# PROGRAMMABLE ASICs

4

Key concepts: programmable logic devices (PLDs) • field-programmable gate arrays (FPGAs) • programming technology • basic logic cells • I/O logic cells • programmable interconnect • software to design and program the FPGA

4.1 The Antifuse

(a)   (b)   (c)
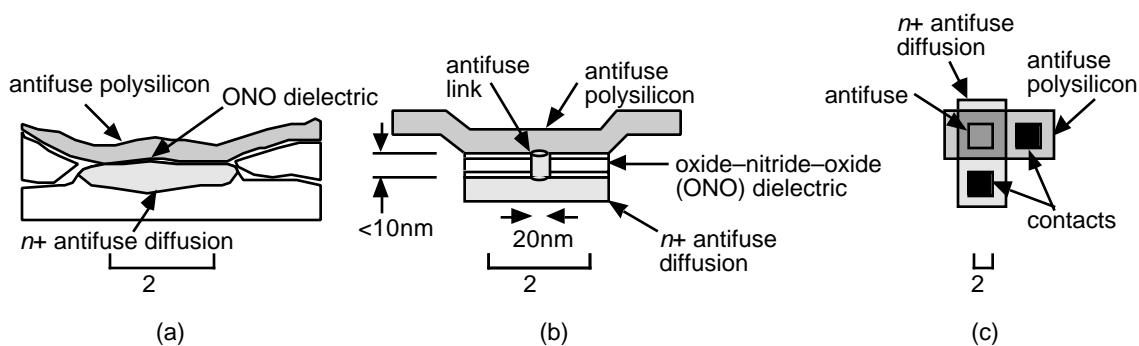
Actel antifuse

antifuse • programming current (about 5mA) • (PLICE') • oxide–nitride–oxide (ONO) dielectric • Activator • in-system programming (ISP) • gang programmers • one-time programmable (OTP) FPGAs

**Number of
antifuses on Actel FPGAs**

Device	Antifuses
A1010	112,000
A1020	186,000
A1225	250,000
A1240	400,000
A1280	750,000

percentage
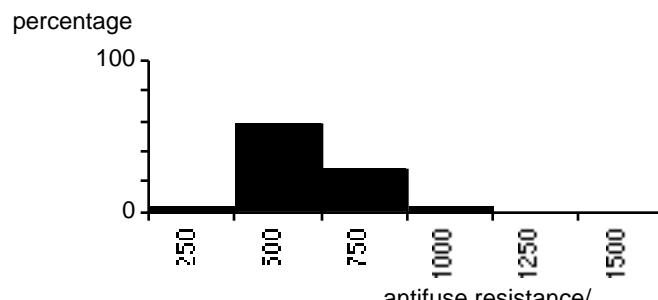
The resistance of blown Actel antifuses

antifuse resistance/

4.1.1 Metal–Metal Antifuse

(a) link

m2

SiO$_2$

via

m1

SiO$_2$

amorphous Si

2

(b) link

m3

tungsten plug

SiO$_2$

amorphous Si

m2

2

4

m2

4

m3

2
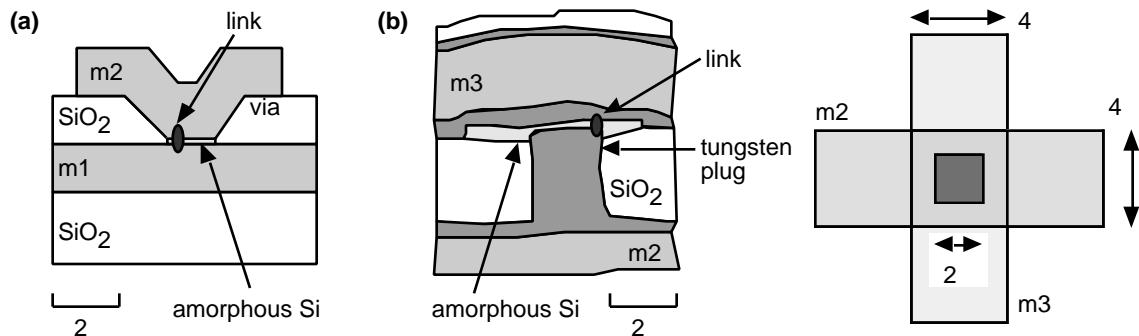
Metal–metal antifuse

QuickLogic metal–metal antifuse (ViaLink') • alloy of tungsten, titanium, and silicon • bulk resistance of about 500m cm

