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People who are really serious about software should make their own hardware. — Alan Kay

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Phillip Stanley-Marbell

Abstract This document describes the hardware design and usage directions for a daughtercard designed to enable measurement of current usage by all the voltage rails employed by the Logicpd i.MX31 evaluation board's processor module.

1 Introduction

The Logicpd ZOOM Freescale i.MX LITEKIT is a hardware evaluation board for evaluating the Freescale i.MX31 embedded processor. It consists of a baseboard with a variety of peripherals and connectors (CompactFlash, USB, RS-232, Ethernet, audio input and output), and a processor module containing a Freescale i.MX31 processor (MCIMX31VKN5B), DRAM, SRAM, flash memory and a voltage regulator (Freescale MC13783 power management and audio integrated circuit, also known as the "ATLAS" IC).

The baseboard provides four voltage rails to the processor module, as illustrated in Figure 1(a). The MC13783 ATLAS system IC contains hardware support for monitoring the charge current when charging a battery ([Freescale Semiconductor, Inc., 2007], Section 1.3) as well as current monitoring from one of the voltage rails (the main system battery) needed to implement battery lifetime estimation (e.g., via Coulomb counting techniques [Freescale Semiconductor, Inc., 2007] Section 4.4.2.5.1). The hardware described in this document is independent of this measurement facility, and provides measurement facilities for all voltage rails. These measurements can be performed without the need to have any software control over the i.MX31 (e.g., when there is no driver support within the OS running on the i.MX31 for reading the A/D converters that read off the battery current sense resistors). Using an external current monitoring framework also eliminates possible interference between software executing on the i.MX31 processor, which would be needed to read measurement values off the MC13783's A/D converters (through software transfers or DMA), and the measurements being taken.

2 System Architecture

The implementation of the current monitoring facilities are straightforward. The current being provided to the processor module (referred to by Logicpd as the SOM-LV), via each of the four different voltage rails, is passed through a current sensing resistor. The power supply architecture of the Logicpd baseboard and processor module are illustrated in Figure 1(a), and described in more detail in the *i.MX31-10 Hardware Specification, Logic PN: 1005992* [Logic Product Development, Inc., 2006].

The voltage across the current sensing resistor is amplified by a current shunt monitor IC with a voltage output. This amplified voltage output can be be displayed on an oscilloscope or data-acquisition (DAQ) hardware to achieve current and hence power consumption measurement. The implementation also provides a set of jumpers for each voltage rail, enabling the current monitoring to be bypassed, or for a current meter to be inserted into the power supply path. The current measurement framework's system architecture is illustrated in Figure 1(b).

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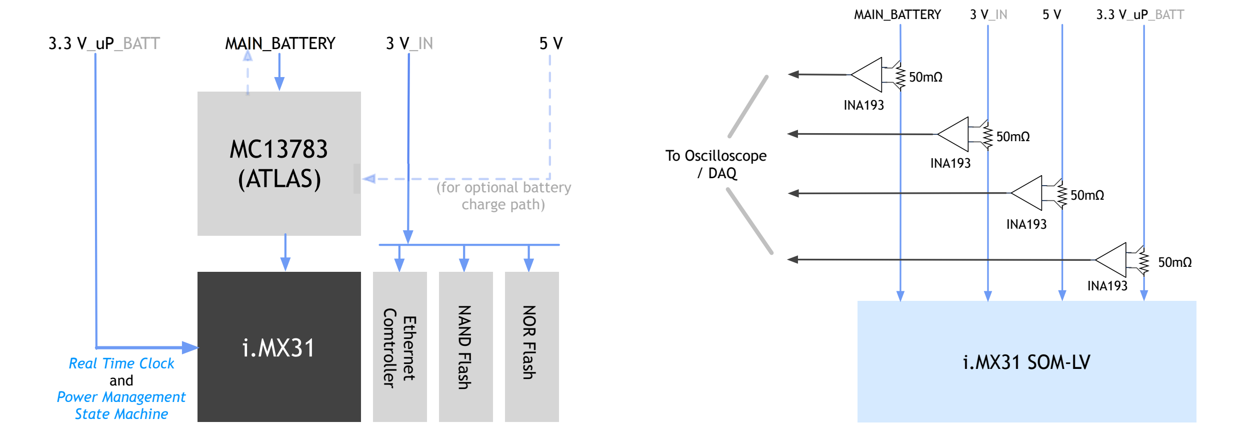
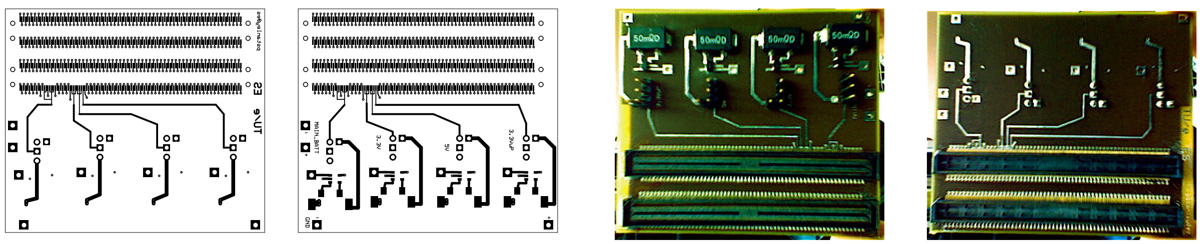


(a) (b)

Fig. 1 Power supplies of the Logicpd i.MX31 processor module, and the current monitoring system that was implemented to measure current on these supply rails.



