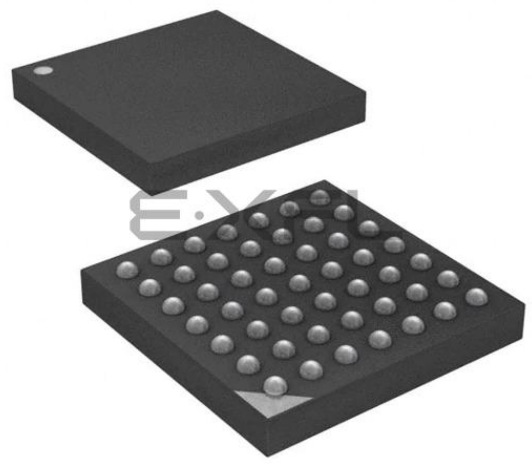

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Understanding Embedded - FPGAs (Field Programmable Gate Array)

Embedded - FPGAs, or Field Programmable Gate Arrays, are advanced integrated circuits that offer unparalleled flexibility and performance for digital systems. Unlike traditional fixed-function logic devices, FPGAs can be programmed and reprogrammed to execute a wide array of logical operations, enabling customized functionality tailored to specific applications. This reprogrammability allows developers to iterate designs quickly and implement complex functions without the need for custom hardware.

Applications of Embedded - FPGAs

The versatility of Embedded - FPGAs makes them indispensable in numerous fields. In telecommunications.

Details	
Product Status	Obsolete
Number of LABs/CLBs	125
Number of Logic Elements/Cells	1000
Total RAM Bits	65536
Number of I/O	37
Number of Gates	-
Voltage - Supply	1.14V ~ 1.26V
Mounting Type	Surface Mount
Operating Temperature	-40°C ~ 100°C (TJ)
Package / Case	49-VFBGA
Supplier Device Package	49-UCBGA (3x3)
Purchase URL	https://www.e-xfl.com/product-detail/lattice-semiconductor/ice40lm1k-cm49

Table 1-1. iCE40LM Family Selection Guide

Part Number	iCE40LM1K	iCE40LM2K	iCE40LM4K
Logic Cells (LUT + Flip-Flop)	1000	2000	3520
RAM4K Memory Blocks	16	20	20
RAM4K RAM Bits	64K	80K	80K
Package	Programmable I/O Count		
25-pin WLCSP, 1.71 x 1.71 mm, 0.35mm	18	18	18
36-pin ucBGA, 2.5 x 2.5 mm, 0.40mm	28	28	28
49-pin ucBGA, 3 x 3 mm, 0.40mm	37	37	37

Introduction

The iCE40LM family of ultra-low power FPGAs has three devices with densities ranging from 1000 to 3520 Look-Up Tables (LUTs). In addition to LUT-based, low-cost programmable logic, these devices also feature Embedded Block RAM (EBR), two Strobe Generators (LPSG, HSSG), two hardened I^2C Controllers and two hardened SPI Controllers. These features allow the devices to be used in low-cost, high-volume consumer and mobile applications,

The iCE40LM devices are fabricated on a 40nm CMOS low power process. The device architecture has several features such as user configurable I^2C and SPI Controllers, either as master or slave, and two Strobe Generators.

The iCE40LM FPGAs are available in very small form factor packages, with the smallest in 25-pin WLCSP. The 25-pin WLCSP package has a 0.35mm ball pitch, resulting to an overall package size of 1.71mm x 1.71mm that easily fits into a lot of mobile applications. Table 1-1 shows the LUT densities, package and I/O pin count.

The iCE40LM devices offer enhanced I/O features such as pull-up resistors. Pull-up features are controllable on a "per-pin" basis.

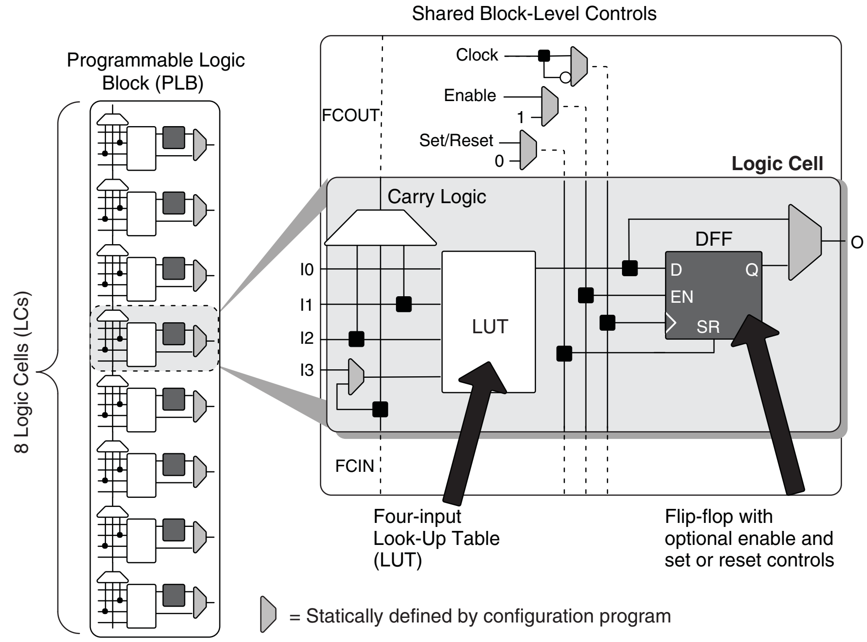
Lattice provides a variety of design tools that allow complex designs to be efficiently implemented using the iCE40LM family of devices. Popular logic synthesis tools provide synthesis library support for iCE40LM. Lattice design tools use the synthesis tool output along with the user-specified preferences and constraints to place and route the design in the iCE40LM device. These tools extract the timing from the routing and back-annotate it into the design for timing verification.