Resistance values for the QuickLogic metal–metal antifuse

percentage

100

0

antifuse resistance/

4.2 Static RAM

Xilinx SRAM (static RAM) configuration cell

• use in reconfigurable hardware

• use of programmable read-only memory or PROM to hold configuration
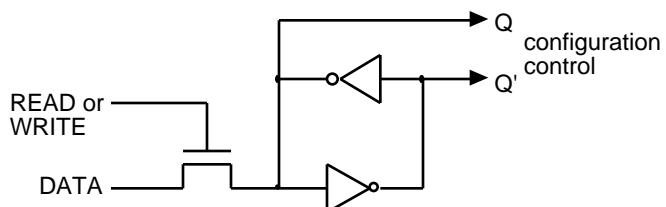
4.3 EPROM and EEPROM Technology
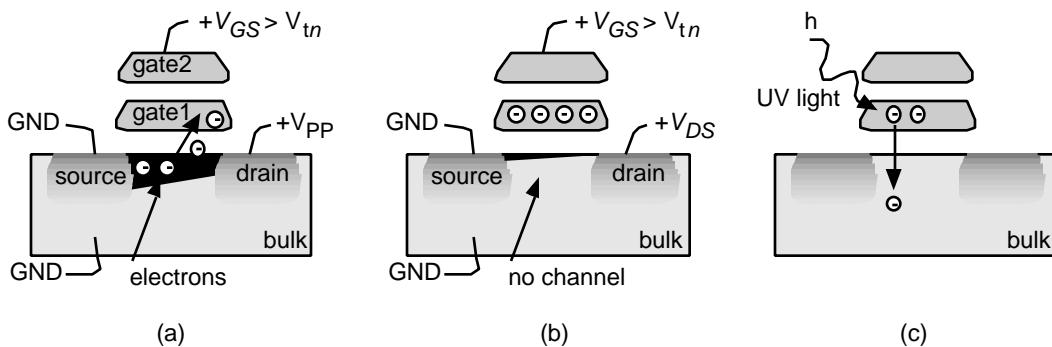
An EPROM transistor

(a) With a high (>12V) programming voltage, V_{PP}, applied to the drain, electrons gain enough energy to "jump" onto the floating gate (gate1)

(b) Electrons stuck on gate1 raise the threshold voltage so that the transistor is always off for normal operating voltages

(c) UV light provides enough energy for the electrons stuck on gate1 to "jump" back to the bulk, allowing the transistor to operate normally

Facts and keywords: Altera MAX 5000 EPLDs and Xilinx EPLDs both use UV-erasable electrically programmable read-only memory (EPROM) • hot-electron injection or avalanche injection • floating-gate avalanche MOS (FAMOS)

4.4 Practical Issues

Hardware security key

computer-aided engineering (**CAE**) tools • PC vs. workstation •
ease of use • cost of ownership
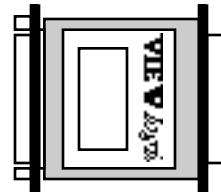
4.4.1 FPGAs in Use

- **inventory**
- **risk inventory** or safety supply
- **just-in-time** (**JIT**)
- **printed-circuit boards** (**PCBs**)
- **pin locking** or **I/O locking**

4.5 Specifications

- **qualification kit**
- **down-binning**

4.6 PREP Benchmarks

- **Programmable Electronics Performance Company** (**PREP**)
- `http://www.prep.org`

4.7 FPGA Economics

Xilinx part-naming convention

Not all parts are available in all packages

Some parts are packaged with fewer leads than I/Os

XC4010-10 PG156C

- temperature range
- number of pins
- package
- speed
- device type
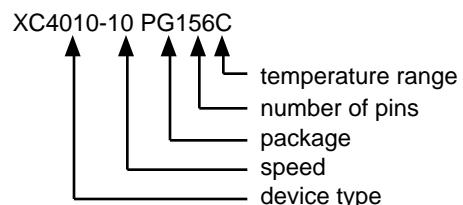
Programmable ASIC part codes				
Item	**Code**	**Description**	**Code**	**Description**
Manufacturer's code	A	Actel	ATT	AT&T (Lucent)
	XC	Xilinx	isp	Lattice Logic
	EPM	Altera MAX	M5	AMD MACH 5 is on the device
	EPF	Altera FLEX	QL	QuickLogic
	CY7C	Cypress		
Package type	PL or PC	plastic J-leaded chip carrier, PLCC	VQ	very thin quad flatpack, VQFP
	PQ	plastic quad flatpack, PQFP	TQ	thin plastic flatpack, TQFP
	CQ or CB	ceramic quad flatpack, CQFP	PP	plastic pin-grid array, PPGA
	PG	ceramic pin-grid array, PGA	WB, PB	ball-grid array, BGA
Application	C	commercial	B	MIL-STD-883
	I	industrial	E	extended
	M	military		

