White Paper

ATF1500AS Analysis Report

Introduction

The Altera® MAX® 7000 family has many features that make it a leader in the programmable logic industry. MAX 7000 devices consume minimal power and are reliable at high frequencies. Additionally, these devices were designed for optimum timing characteristics and to support in-system programmability (ISP).

Atmel claims on their web site that ATF1500AS devices are equivalent to Altera MAX 7000 devices. The ATF1500AS devices have similar pin-outs and functions as the Altera devices, but Atmel implies they have timing and power consumption similarities as well. Specifically, Atmel's web site, **http://www.atmel.com/atmel/products/prod2.htm**, states:

> "The ATF1500AS family of CPLDs from Atmel is a pin-compatible superset of the popular Altera [MAX] 7000 series with macrocell counts from 32 to 256 and propagation delays that vary from 7.5 ns to 15 ns for standard power versions…For straight conversion that involves generating an Atmel JEDEC programming file from an Altera POF file, there is the POF2JED utility on the web."

Altera Applications ran many experiments, which are documented in this report, on the Atmel devices to determine how well they match Altera's MAX 7000 device specifications. All of the tests were repeated at least twice to verify the results.

The test results show that ATF1508AS devices are not equivalent to EPM7128S devices. The Atmel devices have slower timing characteristics (which caused problems for both synchronous and asynchronous circuits) and different data sheet parameters than Altera devices. Additionally, they consume up to four times more current than Altera devices, which causes the Atmel devices to exceed thermal reliability limits at certain frequencies. This increase in power consumption could be attributed to the fact that the ATF1508AS die size is twice as large as the EPM7128S die. Lastly, the Atmel devices do not support ISP in manufacturing environments with in-circuit testers.

Test Design

All of the test designs were created using the MAX+PLUS® II software. The programming files for the EPM7128SLC84-7 device were generated directly from the MAX+PLUS II software, and the programming files for the ATF1508AS-84JC7 device were generated from the POF2JED utility that Atmel supplies. The EPM7128SLC84-7 devices were programmed using the Altera Master Programming Unit (MPU), and the ATF1508AS-84JC7 devices were programmed on a BP Microsystems BP-1400 programmer (software version 3.33).

All of the tests were completed using an Altera EPM7128SLC84-7 device and an Atmel ATF1508AS-84JC7 device. The specifications of both devices are listed in Table 1.

Table 1. Device Specifications *Note (1)*

Parameter	EPM7128SLC84-7	ATF1508AS-84JC7
Macrocell count	128	128
Package	84-pin PLCC, *(2)*	84-pin PLCC, *(2)*
Speed grade	7.5 ns	7.5 ns
ISP	Yes	Yes

Notes:

(1) Sources: *MAX 7000 Programmable Logic Device Family Data Sheet*, Atmel web site.

(2) PLCC: plastic J-lead chip carrier.

The following features were analyzed on both devices:

- Power consumption
- Timing parameters
- Maximum operating frequencies
- In-system programmability
- Die size comparison

Power Consumption

The internal power consumption of the ATF1508AS-84JC7 device and the EPM7128SLC84-7 device was compared with the Turbo Bit turned both on and off.

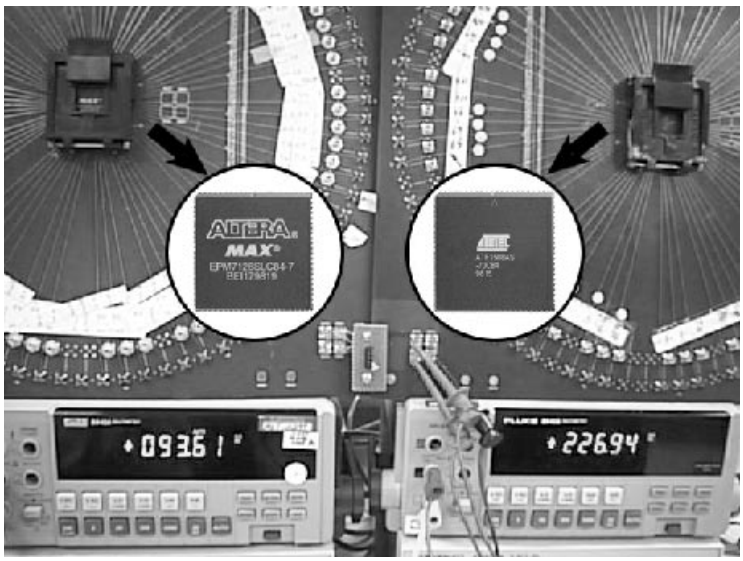
Lab Setup

The following equipment was used for the tests:

- HP 54502A Digital Scope
- HP 8110A 150 MHz Pulse Generator
- HP 6236B Power Supplies
- Fluke 8840A Digital Multimeters
- Pre-prepared boards with an IEEE Std. 1149 Joint Test Action Group (JTAG) pin header

Internal power consumption (V_{CCINT}) and I/O buffer power consumption (V_{CCIO}) were powered-up separately with two voltage supplies that had common grounds. The current was measured from the V_{CCINT} power supply. Figure 1 shows the lab setup for the power consumption comparison.