Lattice provides many pre-engineered IP (Intellectual Property) modules, including a number of reference designs, licensed free of charge, optimized for the iCE40LM FPGA family. Lattice also can provide fully verified bit-stream for some of the widely used target functions in mobile device applications, such as ultra-low power sensor management, gesture recognition, IR remote, barcode emulator functions. Users can use these functions as offered by Lattice, or they can use the design to create their own unique required functions. For more information regarding Lattice's Reference Designs or fully-verified bitstreams, please contact your local Lattice representative.

PLB Blocks

The core of the iCE40LM device consists of Programmable Logic Blocks (PLB) which can be programmed to perform logic and arithmetic functions. Each PLB consists of eight interconnected Logic Cells (LC) as shown in Figure 2-2. Each LC contains one LUT and one register.

Figure 2-2. PLB Block Diagram



Logic Cells

Each Logic Cell includes three primary logic elements shown in Figure 2-2.

- A four-input Look-Up Table (LUT) builds any combinational logic function, of any complexity, requiring up to four inputs. Similarly, the LUT element behaves as a 16x1 Read-Only Memory (ROM). Combine and cascade multiple LUTs to create wider logic functions.
- A 'D'-style Flip-Flop (DFF), with an optional clock-enable and reset control input, builds sequential logic functions. Each DFF also connects to a global reset signal that is automatically asserted immediately following device configuration.
- Carry Logic boosts the logic efficiency and performance of arithmetic functions, including adders, subtracters, comparators, binary counters and some wide, cascaded logic functions.

Table 2-1. Logic Cell Signal Descriptions

Function	Type	Signal Names	Description
Input	Data signal	I0, I1, I2, I3	Inputs to LUT
Input	Control signal	Enable	Clock enable shared by all LCs in the PLB
Input	Control signal	Set/Reset[1]	Asynchronous or synchronous local set/reset shared by all LCs in the PLB.
Input	Control signal	Clock	Clock one of the eight Global Buffers, or from the general-purpose interconnects fabric shared by all LCs in the PLB
Input	Inter-PLB signal	FCIN	Fast carry in
Output	Data signals	O	LUT or registered output
Output	Inter-PFU signal	FCOUT	Fast carry out

1. If Set/Reset is not used, then the flip-flop is never set/reset, except when cleared immediately after configuration.

Routing

There are many resources provided in the iCE40LM devices to route signals individually with related control signals. The routing resources consist of switching circuitry, buffers and metal interconnect (routing) segments.

The inter-PLB connections are made with three different types of routing resources: Adjacent (spans two PLBs), x4 (spans five PLBs) and x12 (spans thirteen PLBs). The Adjacent, x4 and x12 connections provide fast and efficient connections in the diagonal, horizontal and vertical directions.

The design tool takes the output of the synthesis tool and places and routes the design.

Clock/Control Distribution Network

Each iCE40LM device has six global inputs, two pins on the top bank and four pins on the bottom bank

These global inputs can be used as high fanout nets, clock, reset or enable signals. The dedicated global pins are identified as Gxx and the global buffers are identified as GBUF[7:0]. These six inputs may be used as general purpose I/O if they are not used to drive the clock nets.

Table 2-2 lists the connections between a specific global buffer and the inputs on a PLB. All global buffers optionally connect to the PLB CLK input. Any four of the eight global buffers can drive logic inputs to a PLB. Even-numbered global buffers optionally drive the Set/Reset input to a PLB. Similarly, odd-numbered buffers optionally drive the PLB clock-enable input. GBUF[7:6, 3:0] can connect directly to G[7:6, 3:0] pins respectively. GBUF4 and GBUF5 can connect to the two on-chip Strobe Generators (GBUF4 connects to LPSG, GBUF5 connects to HSSG).

Table 2-2. Global Buffer (GBUF) Connections to Programmable Logic Blocks

Global Buffer	LUT Inputs	Clock	Clock Enable	Reset
GBUF0	Yes, any 4 of 8 GBUF Inputs	✓	✓	
GBUF1		✓		✓
GBUF2		✓	✓	
GBUF3		✓		✓
GBUF4		✓	✓	
GBUF5		✓		✓
GBUF6		✓	✓	
GBUF7		✓		✓

The maximum frequency for the global buffers are shown in the iCE40LM External Switching Characteristics tables later in this document.

Global Hi-Z Control

The global high-impedance control signal, GHIZ, connects to all I/O pins on the iCE40LM device. This GHIZ signal is automatically asserted throughout the configuration process, forcing all user I/O pins into their high-impedance state.

Global Reset Control

The global reset control signal connects to all PLB and PIO flip-flops on the iCE40LM device. The global reset signal is automatically asserted throughout the configuration process, forcing all flip-flops to their defined wake-up state. For PLB flip-flops, the wake-up state is always reset, regardless of the PLB flip-flop primitive used in the application.

RAM Initialization and ROM Operation

If desired, the contents of the RAM can be pre-loaded during device configuration.

By preloading the RAM block during the chip configuration cycle and disabling the write controls, the sysMEM block can also be utilized as a ROM.

Memory Cascading

Larger and deeper blocks of RAM can be created using multiple EBR sysMEM Blocks.

RAM4k Block

Figure 2-4 shows the 256x16 memory configurations and their input/output names. In all the sysMEM RAM modes, the input data and addresses for the ports are registered at the input of the memory array.