1992 base Actel FPGA prices		1992 base Xilinx XC3000 FPGA prices	
Actel part	**1H92 base price**	**Xilinx part**	**1H92 base price**
A1010A-PL44C	$23.25	XC3020-50PC68C	$26.00
A1020A-PL44C	$43.30	XC3030-50PC44C	$34.20
A1225-PQ100C	$105.00	XC3042-50PC84C	$52.00
A1240-PQ144C	$175.00	XC3064-50PC84C	$87.00
A1280-PQ160C	$305.00	XC3090-50PC84C	$133.30

4.7.1 FPGA Pricing

"How much do FPGAs cost?" • "How much does a car cost?" • pricing matrix

Actel price adjustment factors

Purchase quantity, all types

(1–9)	(10–99)	(100–999)
100%	96%	84%

Purchase time, in (100–999) quantity

1H92	2H92	93
100%	80–95%	60–80%

Qualification type, same package

Commercial	Industrial	Military	883-B
100%	120%	150%	230–300%

Speed bin[1]

ACT 1-Std	ACT 1-1	ACT 1-2	ACT 2-Std	ACT 2-1
100%	115%	140%	100%	120%

Package type

A1010:	PL44, 64, 84	PQ100	PG84		
	100%	125%	400%		
A1020:	PL44, 64, 84	PQ100	JQ44, 68, 84	PG84	CQ84
	100%	125%	270%	275%	400%
A1225:	PQ100	PG100			
	100%	175%			
A1240:	PQ144	PG132			
	100%	140%			
A1280:	PQ160	PG176	CQ172		
	100%	145%	160%		

[1]Actel bins: Std=standard speed grade; 1=medium speed grade; 2=fastest speed grade

4.7.2 Pricing Examples

base prices and **adjustment factors** • "sticker price"

Example Actel part-price calculation		
Example: A1020A-2-PQ100 in (100–999) quantity, purchased 1H92.		
Factor	**Example**	**Value**
Base price	A1020A	$43.30
Quantity	100–999	84%
Time	1H92	100%
Qualification type	Industrial (I)	120%
Speed bin[1]	2	140%
Package	PQ100	125%
Estimated price (1H92)		$76.38
Actual Actel price (1H92)		$75.60
[1]The speed bin is a manufacturer's code (usually a number) that follows the family part number and indicates the maximum operating speed of the device		

- Marshall at `http://marshall.com`, carry Xilinx

- Hamilton-Avnet, at `http://www.hh.avnet.com`, carry Xilinx

- Wyle, at `http://www.wyle.com` carries Actel and Altera

4.8 Summary

Programmable ASIC technologies				
	Actel	**Xilinx LCA[1]**	**Altera EPLD**	**Xilinx EPLD**
Programming technology	Poly–diffusion antifuse, PLICE	Erasable SRAM ISP	UV-erasable EPROM (MAX 5k) EEPROM (MAX 7/9k)	UV-erasable EPROM
Size of programming element	Small but requires contacts to metal	Two inverters plus pass and switch devices. Largest.	One n-channel EPROM device. Medium.	One n-channel EPROM device. Medium.
Process	Special: CMOS plus three extra masks.	Standard CMOS	Standard EPROM and EEPROM	Standard EPROM
Program-ming method	Special hardware	PC card, PROM, or serial port	ISP (MAX 9k) or EPROM program-mer	EPROM program-mer
	QuickLogic	**Crosspoint**	**Atmel**	**Altera FLEX**
Programming technology	Metal–metal antifuse, ViaLink	Metal–polysilicon antifuse	Erasable SRAM. ISP.	Erasable SRAM. ISP.
Size of programming element	Smallest	Small	Two inverters plus pass and switch devices. Largest.	Two inverters plus pass and switch devices. Largest.
Process	Special, CMOS plus ViaLink	Special, CMOS plus antifuse	Standard CMOS	Standard CMOS
Program-ming method	Special hardware	Special hardware	PC card, PROM, or serial port	PC card, PROM, or serial port
[1]Lucent (formerly AT&T) FPGAs have almost identical properties to the Xilinx LCA family				

All FPGAs have the following key elements:

- The programming technology
- The basic logic cells
- The I/O logic cells
- Programmable interconnect
- Software to design and program the FPGA

4.9 Problems