AMD Alchemy™ Au1100™ Processor Power Measurement

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1.0 Introduction

The AMD Alchemy™ Au1100™ processor is designed to provide power management features that allow software to dynamically regulate power consumption based on processing requirements. By taking advantage of the power management features, a system based on the Au1100 processor has the processing performance of a 336-500 MHz MIPS core, while at the same time achieving low power characteristics during periods of low system activity. In other words, instead of consuming full power at all times, the Au1100 processor can efficiently adapt to changing system power requirements.

For the system designer evaluating the Au1100 processor, focusing only on the specified *maximum power* consumption can be misleading because this measurement generally represents only a worst-case condition in which the part is consuming greater than usual power for only a brief period. In contrast, *typical power* consumption is a much more accurate representation of the part's behavior over time because this averaged measurement is made under more realistic conditions and reflects the benefits of the power management features.

This paper presents an overview of the Au1100 processor's power management techniques that affect typical power consumption during runtime. Following the overview, this paper discusses power measurement on the Au1100 processor and reports the results of the measurements.

2.0 Power Management Overview

The Au1100 processor provides a wide variety of power management techniques that make it ideal for use in low-power systems. During runtime, the Au1100 processor employs an IDLE mechanism and automatic bus switching to facilitate low power consumption. The IDLE mechanism allows the processor core to enter a static state. In this state, clocks to the core are gated off; however, all registers retain their values.

Software initiates the IDLE mechanism using the WAIT instruction. Typically the IDLE state is entered during an operating system's wait loop in which the core has no processes to run. While the processor core is in IDLE, the peripherals, DMA engine, and the interrupts remain active so that the system is still functional. To the user, the system appears fully functional, yet power consumption is dramatically reduced when the operating system takes advantage of the IDLE state.

The Au1100 processor also employs automatic bus switching when the internal system bus is not being used. When this feature is enabled the system bus clock is automatically divided by two when not in use. The bus switching feature can be enabled such that the divide happens only when the processor is in IDLE, or it can be enabled to happen whenever there is no system bus activity.

2.1 Power Measurement

Because of the power management features on the Au1100 processor, it is necessary to take into account the power consumed by the processor both while working and while IDLE when measuring power consumption for a typical application. In other words, a weighted average must be used to accurately measure typical power consumption because the instantaneous power may not represent the typical power over time. The weighted average is the percentage of time in IDLE multiplied by the power consumed in IDLE plus the percentage of time working multiplied by the power consumed working:

$$P_{typical} = (T_{idle} * P_{idle}) + ((1-T_{idle}) * P_{working})$$

where:

$P_{typical}$: Typical power
T_{idle}: Percentage of time spent in IDLE (1 represents 100%)
P_{idle}: Power consumed in IDLE
$P_{working}$: Power consumed while working

2.2 System Design Power Considerations

From a system design standpoint, the maximum instantaneous power consumption must be considered when choosing a regulator because the maximum power represents the worst-case load. A system designer typically guard bands the maximum power specification because there may be absolute worst-case loads, bus behavior, and activity not modeled when measuring the maximum power consumption.

When choosing a battery, the system designer should use the typical power consumption to represent what is drawn from the battery over time. The typical power may vary from system to system (and between applications) according to the system's processing requirements.

3.0 Measuring Power on the Au1100™ Processor

Power consumed by the Au1100 processor can be measured by isolating the internal supply VDDI, the external supply VDDX (assuming that it is tied to XPWR12 and XPWR32), and the SDRAM interface power supply VDDY. The current can be monitored with a current meter on a power supply or by connecting an amp meter in series with the voltage source.

For accurate measurements, be sure the power supply for the Au1100 processor is isolated from the rest of the board. Otherwise, the current readings will be artificially low if the Au1100 device is getting supplemental current from sources other than the monitored supply, or the readings will be artificially high if the monitored supplies are also sourcing other components besides the processor.

3.1 Typical Power Measurement

Measuring typical power consumption on the Au1100 processor is more complex than measuring maximum power because the measurement must take into account the amount of time that is spent in IDLE. The power consumption under IDLE is significantly lower compared to active (working) operation, so it is important to include IDLE time to get an accurate representation of typical power consumption. In different applications the amount of time spent in IDLE can be as much as 97% (awaiting user input).