Figure 2-4. sysMEM Memory Primitives

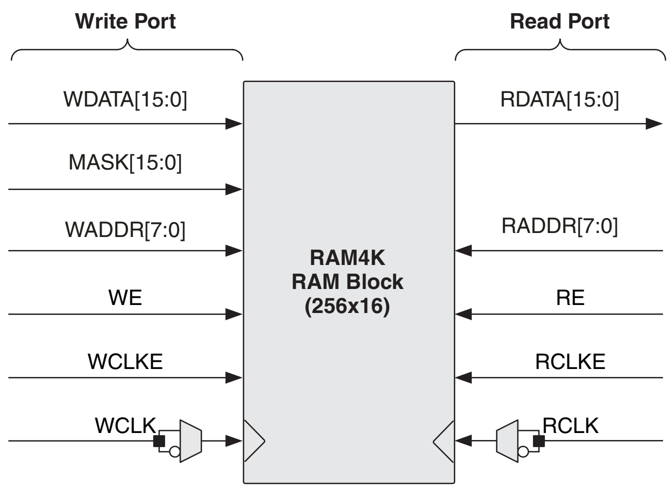


Table 2-5. EBR Signal Descriptions

Signal Name	Direction	Description
WDATA[15:0]	Input	Write Data input.
MASK[15:0]	Input	Masks write operations for individual data bit-lines. 0 = write bit; 1 = don't write bit
WADDR[7:0]	Input	Write Address input. Selects one of 256 possible RAM locations.
WE	Input	Write Enable input.
WCLKE	Input	Write Clock Enable input.
WCLK	Input	Write Clock input. Default rising-edge, but with falling-edge option.
RDATA[15:0]	Output	Read Data output.
RADDR[7:0]	Input	Read Address input. Selects one of 256 possible RAM locations.
RE	Input	Read Enable input.
RCLKE	Input	Read Clock Enable input.
RCLK	Input	Read Clock input. Default rising-edge, but with falling-edge option.

The iCE40LM EBR block functions the same as EBR blocks in the iCE40 family. For further information on the sysMEM EBR block, please refer to TN1250, Memory Usage Guide for iCE40 Devices.

Figure 2-6. iCE I/O Register Block Diagram

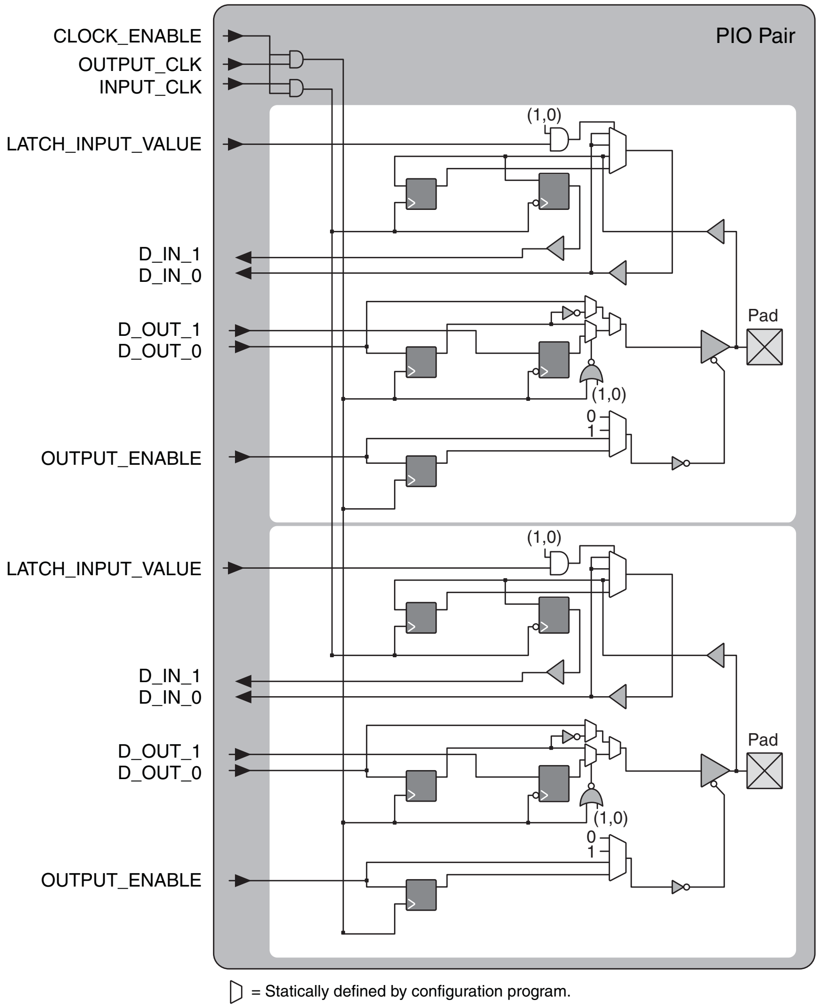


Table 2-6. PIO Signal List

Pin Name	I/O Type	Description
OUTPUT_CLK	Input	Output register clock
CLOCK_ENABLE	Input	Clock enable
INPUT_CLK	Input	Input register clock
OUTPUT_ENABLE	Input	Output enable
D_OUT_0/1	Input	Data from the core
D_IN_0/1	Output	Data to the core
LATCH_INPUT_VALUE	Input	Latches/holds the Input Value

sysIO Buffer

Each I/O is associated with a flexible buffer referred to as a sysIO buffer. These buffers are arranged around the periphery of the device in groups referred to as banks. The sysIO buffers allow users to implement a wide variety of standards that are found in today's systems with LVCMOS interfaces.