Figure 1. Lab Setup Showing Internal Current Consumption of 5 × 4-Bit Multiplier, Turbo Bit Off at 25 MHz

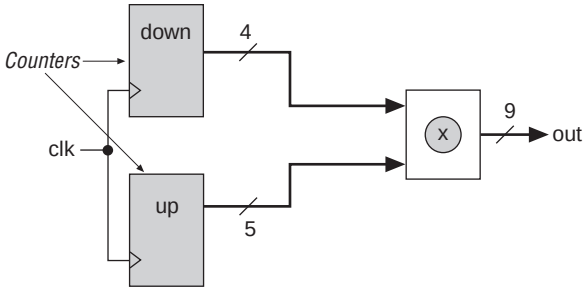


The internal current consumption (I_{CC}) of both the ATF1508AS-7JC84 and EPM7128SLC84-7 devices was measured using the two designs described below. Both designs utilize a high percentage of the device resources, including routing, logic, and register resources.

5 × 4-Bit Multiplier

This design has a 90% device utilization rate. A 4-bit down and 5-bit up counter drive a 5 × 4-bit multiplier, which produces a vector input to the multiplier. These inputs allow an average power measurement for the design. Figure 2 shows a diagram of this design.

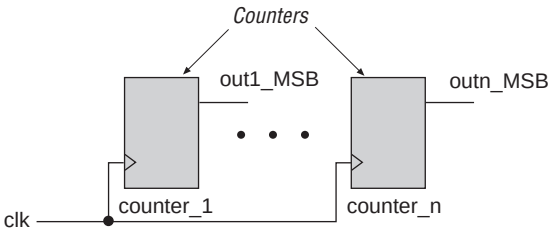
Figure 2. 5 × 4-Bit Multiplier



Sixteen 8-Bit Counters

This design has a 100% device utilization rate, and is self-exciting with one shared clock signal. See Figure 3 for a diagram of the design.

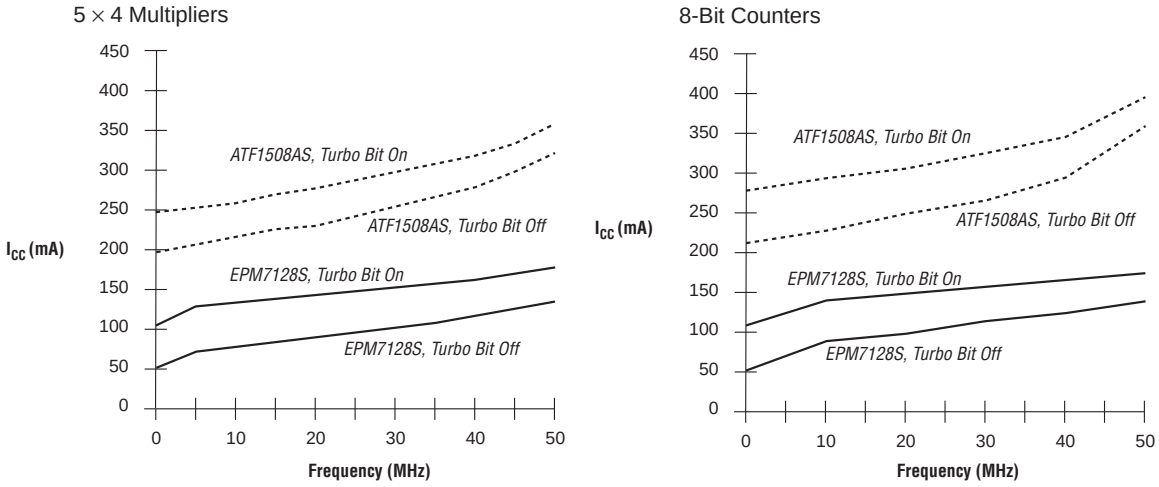
Figure 3. 8-Bit Counter



Results

Figure 4 compares the internal power consumption of the two designs.

Figure 4. I_{CC} of the 5 × 4-Bit Multiplier and 8-Bit Counters



Source: Altera Applications.

