

## *Lecture 18 objectives*

- Embedded systems (Lab 8 decisions)
- Power
- Manufacturability

## *An embedded system is a system*

- Microcontroller (LM3S811 or MSP430)
- Electrical circuits
- Mechanical devices (input/output)
- Power
- Package

## *Lab 8 Decisions*

### 1) What should it do?

Game (graphics, sound, keys)

Measure something

Medical instrument (hearing aid, heart sounds, ekg)

### 2) Input devices

Switches (B3Fxxx.pdf)

Keypad

Microphone (Electretxxx.pdf)

Accelerometer (ADXL202.pdf)

### 3) Output devices

LEDs

1mA red, 2mA yellow, 2mA green

20 mA orange, 20 mA blue

LCD (16 by 1 or 20 by 4 line) from checkout

Samtec BCS-114-L-S-TE

LCD (16 by 2 line) from Valvano

Samtec BCS-116-L-S-TE

LCD 64 by 128 graphics, \$10 from BGMicro

LCD1030.pdf, AGM1264\_1968.zip

Samtec BCS-120-L-S-TE

32 ohm speaker

Solid state relay

#### 4) Microcontroller

LM3S811 like Lab 6

Free sample from Texas Instrument (get from professor)

Other LM3Sxxx (get parts)

MSP430F2012 or MSP430F2013

1.8V to 3.7V, very low power

2 KiB EEPROM, 128 bytes RAM

14-pin PDIP package

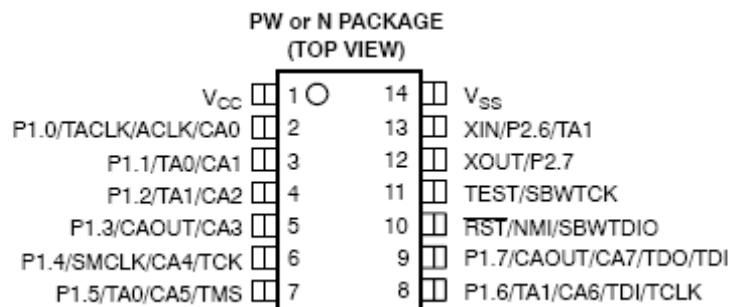
10 I/O pins

SCI, SPI, I<sup>2</sup>C, 10/16-bit ADC

Debugger, assembler, compiler for free

Samtec SLM-104-01-G-S

TI MSP430F2012IN or MSP430F2013IN



#### 5) Risk versus reward

### Requirements Document (1 page)

#### 1. Overview

**1.1. Objectives:** Why are we doing this project? What is the purpose?

**1.2. Roles and Responsibilities:** Who will do what? Who are the clients?

**1.3. Interactions with Existing Systems:**

LCD, Tech Arts board

## 2. Function Description

**2.1. Functionality:** What will the system do precisely?

**2.4. Performance:** Define the measures and describe how they will be determined.

**2.5. Usability:** Describe the interfaces. Be quantitative if possible.

## 3. Deliverables

**3.1. Reports:** Simply state the reports for Labs 8 and 11 will be written

**3.2. Outcomes:** Simply copy/paste the Lab 8 and Lab 11 deliverables.

## Bill of Materials

Collect example parts during the design

3-D design

## Power Budget

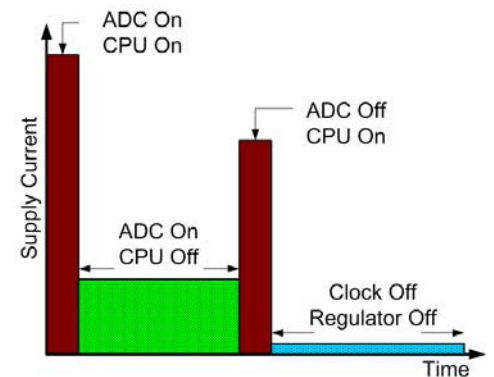
**Average Current** must be less than  $E/t_{life}$