User I^2C IP

The iCE40LM devices have two I^2C IP cores. Either of the two cores can be configured either as an I^2C master or as an I^2C slave. Both I^2C cores have preassigned pins, or user can select different pins, when the core is used.

When the IP core is configured as master, it will be able to control other devices on the I^2C bus through the pre-assigned pin interface. When the core is configured as the slave, the device will be able to provide I/O expansion to an I^2C Master. The I^2C cores support the following functionality:

- Master and Slave operation
- 7-bit and 10-bit addressing
- Multi-master arbitration support
- Clock stretching
- Up to 400 KHz data transfer speed
- General Call support

For further information on the User I^2C, please refer to TN1274, iCE40LM SPI/I2C Hardened IP Usage Guide.

User SPI IP

The iCE40LM devices have two SPI IP cores. Both SPI cores have preassigned pins, or user can select different pins, when the SPI core is used. Both SPI IP core can be configured as a SPI master or as a slave. When the SPI IP core is configured as a master, it controls the other SPI enabled devices connected to the SPI Bus. When SPI IP core is configured as a slave, the device will be able to interface to an external SPI master.

The SPI IP core supports the following functions:

- Configurable Master and Slave modes
- Full-Duplex data transfer
- Mode fault error flag with CPU interrupt capability
- Double-buffered data register
- Serial clock with programmable polarity and phase
- LSB First or MSB First Data Transfer

For further information on the User SPI, please refer to TN1274, iCE40LM SPI/I2C Hardened IP Usage Guide.

High Drive I/O Pins

The iCE40LM family devices offer 3 High Drive (HD) outputs in each device in the family. The HD outputs are ideal to drive LED signals on mobile application.

These HD outputs can be driven in different drive modes. The default is standard drive, which source/sink 8mA current nominally. When HD drive option is selected, these HD outputs can source/sink 24mA current nominally.

The pins on the HD I/Os are labeled with HD in it.

Power On Reset

iCE40LM devices have power-on reset circuitry to monitor V_{CC}, V_{CCIO_2} and V_{CC_SPI} voltage levels during power-up and operation. At power-up, the POR circuitry monitors these voltage levels. It then triggers download from the external Flash memory after reaching the power-up levels specified in the Power-On-Reset Voltage table in the DC and Switching Characteristics section of this data sheet. Before and during configuration, the I/Os are held in tri-state. I/Os are released to user functionality once the device has finished configuration.

iCE40LM Configuration

This section describes the programming and configuration of the iCE40LM family.

Device Configuration

There are various ways to configure the Configuration RAM (CRAM) including:

- From a SPI Flash (Master SPI mode)
- System microprocessor to drive a Serial Slave SPI port (SSPI mode)

For more details on configuring the iCE40LM, please see TN1248, iCE40 Programming and Configuration.

Power Saving Options

The iCE40LM devices feature iCEGate and PLL low power mode to allow users to meet the static and dynamic power requirements of their applications. Table 2-9 describes the function of these features.

Table 2-9. iCE40LM Power Saving Features Description

Device Subsystem	Feature Description
PLL	When LATCHINPUTVALUE is enabled, forces the PLL into low-power mode; PLL output held static at last input clock value.
iCEGate	To save power, the optional iCEGate latch can selectively freeze the state of individual, non-registered inputs within an I/O bank. Registered inputs are effectively frozen by their associated clock or clock-enable control.

October 2013 | Advance Data Sheet DS1045

Absolute Maximum Ratings[1, 2, 3]

Supply Voltage V_{CC} . . . . -0.5 to 1.42V

Output Supply Voltage V_{CCIO} and V_{CC_SPI} . . . . -0.5 to 3.60V

PLL Power Supply, V_{CCPLL} . . . . -0.5 to 1.3V

I/O Tri-state Voltage Applied. . . . . -0.5 to 3.60V

Dedicated Input Voltage Applied . . . . -0.5 to 3.60V

Storage Temperature (Ambient). . . . . -65°C to 150°C

Junction Temperature (T_J) . . . . -55°C to 125°C

1. Stress above those listed under the "Absolute Maximum Ratings" may cause permanent damage to the device. Functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.
2. Compliance with the Lattice Thermal Management document is required.
3. All voltages referenced to GND.

Recommended Operating Conditions[1]

Symbol	Parameter		Min.	Max.	Units
V_{CC}[1]	Core Supply Voltage		1.14	1.26	V
V_{CCIO}[1, 2, 3]	I/O Driver Supply Voltage	V_{CCIO_0}, V_{CCIO_2}	1.71	3.46	V
V_{CCPLL}[4]	PLL Power Supply Voltage		1.14	1.26	V
V_{CC_SPI}[5]	Config SPI port Power Supply Voltage		1.71	3.46	V
t_{JIND}	Junction Temperature Industrial Operation		-40	100	°C

1. Like power supplies must be tied together. V_{CC} to V_{CCPLL}, V_{CCIO_0} to V_{CCIO_2} if they are at same supply voltage.
2. See recommended voltages by I/O standard in subsequent table.
3. V_{CCIO} pins of unused I/O banks should be connected to the V_{CC} power supply on boards.
4. For 25-pin WLCSP, PLL is not supported.
5. For 25-pin WLCSP, V_{CC_SPI} is connected to V_{CCIO_2} on the package. For all other packages, V_{CC_SPI} is used to power the SPI1 ports in both configuration mode and user mode.