The graphs indicate that internal current consumption of the ATF1508AS device is 2 to 4 times higher than it is for the EPM7128S device. Even with the Turbo Bit turned on for a design running at 50 MHz, the Altera device consumed less current than the Atmel device with the Turbo Bit turned off in standby mode. Table 2 shows the current consumption for both the Altera and Atmel devices. The EPM7128S device with the Turbo Bit turned off uses 54% less power compared to the same conditions with the Turbo Bit turned on. The ATF1508AS device with the Turbo Bit turned off uses 21% less power than with the Turbo Bit turned on. Therefore, the non-turbo function in the ATF1508AS is significantly less effective than it is in the EPM7128S device.

Table 2. Current Consumption: ATF1508AS vs. EPM7128S *Note (1)*

Turbo Bit On/Off	Mode	Current Consumption (mA)		Atmel/Altera Power Ratio
		EPM7128S	ATF1508AS	
On	Standby	109	262	240%
	50 MHz	182	378	208%
Off	Standby	50	204	408%
	50 MHz	137	340	248%

Note:

(1) Source: Altera Applications.

The Atmel data sheet states that the standby current of the ATF1508AS device is 160 mA. When this device was tested in the lab, the results show the standby current to be 63% higher than the data sheet specification. Table 3 compares the discrepancy between data sheet and measured standby current values.

Table 3. Data Sheet vs. Measured Power Consumption *Note (1)*

	Power Consumption (mA)	
	EPM7128S	ATF1508AS
Data Sheet Specification	120	160
Measured Result	109	262
Percent Difference	9% less	63% more

Note:

(1) Sources: Altera Applications, *MAX 7000 Programmable Logic Device Family Data Sheet*, and the Atmel web site.

The high power consumption of the Atmel devices raises reliability issues with certain device packages. The ATF1508AS device exceeds the maximum thermal reliability limit at certain frequencies for all the available package offerings. Therefore, the devices are likely to have thermal reliability failures over time during normal operation. Table 4 shows the calculation for the maximum power that can be consumed by the ATF1508AS devices in the available packages. The calculations assume an ambient temperature (T_A) of 55° C and a maximum junction temperature (T_J) of 135° C.

Table 4. Maximum Power for ATF1508AS Device Packages *Note (1)*

Package	θ_{JA} (°C/W) 100 ft./min.	Assumed T_A (°C)	Maximum T_J (°C)	Maximum Power (W)
100-pin QFP, *(2)*	43	55	135	1.9
100-pin TQFP, *(2)*	38	55	135	2.1
160-pin PQFP, *(2)*	26	55	135	3.1

Notes:

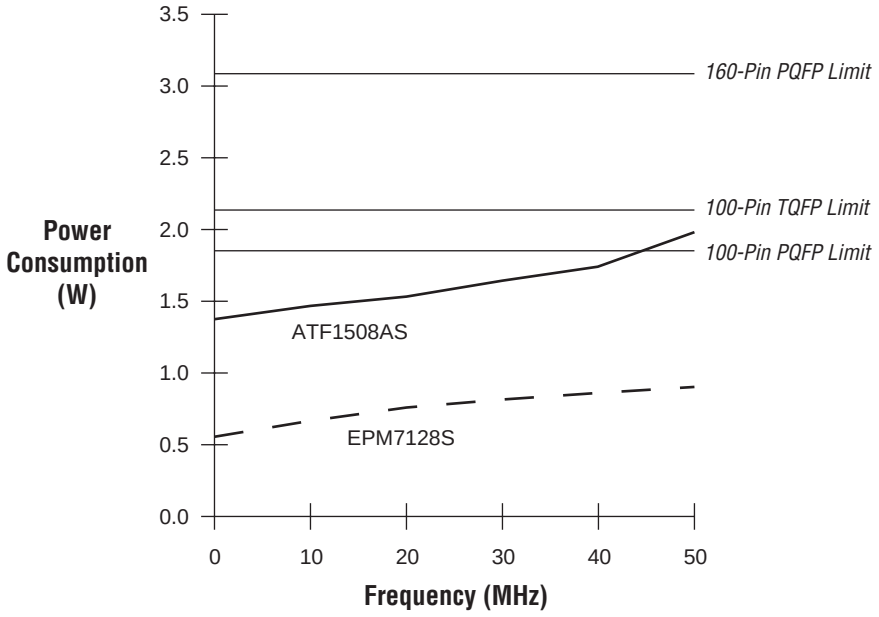
(1) Airflow = 100 feet per minute.

(2) QFP: quad flat pack; TQFP: thin quad flat pack; PQFP: plastic quad flat pack.

Figure 5 illustrates how the power consumption of the Atmel device exceeds the power limit for several of the ATF1508AS packages.

