit general-purpose timers
- Timer interrupt

The MAX78000 provides six 32-bit timers (TMR0, TMR1, TMR2, TMR3, LPTMR0, and LPTMR1). LPTMR0 and LPTMR1 are capable of operation in the SLEEP, LOW POWER, and MICRO POWER modes.

I/O functionality is supported for all of the timers. Note that the function of a port can be multiplexed with other functions on the GPIO pins, so it might not be possible to use all of the ports depending on the device configuration. See Table 3 for individual timer features.

Table 3. Timer Configuration Options

INSTANCE	REGISTER ACCESS NAME	SINGLE 32 BIT	DUAL 16 BIT	SINGLE 16 BIT	POWER MODE	CLOCK SOURCE						
						PCLK	ISO	IBRO	INRO	ERTCO	LPTMR0_CLK	LPTMR1_CLK
TMR0	TMR0	Yes	Yes	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	Yes	No	Yes	No	No
TMR1	TMR1	Yes	Yes	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	Yes	No	Yes	No	No
TMR2	TMR2	Yes	Yes	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	Yes	No	Yes	No	No
TMR3	TMR3	Yes	Yes	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	Yes	No	Yes	No	No
LPTMR0	TMR4	No	No	Yes	ACTIVE, SLEEP, LOW POWER, MICRO POWER	No	No	Yes	Yes	Yes	Yes	No
LPTMR1	TMR5	No	No	Yes	ACTIVE, SLEEP, LOW POWER, MICRO POWER	No	No	Yes	Yes	Yes	No	Yes

Watchdog Timer (WDT)

Microcontrollers are often used in harsh environments where electrical noise and electromagnetic interference (EMI) are abundant. Without proper safeguards, these hazards can disturb device operation and corrupt program execution. One of the most effective countermeasures is the windowed watchdog timer (WDT), which detects runaway code or system unresponsiveness.

The WDT is a 32-bit, free-running counter with a configurable prescaler. When enabled, the WDT must be periodically reset by the application software. Failure to reset the WDT within the user-configurable timeout period indicates that the application software is not operating correctly and results in a WDT timeout. A WDT timeout can trigger an interrupt, system reset, or both. Either response forces the instruction pointer to a known good location before resuming instruction execution. The windowed timeout period feature provides more detailed monitoring of system operation, requiring the WDT to be reset within a specific window of time. See Table 4 for individual timer features.

The MAX78000 provides two instances of the watchdog timer—WDT0 and LPWDT0.

Table 4. Watchdog Timer Configuration Options

INSTANCE NAME	REGISTER ACCESS NAME	POWER MODE	CLOCK SOURCE			
			PCLK	IBRO	INRO	ERTCO
WDT0	WDT0	ACTIVE, SLEEP, LOW POWER	Yes	Yes	No	No
LPWDT0	WDT1	ACTIVE, SLEEP, LOW POWER, MICRO POWER	No	Yes	Yes	Yes

Pulse Train Engine (PT)

Multiple, independent pulse train generators can provide either a square-wave or a repeating pattern from 2 to 32 bits in length. Any single pulse train generator or any desired group of pulse train generators can be synchronized at the bit level, allowing for multibit patterns. Each pulse train generator is independently configurable.

The pulse train generators provide the following features:

- Independently enabled
- Safe enable and disable for pulse trains without bit banding
- Multiple pin configurations allow for flexible layout
- Pulse trains can be started/synchronized independently or as a group
- Frequency of each enabled pulse train generator is also set separately, based on a divide down (such as divide by 2, divide by 4, and divide by 8) of the input pulse train module clock
- Input pulse train module clock can be optionally configured to be independent from the system AHB clock
- Multiple repetition options
  - Single shot (nonrepeating pattern of 2 to 32 bits)
  - Pattern repeats user-configurable number of times or indefinitely
  - Termination of one pulse train loop count can restart one or more other pulse trains

The pulse train engine feature is an alternate function associated with a GPIO pin. In most cases, enabling the pulse train engine function supersedes the GPIO function.

The MAX78000 provide up to four instances of the pulse train engine peripheral (PT[3:0]).

Serial Peripherals

I²C Interface (I2C)

The I²C interface is a bidirectional, two-wire serial bus that provides a medium-speed communications network. It can operate as a one-to-one, one-to-many or many-to-many communications medium. These engines support standard-

mode, fast-mode, fast-mode plus and high-speed mode I2C speeds. It provides the following features:

- Master or slave mode operation
  - Supports up to 4 different slave addresses in slave mode
- Supports standard 7-bit addressing or 10-bit addressing
- RESTART condition
- Interactive receive mode
- Tx FIFO preloading
- Support for clock stretching to allow slower slave devices to operate on higher speed busses
- Multiple transfer rates
  - Standard mode: 100kbps
  - Fast mode: 400kbps
  - Fast mode plus: 1000kbps
  - High-speed mode: 3.4Mbps
- Internal filter to reject noise spikes
- Receiver FIFO depth of 8 bytes
- Transmitter FIFO depth of 8 bytes

The MAX78000 provides three instances of the I2C peripheral—I2C0, I2C1, and I2C2.