Power Supply Ramp Rates[1]

Symbol	Parameter	Min.	Max.	Units
t_{RAMP}	Power supply ramp rates for all power supplies.	0.6	10	V/ms

1. Assumes monotonic ramp rates.

Supply Current [1, 2, 3, 4]

Symbol	Parameter	Typ. VCC[4]	Units
$I_{CCSTDBY}$	Core Power Supply Static Current	100	µA
$I_{CCPLLSTDBY}$	PLL Power Supply Static Current		µA
$I_{CCIOSTDBY}$, $I_{CC\_SPISTDBY}$	V_{CCIO}, V_{CC_SPI} Power Supply Static Current		µA
I_{CCPEAK}	Core Power Supply Startup Peak Current		µA
$I_{CCPLLPEAK}$	PLL Power Supply Startup Peak Current		µA
$I_{CCIOPEAK}$, $I_{CC\_SPIPEAK}$	V_{CCIO}, V_{CC_SPI} Power Supply Startup Peak Current		µA

1. Assumes blank pattern with the following characteristics: all outputs are tri-stated, all inputs are configured as LVCMOS and held at V_{CCIO} or GND, on-chip PLL is off. For more detail with your specific design, use the Power Calculator tool. Power specified with master SPI configuration mode. Other modes may be up to 25% higher.
2. Frequency = 0 MHz.
3. TJ = 25°C, power supplies at nominal voltage.
4. Does not include pull-up.
5. For 25-pin WLCSP, V_{CCPLL} is tied internally on the package, and V_{CC_SPI} is also connected to V_{CCIO_2} on the package.

User I²C Specifications

Parameter Symbol	Parameter Description	spec (STD Mode)			spec (FAST Mode)			Units
		Min	Typ	Max	Min	Typ	Max	
f_{SCL}	Maximum SCL clock frequency	—	—	100	—	—	400	KHz
t_{HI}	SCL clock HIGH Time	4	—	—	0.6	—	—	us
t_{LO}	SCL clock LOW Time	4.7	—	—	1.3	—	—	us
$t_{SU,DAT}$	Setup time (DATA)	250	—	—	100	—	—	ns
$t_{HD,DAT}$	Hold time (DATA)	0	—	—	0	—	—	ns
$t_{SU,STA}$	Setup time (START condition)	4.7	—	—	0.6	—	—	us
$t_{HD,STA}$	Hold time (START condition)	4	—	—	0.6	—	—	us
$t_{SU,STO}$	Setup time (STOP condition)	4	—	—	0.6	—	—	us
t_{BUF}	Bus free time between STOP and START	4.7	—	—	1.3	—	—	us
$t_{CO,DAT}$	SCL LOW to DATAOUT valid	—	—	3.4	—	—	0.9	us

User SPI Specifications

Parameter Symbol	Parameter Description	Min	Typ	Max	Units
f_{MAX}	Maximum SCK clock frequency	—	—	45	MHz
t_{HI}	HIGH period of SCK clock	9	—	—	ns
t_{LO}	LOW period of SCK clock	9	—	—	ns
$t_{SUmaster}$	Setup time (master mode)	2	—	—	ns
$t_{HOLDmaster}$	Hold time (master mode)	5	—	—	ns
$t_{SUslave}$	Setup time (slave mode)	2	—	—	ns
$t_{HOLDslave}$	Hold time (slave mode)	5	—	—	ns
$t_{SCK2OUT}$	SCK to out (slave mode)	—	—	13.5	ns

sysIO Recommended Operating Conditions

Standard	V_{CCIO} (V)		
	Min.	Typ.	Max.
LVCMOS 3.3	3.14	3.3	3.46
LVCMOS 2.5	2.37	2.5	2.62
LVCMOS 1.8	1.71	1.8	1.89

sysIO Single-Ended DC Electrical Characteristics

Input/ Output Standard	V_{IL}		V_{IH} [1]		V_{OL} Max. (V)	V_{OH} Min. (V)	I_{OL} Max. (mA)	I_{OH} Max. (mA)
	Min. (V)	Max. (V)	Min. (V)	Max. (V)				
LVCMOS 3.3	-0.3	0.8	2.0	V_{CCIO} + 0.2V	0.4	V_{CCIO} - 0.5	8	-8
					0.2	V_{CCIO} - 0.2	0.1	-0.1
LVCMOS 2.5	-0.3	0.7	1.7	V_{CCIO} + 0.2V	0.4	V_{CCIO} - 0.5	6	-6
					0.2	V_{CCIO} - 0.2	0.1	-0.1
LVCMOS 1.8	-0.3	0.35V_{CCIO}	0.65V_{CCIO}	V_{CCIO} + 0.2V	0.4	V_{CCIO} - 0.4	4	-4
					0.2	V_{CCIO} - 0.2	0.1	-0.1

1. Some products are clamped to a diode when V_{IN} is larger than V_{CCIO}.

Typical Building Block Function Performance[1, 2]

Pin-to-Pin Performance (LVCMOS25)

Function	Timing	Units
Basic Functions		
16-bit decoder	16.5	ns
4:1 MUX	18.0	ns
16:1 MUX	19.5	ns

Register-to-Register Performance

Function	Timing	Units
Basic Functions		
16:1 MUX	110	MHz
16-bit adder	100	MHz
16-bit counter	100	MHz
64-bit counter	40	MHz
Embedded Memory Functions		
256x16 Pseudo-Dual Port RAM	150	MHz

1. The above timing numbers are generated using the iCECube2 design tool. Exact performance may vary with device and tool version. The tool uses internal parameters that have been characterized but are not tested on every device.
2. Using a V_{CC} of 1.14V at Junction Temp 85C.