Figure 5. Thermal Reliability Threshold (Turbo Bit On) *Notes (1), (2)*

The horizontal lines represent the reliability limits for indicated packages. A device with power consumption that exceeds these limits is considered unreliable, and is prone to failure. The ATF1508AS device in the 100-pin PQFP package becomes unreliable at a frequency of approximately 44 MHz. If the graph continued past 50 MHz, the ATF1508AS device in the 100-pin TQFP package would become unreliable before reaching 75 MHz.



Notes:

(1) Airflow = 100 feet per minute.

(2) Source: Altera Applications.

Table 5 shows that with airflow equal to 100 feet per minute and a maximum T_J of 135° C, the ATF1508AS device exceeds the thermal reliability threshold for the 100-pin PQFP package above 50 MHz and 100-pin TQFP package before reaching 75 MHz. In these cases, the device is likely to have reliability failures during normal in-field operation.

Table 5. EPM7128S and ATF1508AS Reliability vs. Frequency *Notes (1), (2), (3)*

Operating Frequency (MHz)	100-pin PQFP		100-pin TQFP		160-pin PQFP	
	Altera	Atmel	Altera	Atmel	Altera	Atmel
0	✓	✓	✓	✓	✓	✓
25	✓	✓	✓	✓	✓	✓
50	✓	×	✓	✓	✓	✓
75	✓	×	✓	×	✓	✓

Notes:

(1) Airflow = 100 feet per minute.

(2) ✓ = reliable, × = unreliable.

(3) Source: Altera Applications.

Timing Parameters

The ATF1500AS and MAX 7000 data sheets show many discrepancies. See Table 6.

These timing differences can cause failures for both synchronous and asynchronous designs. The most significant is the ATF1508AS device global setup time difference, which may cause sporadic failures for high-performance applications. In addition, the output hold delay ($\mathbf{t_{ODH}}$) is not specified by Atmel for any speed grade. Altera specifies the output hold delay to be a minimum of 1 ns. If this parameter is not specified, clock skew between multiple devices can cause race conditions whenever the clock skew exceeds the clock-to-output delay. All of these data sheet timing discrepancies may cause intermittent functional failures in Atmel devices.

Table 6. EPM7128S and ATF1508AS Timing Discrepancies *Note (1)*

Symbol	Parameter	Speed Grade							
		-7 (7.5 ns)		-10 (10 ns)		-15 (15 ns)		-20 (20 ns)	
		Altera	Atmel	Altera	Atmel	Altera	Atmel	Altera	Atmel
t_{SU}	Global setup time	6	7					12	16
t_{ODH}	Output data hold time	1	Not Specified	1	Not Specified	1	Not Specified	1	Not Specified
t_{AH}	Array clock hold time	2	2.5						
t_{FH}	Global clock hold time of fast Input					0	1	0	1.5
t_{ASU}	Array clock setup time			2	3				

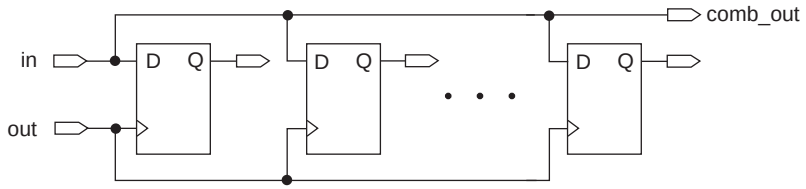
Note:

(1) Source: *MAX 7000 Programmable Logic Device Family Data Sheet*, and the Atmel web site.

Maximum Operating Frequencies

The ATF1508AS devices were tested to determine whether they met their data sheet timing specifications. Figure 6 shows a diagram of the design tested.

Figure 6. Maximum Operating Frequency Test Design



The test design consisted of multiple registers that were cascaded together and clocked by the same signal. The registers were scattered throughout the device to measure worst-case timing characteristics. The input frequency was then increased incrementally to a maximum of 100 MHz to determine if the device would fail to function. Table 7 summarizes the results of this test.

Table 7. Maximum Operating Frequency Comparison *Notes (1), (2)*

Device	Maximum Simulation Frequency (MHz)	Tested at 50 MHz	Tested at 75 MHz	Tested at 100 MHz
EPM7128S	125	Pass	Pass	Pass
ATF1508AS	125	Pass	**Fail**	**Fail**

Notes:

(1) Source: Altera Applications.
(2) T = 25° C, V_{CC} = 4.75 V.

The EPM7128S-7 device did not fail at any frequency, and it operated within the range shown in the data sheet. However, the ATF1508AS-7 device failed at 75 MHz and above.

