Using the 3.3-V Am186™ER or Am188™ER Microcontroller in a 5-V System

AMD

Application Note

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The AMD® Am186™ER and Am188™ER microcontrollers feature 5-V tolerant signal operation with a 3.3-V power supply. The move to 3.3 V is driven by industry requirements for higher performance and lower cost through smaller geometry process technology. This application note discusses considerations for designing 5-V systems with the 3.3-V Am186ER microcontroller. All references in the document to the Am186ER apply equally to the Am188ER microcontroller.

BACKGROUND

The use of a 3.3-V device in a 5-V system has become a common theme with today's denser, faster microcontrollers. Using these processors in a 5-V design, without redesigning the end system for 3.3 V, has considerations.

The Am186ER microcontroller features 5-V tolerant inputs; the device can interface to both 3.3-V and 5-V signal inputs, even though it operates from a 3.3-V supply. The input circuit provides protection from a 5-V signal level, but utilizes the same TTL-compatible thresholds that are familiar from existing 5-V technology devices. Ostensibly, a designer need not be concerned about the 5-V-to-3-V interface, thanks to this input circuit.

In systems without an additional 3.3-V power supply tap, 3.3 V for the microcontroller must be synthesized from the existing 5-V supply. This can be accomplished in a number of different ways, discussed below.

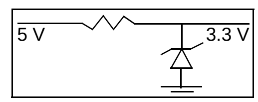
SUPPLY VOLTAGE CONSIDERATIONS

In recent years there have been numerous voltage-regulation solutions introduced specifically to generate 3.3-V supply power from 5-V supplies. These are broken into three main groups: passive zener diode, active switching and active linear regulators.

The preliminary recommendation for total provided supply current for the Am186ER microcontroller (without termination) is approximately 5 mA/Mhz, or 200 mA at 40 Mhz and 125 mA at 25 Mhz. Regardless of the method of power supply, the designer should be sure that the solution provides for peak current requirements, not only of the processor operation, but of the current sourcing on the I/O pins.

Regulator Types

Zener Diode Regulators



The zener diode is the simplest and least expensive solution, but has a slower response than an active supply. It also requires strong current biasing, and may dissipate a good deal of power, as the difference voltage is dropped across the diode and bias resistor.

The nature of this solution is that the current supplied by the 5-V power supply is nearly constant; this means that as the load current decreases the current is shunted through the zener diode. The increased current through the zener diode causes a corresponding increase in the voltage across the zener diode. Because of this, when using this solution, care must be given to insure that variations in the load do not result in excessive variation in the regulated voltage. A complete analysis of system current requirements must be completed to properly specify the bias resistor and zener diode. Care must be taken to include all devices that draw current from the 3.3-V power plane. It is also very important that the zener diode be able to handle the maximum current shunted from the load. If the zener diode is over driven to the point of failure, the only protection left for the microcontroller is the series bias resistor which will typically result in the microcontroller being driven with a voltage over the maximum rated V_{cc} of 3.6 V.

This solution is not recommended for use in designs that operate at greater than 25 Mhz due to the higher current requirements of such designs. This solution is also inappropriate for designs that use power save mode since this results in a very large variation in the current drawn from 3.3-V power plane and causes excessive variation in the regulated voltage and potential damage to the microcontroller.

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These devices are marketed in surface-mounted packages by a number of suppliers, and some devices are even optimized directly for operation as a 5-V-to-3.3-V converter. Cost of these devices is relatively low, compared to the other solutions shown. Total cost, including the cost of a bias current resistor, is less than $0.40 in single quantity surface mount packages.

Switching Regulators

The switching regulator solution can work well over a large range of input voltages, including 5 V. The power translation is usually very efficient; typical efficiency ranges are from 85% to 95%. The negatives are that a switcher may add noise problems (at the switching frequency and the resulting harmonic frequencies), and IC-based solutions typically require additional passive (especially magnetic) components.

Switching regulator chips are available from companies such as Linear Technology, Maxim, Micro Linear, and Motorola, among others. The driver IC typically includes the low-on-resistance boost-current FET device on-chip, to minimize cost and complexity. However, such solutions still require a passive magnetic component (a transformer or inductor), and bulk current supply capacitor.

Costs for switching regulator solutions are the highest among the three groups described. The total cost of a switching regulator, including passive components, can cost over $5, in OEM volume.

Modular switchers, sometimes known as DC-DC converters, are complete switching regulator systems, including all ICs, passives, and actives in a single potted module. An example of such a device is the Power Trends Modular 3.3-V converter, which includes power-down controls, for low-power or shutdown applications, and is available in a small 12-pin SIP package. These solutions are around $15 each, in volume.

Linear Regulators

Linear regulators provide tightly regulated output voltage levels in a simple single-chip solution. More specifically, LDO (low-drop-out) regulators provide the capability to generate 3.3 V from a 5-V supply. Manufacturers such as Linear Technology, Micrel, Semtech, and National Semiconductor sell such devices. A disadvantage is that these devices are less efficient than switchers, as they drop the difference voltage across the pass transistor.