To measure typical power consumption, one must monitor the amount of time in IDLE and the amount of time working. In order to track IDLE time, a special OS build needs to be used which records the amount of time spent in IDLE compared with the amount of time spent working. This can be accomplished using the RTC (real-time clock) and logging to memory the number of ticks spent in IDLE and the number of ticks spent working. The log can then be parsed to compute the relative percentages.

With the percentage of working time and percentage of IDLE time, the current consumption under IDLE and the current consumption while working, the typical power can be computed using the following formula:

$$\begin{aligned} P_{typical} = \ & (\{ (Ivddi_{idle} * T_{idle}) + [Ivddi_{work} * (1 - T_{idle})] \} * VDDI) \\ & + (\{ (Ivddx_{idle} * T_{idle}) + [Ivddx_{work} * (1 - T_{idle})] \} * VDDX) \\ & + (\{ (Ivddy_{idle} * T_{idle}) + [Ivddy_{work} * (1 - T_{idle})] \} * VDDY) \end{aligned}$$

where

$P_{typical}$:	Typical power
T_{idle}:	Percentage of time spent in IDLE (1 represents 100%)
$Ivddi_{idle}$:	IDLE VDDI current
$Ivddi_{work}$:	Working VDDI current
$Ivddx_{idle}$:	IDLE VDDX current
$Ivddx_{work}$:	Working VDDX current
$Ivddy_{idle}$:	IDLE VDDY current
$Ivddy_{work}$:	Working VDDY current
VDDI:	Internal voltage supply level
VDDX:	External voltage supply level
VDDY:	External SDRAM interface voltage supply level

3.2 Maximum Power Measurement

To measure maximum power, monitor the worst-case current consumption and then convert the reading to power based on the supply voltages being used. After recording the maximum current consumption, the maximum power can be computed as follows:

$$P_{max} = (Ivddx_{max} * VDDX) + (Ivddy_{max} * VDDY) + (Ivddi_{max} * VDDI)$$

where

P_{max}:	Maximum power
$Ivddx_{max}$:	Maximum VDDX current (including XPWR12 and XPWR32)
$Ivddy_{max}$:	Maximum VDDY current
$Ivddi_{max}$:	Maximum VDDI current
VDDX:	External voltage supply level (including XPWR12 and XPWR32)
VDDY:	External SDRAM interface voltage supply level
VDDI:	Internal voltage supply level

4.0 Power Measurement Results (Typical and Max)

Using the techniques described in the previous section, this section shows the typical power consumption of the Au1100 processor running typical applications and reports on the maximum power consumption under worst-case conditions.

4.1 Typical Power

As shown in Table 4-1, the IDLE current is significantly lower than the current consumed when the processor core is working. The variations in the IDLE current numbers are due to the operating systems performing different activities on the peripherals that are still active during IDLE.

The following conditions are common for all experiments on a fully populated AMD Alchemy™ Pb1100™ development board with an Au1100 processor silicon revision 1.1 part:

- VDDX = 3.3V, VDDY = 2.5V, VDDI = 1.2V
- The following peripherals were enabled:
  — AC97
  — 1 Ethernet MAC
  — LCD driving CRT @ 640x480x16 bpp
  — 1 UART
  — USB Host

Table 4-1 shows typical power consumption measurements on the Au1100 processor. The 100% CPU utilization shown is the typical power consumption when processing requirements demand full CPU utilization (no time spent in IDLE). This measurement differs from *maximum* power in that it represents normal processing conditions in an application requiring full CPU utilization. As described in the following section, maximum power represents an artificial scenario created strictly to maximize power consumption.