## Strategies for low power design

Choose E clock frequency

Sleep mode

Turn off power to op amps



**Table A-9. Supply Current Characteristics for Other Family Members**

Conditions are shown in Table A-4 with internal regulator enabled unless otherwise noted							
Num	C	Rating	Symbol	Min	Typ	Max	Unit
1	P	Run Supply Current Single Chip,	$I_{DD5}$	—	—	45	mA
2	P P C	Wait Supply current All modules enabled VDDR<4.9V, only RTI enabled <sup>2</sup> VDDR>4.9V, only RTI enabled	$I_{DDW}$	— — —	— 2.5 3.5	33 8 —	mA
6	C P C P C P C P	Pseudo Stop Current (RTI and COP disabled) <sup>23</sup> -40°C 27°C 85°C "C" Temp Option 100°C 105°C "V" Temp Option 120°C 125°C "M" Temp Option 140°C	$I_{DDPS}^{(1)}$	— — — — — — — —	190 200 300 400 450 600 650 1000	— 250 — 1400 — 1900 — 4800	μA
4	C C C C C	Pseudo Stop Current (RTI and COP enabled) <sup>(2) (3)</sup> -40°C 27°C 85°C 105°C 125°C	$I_{DDPS}^1$	— — — — —	370 500 590 780 1200	— — — — —	μA
5	C P C P C P C P	Stop Current <sup>3</sup> -40°C 27°C 85°C "C" Temp Option 100°C 105°C "V" Temp Option 120°C 125°C "M" Temp Option 140°C	$I_{DD5}^1$	— — — — — — — —	12 25 130 160 200 350 400 600	— 100 — 1200 — 1700 — 4500	μA

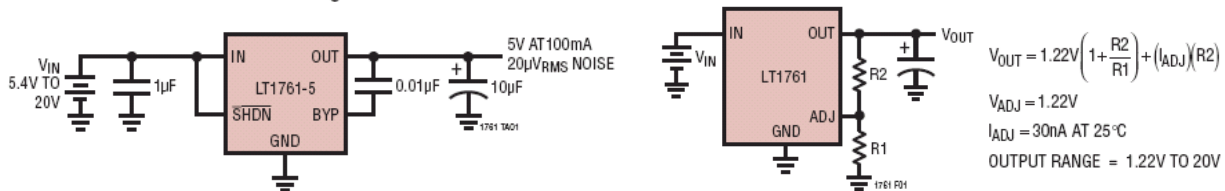
**Regulator (look in Lab08BOM.xls for free options)**

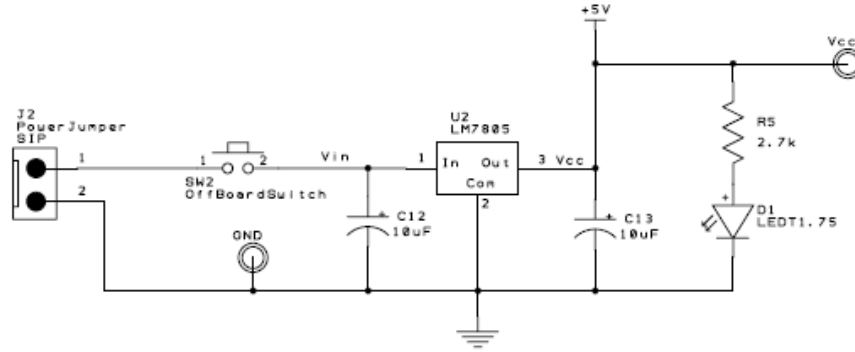
Fixed voltage, like LP2950ACZ-3.3G, LM2937-3.3

Adjustable voltage, LT1761, LM317

Low dropout voltage

**5V Low Noise Regulator**



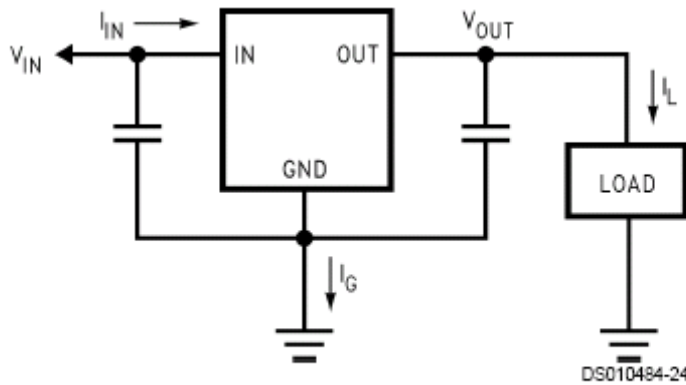


**LM341-5.0, LM78M05C**

Unless otherwise specified:  $V_{IN} = 10V$ ,  $C_{IN} = 0.33 \mu F$ ,  $C_O = 0.1 \mu F$