Derating Logic Timing

Logic timing provided in the following sections of the data sheet and the Lattice design tools are worst case numbers in the operating range. Actual delays may be much faster. Lattice design tools can provide logic timing numbers at a particular temperature and voltage.

Maximum sysIO Buffer Performance[1]

I/O Standard	Max. Speed	Units
Inputs		
LVCMOS33		MHz
LVCMOS25		MHz
LVCMOS18		MHz
Outputs		
LVCMOS33		MHz
LVCMOS25		MHz
LVCMOS18		MHz

1. Measured with a toggling pattern

iCE40LM Family Timing Adders

Over Recommended Commercial Operating Conditions[1, 2, 3]

Buffer Type	Description	Timing	Units
Input Adjusters			
LVCMOS33	LVCMOS, V_{CCIO} = 3.3V	0.18	nS
LVCMOS25	LVCMOS, V_{CCIO} = 2.5V	0.00	nS
LVCMOS18	LVCMOS, V_{CCIO} = 1.8V	0.19	nS
Output Adjusters			
LVCMOS33	LVCMOS, V_{CCIO} = 3.3V	-0.12	nS
LVCMOS25	LVCMOS, V_{CCIO} = 2.5V	0.00	nS
LVCMOS18	LVCMOS, V_{CCIO} = 1.8V	1.32	nS

1. Timing adders are relative to LVCMOS25 and characterized but not tested on every device.
2. LVCMOS timing measured with the load specified in Switching Test Condition table.
3. Commercial timing numbers are shown.

iCE40LM External Switching Characteristics

Over Recommended Commercial Operating Conditions

Parameter	Description	Device			Units
Clocks					
Global Clocks					
f_{MAX_GBUF}	Frequency for Global Buffer Clock network	All devices		185	MHz
t_{W_GBUF}	Clock Pulse Width for Global Buffer	All devices	TBD	—	ns
t_{SKEW_GBUF}	Global Buffer Clock Skew Within a Device	All devices	—	650	ps
Pin-LUT-Pin Propagation Delay					
t_{PD}	Best case propagation delay through one LUT logic	All devices	—	14.0	ns
General I/O Pin Parameters (Using Global Buffer Clock without PLL)					
t_{SKEW_IO}	Data bus skew across a bank of IOs	All devices	—	400	ps
t_{CO}	Clock to Output - PIO Output Register	All devices	—	9.0	ns
t_{SU}	Clock to Data Setup - PIO Input Register	All devices		—	ns
t_H	Clock to Data Hold - PIO Input Register	All devices	5.55	—	ns
General I/O Pin Parameters (Using Global Buffer Clock with PLL)[1]					
t_{CO}	Clock to Output - PIO Output Register	All devices	—	TBD	ns
t_{SU}	Clock to Data Setup - PIO Output Register	All devices	TBD	—	ns
t_H	Clock to Data Hold - PIO Output Register	All devices	TBD	—	ns

1. 25-pin WLCSP package does not support PLL.

sysCLOCK PLL Timing – Preliminary

Over Recommended Operating Conditions

Parameter	Descriptions	Conditions	Min.	Max.	Units
f_{IN}	Input Clock Frequency (REFERENCECLK, EXTFEEDBACK)		TBD	TBD	MHz
f_{OUT}	Output Clock Frequency (PLLOUT)		TBD	TBD	MHz
f_{VCO}	PLL VCO Frequency		TBD	TBD	MHz
f_{PFD}	Phase Detector Input Frequency		TBD	TBD	MHz
AC Characteristics					
t_{DT}	Output Clock Duty Cycle			TBD	%
t_{PH}	Output Phase Accuracy		—	TBD	deg
t_{OPJIT}[1, 5]	Output Clock Period Jitter	f_{OUT} <= 100 MHz	—	TBD	ps p-p
		f_{OUT} > 100 MHz	—	TBD	UIPP
	Output Clock Cycle-to-cycle Jitter	f_{OUT} <= 100 MHz	—	TBD	ps p-p
		f_{OUT} > 100 MHz	—	TBD	UIPP
	Output Clock Phase Jitter	f_{PFD} <= 25 MHz	—	TBD	ps p-p
		f_{PFD} > 25 MHz	—	TBD	UIPP
t_W	Output Clock Pulse Width	At 90% or 10%		TBD	ns
t_{LOCK}[2, 3]	PLL Lock-in Time		—	TBD	us
t_{UNLOCK}	PLL Unlock Time		—	TBD	ns
t_{IPJIT}[4]	Input Clock Period Jitter	$f_{PFD} \geq 20$ MHz	—	TBD	ps p-p
		$f_{PFD} < 20$ MHz	—	TBD	UIPP
t_{FDTAP}	Fine Delay adjustment, per Tap		—	TBD	ps
t_{STABLE}[3]	LATCHINPUTVALUE LOW to PLL Stable		—	TBD	ns
t_{STABLE_PW}[3]	LATCHINPUTVALUE Pulse Width		—	TBD	ns
t_{RST}	RESET Pulse Width		TBD	TBD	ns
t_{RSTREC}	RESET Recovery Time		TBD	TBD	ns
$t_{DYNAMIC\_WD}$	DYNAMICDELAY Pulse Width		TBD	TBD	VCO Cycles

1. Period jitter sample is taken over 10,000 samples of the primary PLL output with a clean reference clock. Cycle-to-cycle jitter is taken over 1000 cycles. Phase jitter is taken over 2000 cycles. All values per JESD65B.
2. Output clock is valid after t_{LOCK} for PLL reset and dynamic delay adjustment.
3. At minimum f_{PFD}. As the f_{PFD} increases the time will decrease to approximately 60% the value listed.
4. Maximum limit to prevent PLL unlock from occurring. Does not imply the PLL will operate within the output specifications listed in this table.
5. The jitter values will increase with loading of the PLD fabric and in the presence of SSO noise.