Table 4-1. AMD Alchemy™ Au1100™ Processor Typical Power Measurements

CPU	Windows® CE 4.2	% Idle	Ivddx (mA)	Ivddy (mA)	Ivddi (mA)	IDLE Ivddx (mA)	IDLE Ivddy (mA)	IDLE Ivddi (mA)	Pvddx (mW)	Pvddy (mW)	Pvddi (mW)	Total Pwr (mW)
336 MHz	At 100% Idle	100%	–	–	–	4	8	70	13	20	84	117
	At Idle ~ 10 seconds	97%	8	10	210	4	8	70	14	20	89	123
	Decoding ice_192_144_400_128.wmv	55%	11	17	224	4	8	70	24	30	167	221
	Decoding ice_256_192_400_128.wmv	47%	11	20	234	4	8	70	25	36	188	250
	Decoding mon_W_320_176_24_400_64.wmv	28%	11	21	237	4	8	70	30	43	228	302
	Decoding mon_W_368_192_24_400_64.wmv	21%	11	22	239	4	8	70	31	48	244	323
	At 100% utilization	0%	11	22	239	–	–	–	36	55	287	378
400 MHz	At 100% Idle	100%	–	–	–	4	9	75	13	23	90	126
	At Idle ~ 10 seconds	97%	9	12	242	4	9	75	14	23	96	132
	Decoding ice_192_144_400_128.wmv	61%	11	22	260	4	9	75	22	35	177	234
	Decoding ice_256_192_400_128.wmv	59%	11	24	261	4	9	75	23	38	182	242
	Decoding mon_W_320_176_24_400_64.wmv	39%	11	25	265	4	9	75	27	47	229	303
	Decoding mon_W_368_192_24_400_64.wmv	32%	11	26	270	4	9	75	29	51	249	329
	At 100% utilization	0%	11	26	270	–	–	–	36	65	324	425
504 MHz	At 100% Idle	100%	–	–	–	5	13	84	17	33	101	150
	At Idle ~ 10 seconds	97%	9	9	299	5	13	84	17	32	109	158
	Decoding ice_192_144_400_128.wmv	68%	11	17	310	5	13	84	23	36	188	246
	Decoding ice_256_192_400_128.wmv	61%	11	20	320	5	13	84	24	39	211	275
	Decoding mon_W_320_176_24_400_64.wmv	52%	11	23	325	5	13	84	26	45	240	310
	Decoding mon_W_368_192_24_400_64.wmv	44%	11	24	330	5	13	84	28	48	266	342
	At 100% utilization	0%	11	24	330	–	–	–	36	60	396	492

4.2 Maximum Power

To measure maximum power, a worst-case scenario was created where all peripherals were enabled, and core and system bus activity was maximized. The IDLE mechanism (invoked by the WAIT instruction) was not used so that the core would not enter a low-power state.

The following conditions were used to measure maximum power on a fully populated AMD Alchemy™ Pb1100™ development board with an Au1100 processor silicon revision 1.2 part:

- VDDX = 3.3V, VDDY = 2.5V, VDDI = 1.2V
- The following peripherals were enabled:
  - AC97
  - USB Host
  - USB Device
  - UART
  - LCD
  - I2S
  - IrDA
  - SSI
  - SD
- All ranks of SDRAM were enabled (but rank 3 was not stuffed).
- Four (4) internal frequency generators were turned on.
- The following clocks were driven as indicated:
  - EXTCLK0 = 24.75 MHz
  - EXTCLK1 = disabled
  - I2SCLK = 3.1 MHz
  - LCDCLK = 28.8 MHz
  - USBDCLK = 48 MHz
  - All others disabled

Under this environment the worst-case maximum power was observed while the processor core was in a tight loop filling SDRAM (see Table 4-2). While the maximum power numbers should be used when specifying a regulator for an Au1100 processor-based system, the numbers are well above the typical power consumption because none of the power-saving design features (such as IDLE, or the automatic system bus divider) are enabled. Note that because the particular application software and external loading affect the power consumption on a given system design, certain conditions may exist which could cause the maximum power consumption to be different than shown.

Table 4-2. AMD Alchemy™ Au1100™ Processor Max Power Measurement (Note 1)

CPU	Ivddx (mA)	Ivddy (mA)	Ivddi (mA)	Pvddx (mW)	Pvddy (mW)	Pvddi (mW)	Total Power (mW)
336 MHz	15	53	247	50	133	296	478
400 MHz	15	65	292	50	163	350	562
504 MHz	16	86	361	53	215	433	701

Note 1. Direct code run on top of YAMON.

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