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_O$	Output Voltage	$I_L = 500 \text{ mA}$	4.8	5.0	5.2	V
		$5 \text{ mA} \leq I_L \leq 500 \text{ mA}$ $P_D \leq 7.5W, 7.5V \leq V_{IN} \leq 20V$	<b>4.75</b>	<b>5.0</b>	<b>5.25</b>	

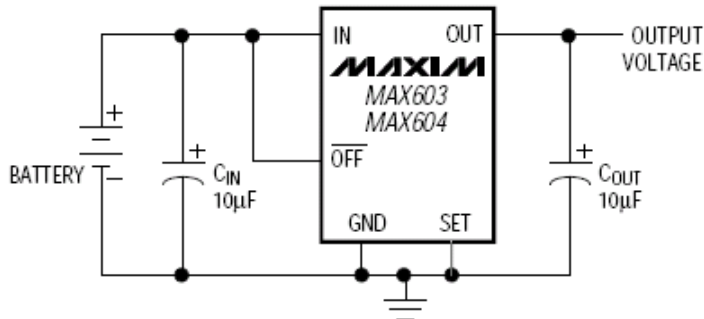
Think about the lost power



$$I_{IN} = I_L + I_G$$

$$P_D = (V_{IN} - V_{OUT}) I_L + V_{IN} I_G$$

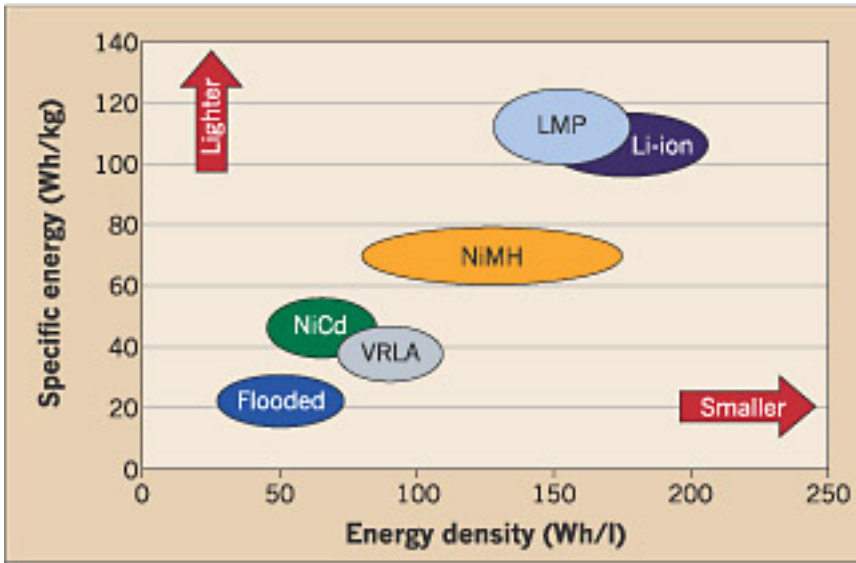
FIGURE 2. Power Dissipation Diagram



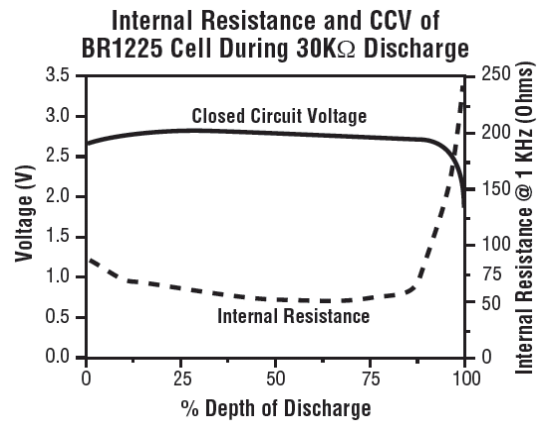
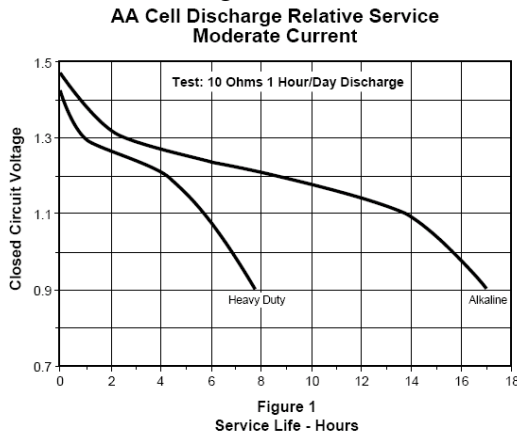
Output Voltage (Note 2)	$V_{OUT}$	$I_{OUT} = 20\mu A \text{ to } 500 \text{ mA}, 6.0V < V_{IN} < 11.5V$	MAX603	4.75	5.00	5.25	V
		$I_{OUT} = 20\mu A \text{ to } 300 \text{ mA}, 4.3V < V_{IN} < 11.5V$	MAX604	3.15	3.30	3.45	