SPI Master Configuration Time[1]

Symbol	Parameter	Conditions	Max.	Units
t_{CONFIG}	POR/CRESET_B to Device I/O Active	All devices - Low Frequency (Default)	70	ms
		All devices - Medium frequency	35	ms
		All devices - High frequency	18	ms

1. Assumes sysMEM Block is initialized to an all zero pattern if they are used.

sysCONFIG Port Timing Specifications

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
All Configuration Modes						
t_{CRESET_B}	Minimum CRESET_B LOW pulse width required to restart configuration, from falling edge to rising edge		200	—	—	ns
t_{DONE_IO}	Number of configuration clock cycles after CDONE goes HIGH before the PIO pins are activated		49	—	—	Cycles
Slave SPI						
t_{CR_SCK}	Minimum time from a rising edge on CRESET_B until the first SPI WRITE operation, first SPI_XCK clock. During this time, the iCE40LM device is clearing its internal configuration memory		1200	—	—	us
f_{MAX}	CCLK clock frequency	Write	1	—	25	MHz
		Read[1]	—	15	—	MHz
t_{CCLKH}	CCLK clock pulsewidth HIGH		20	—	—	ns
t_{CCLKL}	CCLK clock pulsewidth LOW		20	—	—	ns
t_{STSU}	CCLK setup time		12	—	—	ns
t_{STH}	CCLK hold time		12	—	—	ns
t_{STCO}	CCLK falling edge to valid output		13	—	—	ns
Master SPI						
f_{MCLK}	MCLK clock frequency	Low Frequency (Default)	6			MHz
		Medium Frequency[2]	18			MHz
		High Frequency[2]	31			MHz
t_{MCLK}	CRESET_B HIGH to first MCLK edge		1200	—	—	us

1. Supported with 1.2V Vcc and at 25C.
2. Extended range f_{MAX} Write operation support up to 53MHz with 1.2V V_{CC} and at 25C.

Switching Test Conditions

Figure 3-1 shows the output test load used for AC testing. The specific values for resistance, capacitance, voltage, and other test conditions are shown in Table 3-1.

Figure 3-1. Output Test Load, LVCMOS Standards

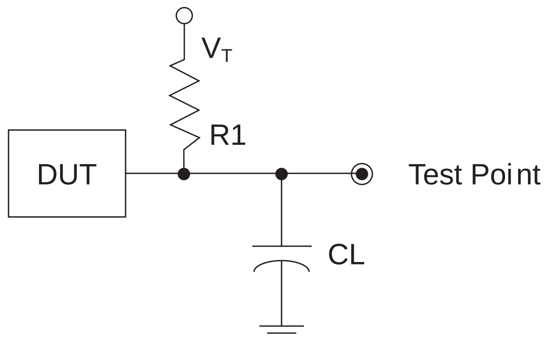


Table 3-1. Test Fixture Required Components, Non-Terminated Interfaces

Test Condition	R_1	C_L	Timing Reference	V_T
LVCMOS settings (L -> H, H -> L)	∞	0 pF	LVCMOS 3.3 = 1.5V	—
			LVCMOS 2.5 = $V_{CCIO}/2$	—
			LVCMOS 1.8 = $V_{CCIO}/2$	—
LVCMOS 3.3 (Z -> H)	188	0 pF	1.5	V_{OL}
LVCMOS 3.3 (Z -> L)			1.5	V_{OH}
Other LVCMOS (Z -> H)			$V_{CCIO}/2$	V_{OL}
Other LVCMOS (Z -> L)			$V_{CCIO}/2$	V_{OH}
LVCMOS (H -> Z)			V_{OH} - 0.15	V_{OL}
LVCMOS (L -> Z)			V_{OL} - 0.15	V_{OH}

Note: Output test conditions for all other interfaces are determined by the respective standards.

Signal Descriptions

Signal Name	Function	I/O	Description
Power Supplies			
V_{CC}	Power	-	Core Power Supply
V_{CCIO_0}	Power	-	Power Supply for I/Os in Bank 0
V_{CCIO_2}	Power	-	Power Supply for I/Os in Bank 2
V_{CC_SPI}	Power	-	Power supply for SPI1 ports. For 25-pin WLCSP, this signal is connected to V_{CCIO_2}
V_{CCPLL}	Power	-	Power supply for PLL. For 25-pin WLCSP, this is connected internally to V_{CC}
GND/GNDPLL	GROUND	-	Ground
Dedicated Configuration Signals			
CRESET	Configuration	I	Configuration Reset, active LOW. No internal pull-up resistor. Either actively driven externally or connect an 10K-ohm pull-up resistor to V_{CCIO_2}.
CDONE	Configuration	I/O	Configuration Done. Includes a weak pull-up resistor to VCCIO_2.
SPI and Config SPI Ports			
SPI1_SCK/PIO[T/B]_x[HD]	User SPI1	I/O	In user mode, used as CLK signal on SPI interface for sensor management function.
	Configuration	I/O	This pins is shared with device configuration. During configuration, this pin is CLK signal connecting to external SPI memory
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI1_MISO/PIO[T/B]_x[HD]	User SPI1	I/O	In user mode, used as Input (Master Mode) or Output (Slave Mode) signal on SPI interface for sensor management function.
	Configuration	I/O	This pins is shared with device configuration. During configuration, this pin is Input signal connecting to external SPI memory.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI1_MOSI/PIO[T/B]_x[HD]	User SPI1	I/O	In user mode, used as Output (Master Mode) or Input (Slave Mode) signal on SPI interface for sensor management function.
	Configuration	I/O	This pins is shared with device configuration. During configuration, this pin is Output signal connecting to external SPI memory.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O