I2S Interface (I2S)

The I2S interface is a bidirectional, four-wire serial bus that provides serial communications for codecs and audio amplifiers compliant with the I2S Bus Specification, June 5, 1996. It provides the following features:

- Master and slave mode operation
- Support for 4 channels
- 8, 16, 24, and 32 bit frames
- Receive and transmit DMA support
- Wakeup on FIFO status (full/empty/threshold)
- Pulse density modulation support for receive channel
- Word select polarity control
- First bit position selection
- Interrupts generated for FIFO status
- Receiver FIFO depth of 32 bytes
- Transmitter FIFO depth of 32 bytes

The MAX78000 provides one instance of the I2S peripheral (I2S0).

Serial Peripheral Interface (SPI)

SPI is a highly configurable, flexible, and efficient synchronous interface among multiple SPI devices on a single bus. The bus uses a single clock signal and multiple data signals, and one or more slave select lines to address only the intended target device. The SPI operates independently and requires minimal processor overhead.

The provided SPI peripherals can operate in either slave or master mode and provide the following features:

- SPI modes 0, 1, 2, or 3 for single-bit communication
- 3- or 4-wire mode for single-bit slave device communication
- Full-duplex operation in single-bit, 4-wire mode
- Dual and quad data modes supported
- Multiple slave selects on some instances
- Multimaster mode fault detection
- Programmable interface timing
- Programmable SCK frequency and duty cycle
- 32-byte transmit and receive FIFOs
- Slave select assertion and deassertion timing with respect to leading/trailing SCK edge

The MAX78000 provides two instances of the SPI peripheral—SPI0 and SPI1. See Table 5 for configuration options.

Table 5. SPI Configuration Options

INSTANCE	DATA	SLAVE SELECT LINES	MAXIMUM FREQUENCY MASTER MODE (MHz)	MAXIMUM FREQUENCY SLAVE MODE (MHz)
		81 CTBGA		
SPI0	3-wire, 4-wire, dual, or quad data support	3	50	50
SPI1	3-wire, 4-wire, dual, or quad data support	1	25	50

UART (UART, LPUART)

The universal asynchronous receiver-transmitter (UART, LPUART) interface supports full-duplex asynchronous communication with optional hardware flow control (HFC) modes to prevent data overruns. If HFC mode is enabled on a given port, the system uses two extra pins to implement the industry-standard request to send (RTS) and clear to send (CTS) flow control signaling. Each instance is individually programmable.

- 2-wire interface or 4-wire interface with flow control
- 8-byte send/receive FIFO
- Full-duplex operation for asynchronous data transfers
- Interrupts available for frame error, parity error, CTS, Rx FIFO overrun, and FIFO full/partially full conditions
- Automatic parity and frame error detection
- Independent baud-rate generator
- Programmable 9th-bit parity support
- Multidrop support
- Start/stop bit support
- Hardware flow control using RTS/CTS
- 12.5Mbps for UART maximum bit rate
- 1.85Mbps for LPUART maximum bit rate
- Two DMA channels can be connected (read and write FIFOs)
- Programmable word size (5 bits to 8 bits)

The MAX78000 provides four instances of the UART peripheral—UART0, UART1, UART2, and LPUART0. LPUART0 is capable of operation in the SLEEP, LOW POWER, and MICRO POWER modes. See Table 6 for configuration options.

Table 6. UART Configuration Options

INSTANCE NAME	REGISTER ACCESS NAME	HARDWARE FLOW CONTROL	POWER MODE	CLOCK SOURCE		
				PCLK	IBRO	ERTCO
UART0	UART0	Yes	ACTIVE, SLEEP, LOW POWER	Yes	Yes	No
UART1	UART1	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	No
UART2	UART2	No	ACTIVE, SLEEP, LOW POWER	Yes	Yes	No
LPUART0	UART3	No	ACTIVE, SLEEP, LOW POWER, MICRO POWER	No	Yes	Yes

1-Wire Master (OWM)

Maxim's 1-Wire bus consists of one signal that carries data and also supplies power to the slave devices and a ground return. The bus master communicates serially with one or more slave devices through the bidirectional, multidrop 1-Wire bus. The single-contact serial interface is ideal for communication networks requiring minimal interconnection.