The `comb_out` signal, shown in Figure 6, was used to measure the combinatorial propagation delay ($\mathbf{t_{PD}}$) of the devices. The $\mathbf{t_{PD}}$ measurement of the ATF1508AS devices was 7.7 ns, which exceeds the data sheet specification of 7.5 ns. This analysis shows that a working design in a MAX 7000 device may operate incorrectly when migrated to an ATF1500AS device. These tests were completed at room temperature with V_{CC} at 4.75 V (the minimum supply voltage specification for both devices). Table 8 compares the measured $\mathbf{t_{PD}}$ with the value listed in the data sheet.

Table 8. Data Book vs. Measured t_{PD}

Device	Data Sheet Specification	Measured t_{PD} *Note (1)*	Test Result
EPM7128S-7	7.5 ns	6.1 ns	Pass
ATF1508AS-7	7.5 ns	7.7 ns	**Fail**

Note:

(1) Source: Altera Applications.

In-System Programmability

MAX 7000S devices support ISP via a variety of programming methods, whereas Atmel devices provide limited ISP support. See Table 9.

Table 9. ISP Support Comparison

Programming Method	EPM7128S	ATF1508AS
Download cable	✓	✓
HP 3070 in-circuit tester support, *(1)*	✓	
Download cable with MAX+PLUS II-produced Jam File, *(2)*	✓	
Embedded processor with MAX+PLUS II-produced Jam File, *(2)*	✓	

Notes:

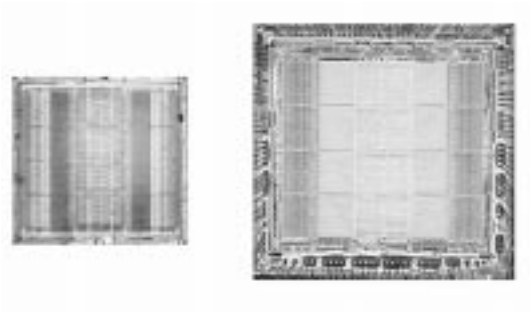
(1) The HP 3070 in-circuit tester requires Pattern Capture Format Files (**.pcf**) to program devices. Atmel does not support this file format. Therefore, ATF1500AS devices cannot be programmed using the HP 3070 equipment.

(2) None of the test cases were successful in programming the ATF1508AS device using Jam Files generated by MAX+PLUS II.

Die Size Comparison

A small die size offers a number of advantages, including lower production costs, lower power consumption, and faster performance. Atmel devices have larger die sizes than comparable MAX 7000 devices. See Figure 7.

Figure 7. Relative Die Size Comparison



	Altera EPM7128S	Atmel ATF1508AS
Macrocells	128	128
Package	84-pin PLCC	84-pin PLCC
Date Code	9815	9815
Relative Size	1.00	2.06

Conclusion

Contrary to what is stated on the Atmel web site, there are significant differences between the Atmel ATF1508AS-84JC7 devices and the Altera EPM7128SLC84-7 devices. Although some features, such as pin-outs and functions, are similar, the two devices are not equivalent. Table 10 summarizes the differences between these two devices.

Table 10. Summary of Results (Part 1 of 2)

Feature	Analysis
Power Consumption	
Turbo on	The Atmel device consumes up to 140% more power than the Altera device.
Turbo off	The Atmel device consumes up to 308% more power than the Altera device.
Stand-by	Experiments show that actual stand-by current for the Atmel device is 63% higher than the data sheet reports.
Timing Parameter Discrepancies	
t_{SU} (global setup time)	7 ns in a –7 speed grade Atmel device. 6 ns in a –7 speed grade Altera device. Additional timing discrepancies are listed in Table 5 on page 7.
Possible consequences with Atmel	There are potential synchronous and asynchronous timing problems in the Atmel device. The slower setup time in the Atmel device may require redesigning. Designs in the Atmel device may function differently than in the MAX 7000E or MAX 7000S devices.
Maximum Operating Frequency	
Sequential designs	Simulation results show that devices should operate at 125 MHz. Test results show that the Atmel device failed above 75 MHz.
Combinatorial designs	A single loaded combinatorial path in the Atmel devices had a propagation delay of 7.7 ns, which exceeded the 7.5-ns t_{PD} value shown in the data sheet. The Atmel devices failed to meet their own data sheet values at room temperature. Results should be worse at higher temperatures.
In-System Programmability	
HP 3070 ATE support	Not supported in the Atmel device.
ISP using download cable with Jam File	Not supported in the Atmel device.
Embedded processor using Jam File	Not supported in the Atmel device.
Die Size	The Atmel die size is twice as large as the Altera die size.