Signal Name	Function	I/O	Description
SPI1_CSN/PIO[T/B]_x[HD]	User SPI1	I/O	In user mode, used as CSN signal on SPI interface for sensor management function. This pin is output pin in Master Mode, and input in in Slave Mode.
	Configuration	I/O	This pins is shared with device configuration. During configuration, this pin is CSN signal connecting to external SPI memory
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI2_SCK/PIO[T/B]_x[HD]	User SPI2	I/O	In user mode, used as CLK signal on SPI interface for sensor management function.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI2_MISO/PIO[T/B]_x[HD]	User SPI2	I/O	In user mode, used as Input (Master Mode) or Output (Slave Mode) signal on SPI interface for sensor management function.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI2_MOSI/PIO[T/B]_x[HD]	User SPI2	I/O	In user mode, used as Output (Master Mode) or Input (Slave Mode) signal on SPI interface for sensor management function.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
SPI2_CSN/PIO[T/B]_x[HD]	User SPI2	I/O	In user mode, used as CSN signal on SPI interface for sensor management function. This pin is output pin in Master Mode, and input in in Slave Mode.
	General I/O	I/O	In user mode, when the SPI interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
I^{2}C Ports			
I2C1_SCL/PIO[T/B]_x[HD]	User I2C1	I/O	Used as CLK signal on I^{2}C interface for sensor management function.
	General I/O	I/O	When the I^{2}C interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
I2C1_SDA/PIO[T/B]_x[HD]	User I2C1	I/O	Used as Data signal on I^{2}C interface for sensor management function.
	General I/O	I/O	When the I^{2}C interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O

Signal Name	Function	I/O	Description
I2C2_SCL/PIO[T/B]_x[HD]	User I2C2	I/O	Used as CLK signal on I^2C interface for sensor management function.
	General I/O	I/O	When the I^2C interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
I2C2_SDA/PIO[T/B]_x[HD]	User I2C2	I/O	Used as Data signal on I^2C interface for sensor management function.
	General I/O	I/O	When the I^2C interface is not used, user can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
Global Signals			
PIO[T/B]_x[HD]/Gn	General I/O	I/O	User can program this pin as general I/O pin for user functions. (x represents ball on the package) [T/B]: T=Vccio_0 bank, B=Vccio_2 bank. [HD]=High Drive I/O
	Global Signal	I	Global input used for high fanout, or clock/reset net. n=0,1,2,3,6,7. The Gn Global input pin can drive the corresponding GBUFn global buffer.
General Purpose I/O			
PIO[T/B]_x[HD]	General I/O	I/O	User can program this pin as general I/O pin for user functions. (x represents ball on the package)

Pin Information Summary

Pin Type		iCE40LM-1K			iCE40LM-2K			iCE40LM-4K		
		SWG25	CM36	CM49	SWG25	CM36	CM49	SWG25	CM36	CM49
General Purpose I/O Per Bank	Bank 0	7	15	20	7	15	20	7	15	20
	Bank 2[1]	11	13	17	11	13	17	11	13	17
Total General Purpose I/Os		18	28	37	18	28	37	18	28	37
Vcc		1	1	2	1	1	2	1	1	2
Vccio	Bank 0	1	1	1	1	1	1	1	1	1
	Bank 2	1	1	1	1	1	1	1	1	1
V_{CC_SPI}		0	0	1	0	0	1	0	0	1
V_{CCPLL}		0	1	1	0	1	1	0	1	1
Miscellaneous Dedicated Pins		2	2	2	2	2	2	2	2	2
GND		2	2	4	2	2	4	2	2	4
NC		0	0	0	0	0	0	0	0	0
Reserved		0	0	0	0	0	0	0	0	0
Total Balls		25	36	49	25	36	49	25	36	49
SPI Interfaces	Bank 0	0	0	0	0	0	0	0	0	0
	Bank 2	1	1	1	2	2	2	2	2	2
I^2C Interfaces	Bank 0	1	1	1	2	2	2	2	2	2
	Bank 2	0	0	0	0	0	0	0	0	0

1. Including General Purpose I/Os powered by V_{CC_SPI} and V_{CCPLL}.

iCE40LM Family Data Sheet Supplemental Information

For Further Information

A variety of technical notes for the iCE40 family are available on the Lattice web site.

- TN1248, iCE40 Programming and Configuration
- TN1274, iCE40LM SPI/I2C Hardened IP Usage Guide
- TN1275, iCE40LM On-Chip Strobe Generator Usage Guide
- TN1276, iCE40LM Advanced SPI/I2C Hardened IP Usage Guide
- TN1250, Memory Usage Guide for iCE40 Devices
- TN1251, iCE40 sysCLOCK PLL Design and Usage Guide
- iCE40LM Pinout Files
- iCE40LM Pin Migration Files
- Thermal Management document
- Lattice design tools
- Schematic Symbols

iCE40LM Family Data Sheet Revision History

October 2013 **Advance Data Sheet DS1045**

Date	Version	Section	Change Summary
August 2013	00.1 EAP	All	Initial release.
September 2013	00.2 EAP	All	General updates to all sections.
October 2013	01.0	All	General updates for product launch.
		Pinout Information	Updated ball map to 25-pin WLCSP.