The provided 1-Wire master supports the following features:

- Single contact for control and operation
- Unique factory identifier for any 1-Wire device
- Multiple device capability on a single line

The OWM supports both standard (15.6kbps) and overdrive (110kbps) speeds.

Standard DMA Controller

The standard DMA controller allows automatic one-way data transfer between two entities. These entities can be either memories or peripherals. The transfers are done without using CPU resources. The following transfer modes are supported:

- 4-channel
- Peripheral to data memory
- Data memory to peripheral
- Data memory to data memory
- Event support

All DMA transactions consist of an AHB burst read into the DMA FIFO followed immediately by an AHB burst write from the FIFO.

The MAX78000 provides one instance of the standard DMA controller.

Security

AES

The dedicated hardware-based AES engine supports the following algorithms:

- AES-128
- AES-192
- AES-256

The AES keys are automatically generated by the engine and stored in dedicated flash to protect against tampering. Key generation and storage is transparent to the user.

True Random Number Generator (TRNG) Non-Deterministic Random Bit Generator (NDRBG)

The device provides a non-deterministic entropy source that can be used to generate cryptographic seeds or strong encryption keys as part of an overall framework for a secure customer application.

Software can use random numbers to trigger asynchronous events that add complexity to program execution to thwart replay attacks or key search methodologies.

The TRNG can support the system-level validation of many security standards. Maxim Integrated will work directly with the customer’s validation laboratory to provide the laboratory with any required information. Contact Maxim Integrated for details of compliance with specific standards.

CRC Module

A cyclic redundancy check (CRC) hardware module provides fast calculations and data integrity checks by application software. It supports a user-defined programmable polynomial up to 32-bits. Direct memory access copies data into the CRC module so that CRC calculations on large blocks of memory are performed with minimal CPU intervention. Examples of common polynomials are depicted in Table 7.

Table 7. Common CRC Polynomials

ALGORITHM	POLYNOMIAL EXPRESSION	ORDER	POLYNOMIAL	CHECK
CRC-32-ETHERNET	$x^{32}+ x^{26}+ x^{23}+ x^{22}+ x^{16} + x^{12}+ x^{11}+ x^{10}+ x^8+ x^7+ x^5+ x^4+ x^2+ x^1+ x^0$	0xEDB8 8320	LSB	0xDEBB 20E3
CRC-CCITT	$x^{16}+ x^{12} + x^5 + x^0$	0x0000 8408	LSB	0x0000 F0B8
CRC-16	$x^{16}+ x^{15} + x^2 + x^0$	0x0000 A001	LSB	0x0000 B001
USB DATA	$x^{16}+ x^{15} + x^2+ x^0$	0x8005 0000	LSB	0x800D 0000
PARITY	$x^1+ x^0$	0x0000 0001	MSB	—

Bootloader

The bootloader allows loading and verification of program memory through a UART or SWD interface. It provides the following features:

- Program loading of Motorola® SREC format files
- Permanent lock state prevents altering or erasing program memory
- Access to the USN for device or customer application identification
- Disable SWD interface to block debug access port functionality

Secure Bootloader

Versions of the device which support the secure feature provides the following features:

- Optional challenge/response through secret HMAC SHA-256 authenticates host before executing bootloader commands
- Automatic program memory verification and authentication before execution after every reset (secure boot)

Debug and Development Interface (SWD, JTAG)

The serial wire debug interface is used for code loading and ICE debug activities for the CM4. JTAG interface is provided for the RV32. All devices in mass production have the debugging/development interface enabled.

Motorola is a registered trademark and registered service mark of Motorola Trademark Holdings, LLC.

Applications Information

Bypass Capacitors

The proper use of bypass capacitors reduces noise generated by the IC into the ground plane. The *Pin Descriptions* table indicates which pins should be connected to bypass capacitors, and the appropriate ground plane.

It is recommended that one instance of a bypass capacitor should be connected to each pin/ball of the IC package. For example, if the *Pin Descriptions* table shows 4 device pins associated with voltage supply A, a separate capacitor should be connected to each pin for a total of 4 capacitors.

Capacitors should be placed as close as possible to their corresponding device pins. Pin descriptions which indicate recommendations for more than one value of capacitor per pin should place them in parallel with the lowest value capacitor first, closest to the pin.

Ordering Information

PART	FLASH (KB)	SYSTEM RAM (KB)	BOOTLOADER	SECURE BOOTLOADER	PIN-PACKAGE
MAX78000EXG+	512	128 + ECC 8	Yes	No	81 CTBGA

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	08/20	Release for intro	—

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Maxim Integrated:

MAX78000EXG+ MAX78000FTHR#