The cost of linear voltage regulators ranges from around $1 to $2, even over the .5 to 1.5 A range. Additional costs include another bulk tantalum capacitor (10 uF). (In either a 5-V or 3.3-V system, decoupling capacitors are used).

Recommendation

For most designs, AMD recommends one of the many low-dropout linear regulators. The Linear Technology LT1129CST-3.3V is a good choice at 700-mA supply current, SOT-223 SMT package, and a 400-mV dropout. Micrel provides the MIC2937A-3.3, also in SMT, at a 750-mA current and 450-mV dropout. Any device in this category would be appropriate for the 33-Mhz or 40-Mhz Am186ER microcontroller application. Other linear regulators are available with various current capabilities and dropout voltages. The current requirements and maximum dropout voltage will be determined by the particular design.

However, if efficiency is important, you may want to use a switching regulator. And if the price of the components is the ultimate consideration, then a zener diode may be applicable. (The use of a zener diode is extremely dependent on design-specific variables and must be carefully evaluated and tested.)

Other Power Concerns

AMD recommends a split power plane, which isolates the Am186ER device. The Am186ER should be in very close proximity to the LDO regulator. Additional PCB planes are not required.

A split plane is a portion of copper, cut out from the PCB power plane (5-V layer) that powers only the 3.3-V device, and should overlap the output pin of the regulator, thus providing low-impedance current supply. Under no circumstances should the ground plane be split; it provides a low impedance current sink and reference.

An output bulk capacitor of 1–10 uF, and distributed capacitors of .01 uF for each power pin (as close to the pin as possible) are recommended. If the regulator is THT (through-hole technology), then the hole should be directly connected to the power plane. If the regulator is SMT (surface-mount technology), then the connection to the power plane should be with large (>.050” width) traces and through two (or more) vias, each with .040” diameter holes and .060” diameter pads. Finally, be sure that the regulator can easily handle the power dissipation your solution implies. A 40-MHz design will require approximately 220 mA, and the regulator will drop 1.7 V, equaling a dissipation of approximately 375 mW of heat.

If compatibility must be maintained with the current 5-V Am186EM/ES or Am188EM/ES microcontrollers, be sure to allow a method of optionally reconnecting the inner plane (microcontroller subplane) directly to the external 5-V plane. The regulator would then be removed or disabled, to allow direct 5-V operation. Assure a low-resistance connection from inner to outer planes; it is recommended that a heavy gauge wire be used to short the regulator input and output together.

Further improvement could be gained when using the 5-V device by adding some large (>.050”) holes around the periphery of the split plane, in pairs, to allow the two planes to be reconnected.

Finally, while the signal pins on the Am186ER controller are 5-V tolerant during normal operation of the part, they are dependent on the actual level of V_{cc}. The signal pins can tolerate a V_{ih} of V_{cc}+2.6 V. This must be considered during system power-up and any other time that the system V_{cc} becomes unstable. If the method of voltage regulation chosen does not adequately track the 5-V power supply or if a 5-V peripheral drives the signal pins of the Am186ER controller to a level greater than 2.6 V above the processor power supply voltage, then damage can occur. To protect the microcontroller, all pull-up resistors should be connected to the 3.3-V power source. Remember to include the pull-ups when doing evaluation of the current requirements for the regulator.

Additionally, all peripherals should be held in RESET until the power is stable on both the 5-V and 3.3-V power planes. If a peripheral can not be placed in a RESET state that guarantees it will not drive any signals, then additional measures such as tristate buffers must be included in the design.

SUMMARY

The use of 3.3-V technology for high-speed microcontrollers is beneficial in many ways: better chip fabrication processes, faster clock speeds, lower EMI, and lower power consumption.

Operation of the Am186ER in a 5-V technology system should be trouble-free. 3.3-V LDO regulators make powering the device easy. Decouple the device carefully, and consider a split power plane, for the 3.3-V supply.

REFERENCES

Am186ER Microcontroller Data Sheet, order# 20732, Advanced Micro Devices.

High Speed Board Design Techniques, order# 16356 (also in order# 10173), Advanced Micro Devices.

Table 1. Manufacturers

Manufacturer	Main Number	Distributors
Linear Technology	(408) 432-1900	Arrow, Insite
Maxim	(408) 737-7600	Arrow, Wyle, Pioneer
Micrel	(408) 944-0800	N/A
Micro Linear	(408) 433-5200	Insite
Motorola Semiconductor	n/a	Arrow, Future, Hamilton/Hallmark
National Semiconductor	n/a	Anthem, Hamilton/Hallmark, Pioneer, Time
Philips	(401) 232-0500	Hamilton/Hallmark, Bell
Power Trends	(708) 406-0900	Hamilton/Hallmark
Rohm	(205) 464-0490	Jaco, Kent, Sterling
Semtech	(805) 498-2111	N/A

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