(a) Layout, bottom. (b) Layout, top. (c) Assembled PCB, top (d) Assembled PCB, bottom

Fig. 2 Layout and final fabricated hardware for the current measurement daughtercard.

3 System implementation

The current measurement "shunt board" was implemented using a 4-layer PCB process, with two signal layers for the daughter-board connector and signal routing, and two plane layers to provide shielding, and also serving as power and ground layers, for the current monitor / amplifier IC. In practice, the current monitor is powered off a battery to provide a noise-free power supply. The PCB layout and assembled PCB are shown in Figure 2.

The design uses four-terminal resistors to achieve Kelvin connections between the current monitor IC and the current sense resistance. The current monitor IC employed is a TI INA193 [Texas Instruments, Inc., 2006], with a gain of 20V/V; this may be replaced with the pin-compatible INA 194 and INA195 ICs which have gains of 50V/V and 100V/V respectively. The bill of materials for the daughtercard is shown in Table 1.

Table 1 Bill of materials for the current monitoring daughtercard.

Description	Manufacturer, Part Number	Digikey Part Number	Quantity
Printed circuit board	—	—	1
50 mΩ current sense resistor	Ohmite, RW1S0CKR050DET	RW1S0CKR050DEND	4
Current shunt monitor amplifier	TI, INA193	296-17163-1-ND	4
Jumper header connector, 0.1"	Molex, 22-28-4364	WM6736-ND	16/36
Shorting jumper connector	Sullins, SPC02SYAN	S9001-ND	8
Board-to-board connector	Samtec, BSH-120-01-L-D-A	—	2
Board-to-board connector	Samtec, BTH-120-01-L-D-A	—	2

4 System Evaluation

The daughtercard was fabricated and installed in the Logicpd LITEKIT evaluation platform. For a supply current of i Amperes, the voltage drop across the current sense resistor is $(i \times 50E-3)\,V$, and the voltage at the

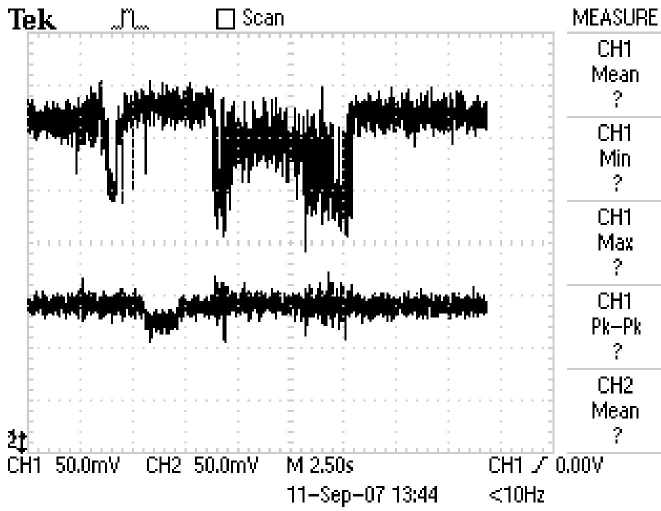


Fig. 3 Supply current profile for Linux booting on the i.MX31 LITEKIT processor module. The `MAIN_BATTERY` current is shown on channel 1 (top), and $3.3\,V$ legacy device supply is shown on channel 2 (bottom).

output of the current monitor amplifier, which has a gain of 20V/V, will be $(20 \times i \times 50E - 3)\,V = i\,V$. Thus the voltage reading at the output of the current monitor amplifier is identically the current being drawn from the supply. Thus, for example, a voltage reading of $300\,mV$ at the output of the current monitoring amplifier, corresponds to a supply current of $300\,mA$. Figure 3 shows the supply current for the `MAIN_BATTERY` supply rail, which is the primary power source for the i.MX31 processor module, and the secondary $3.3\,V$ power rail, on channels 1 and 2 of an oscilloscope respectively, while booting the Linux kernel on the SOM-LV.

The accuracy of the output of the INA193 family of devices depends on the sense voltage $V_{\mathrm{SENSE}} = V_{\mathrm{IN+}} - V_{\mathrm{IN-}}$ as well as on the common mode voltage V_{CM}. The accuracy of the INA193 family of devices varies with the range of values of V_{SENSE} and V_{CM}, and *it is important that the user of the daughtercard determine in which operating region the INA193 is operating, and hence the accuracy of its output.* The output of the INA193 family is most accurate for $V_{\mathrm{SENSE}} \geq 20\,mV$, which would correspond to a $400\,mA$ supply current passing through the $50\,m\Omega$ current sense resistor.

5 Summary and Conclusion

This document provided an overview of a daughtercard designed to enable current measurement on the Logicpd i.MX31 LITEKIT. The relevant supply voltage rails powering the hardware's processor module or SOM-LV, which is the device under test for which current is desired to be measured, were outlined. The design of the measurement circuits was presented, along with their implementation and example measurements taken with the hardware. The document concluded with cautionary notes that should be taken into consideration when using the measurement hardware.

References

Freescale Semiconductor, Inc. Technical Data, MC13783 Power Management and Audio Circuit, Document Number: MC13783/D, Rev. 3.4, 3/2007. 2007.

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