## Batteries



However, embedded systems that use these types of battery will require a voltage regulator to maintain a constant voltage for the electronics. For example, a +5V 9S12DP512 will operate with a power supply voltage from 4.5 to 5.25 V. The curve on the left is a BR1225 Lithium battery, which maintains a constant voltage until 85-90% of the energy is discharged.

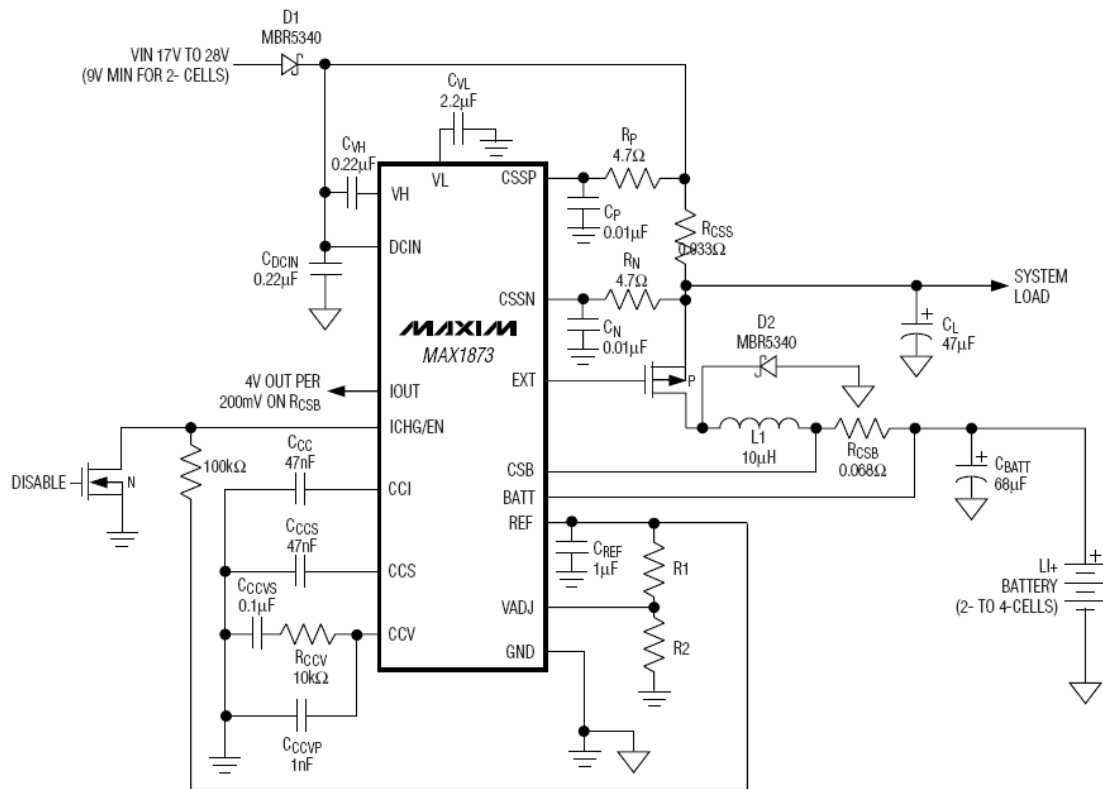


AA-sized batteries are 50 mm tall by 14 mm diameter.

Battery	Voltage (V)	Energy (mAh)	Type
Alkaline	1.5	2000	Primary
Lithium	1.5	3000	Primary
NiCad	1.2	1200	Secondary
NiMH	1.2	1800	Secondary
Li-ion	3.6	1900	Secondary

*Energy storage for different battery types of AA size.*

*If you use a rechargeable battery, how will it be charged?  
 If you use a disposable battery, how easy is it to change?*



[http://www.engineersedge.com/battery/battery\\_knowledge\\_menu.shtml](http://www.engineersedge.com/battery/battery_knowledge_menu.shtml)

bq24004  
 bq24005  
 bq24006



SLUS478D—DECEMBER 2000—REVISED SEPTEMBER 2005

APPLICATION INFORMATION

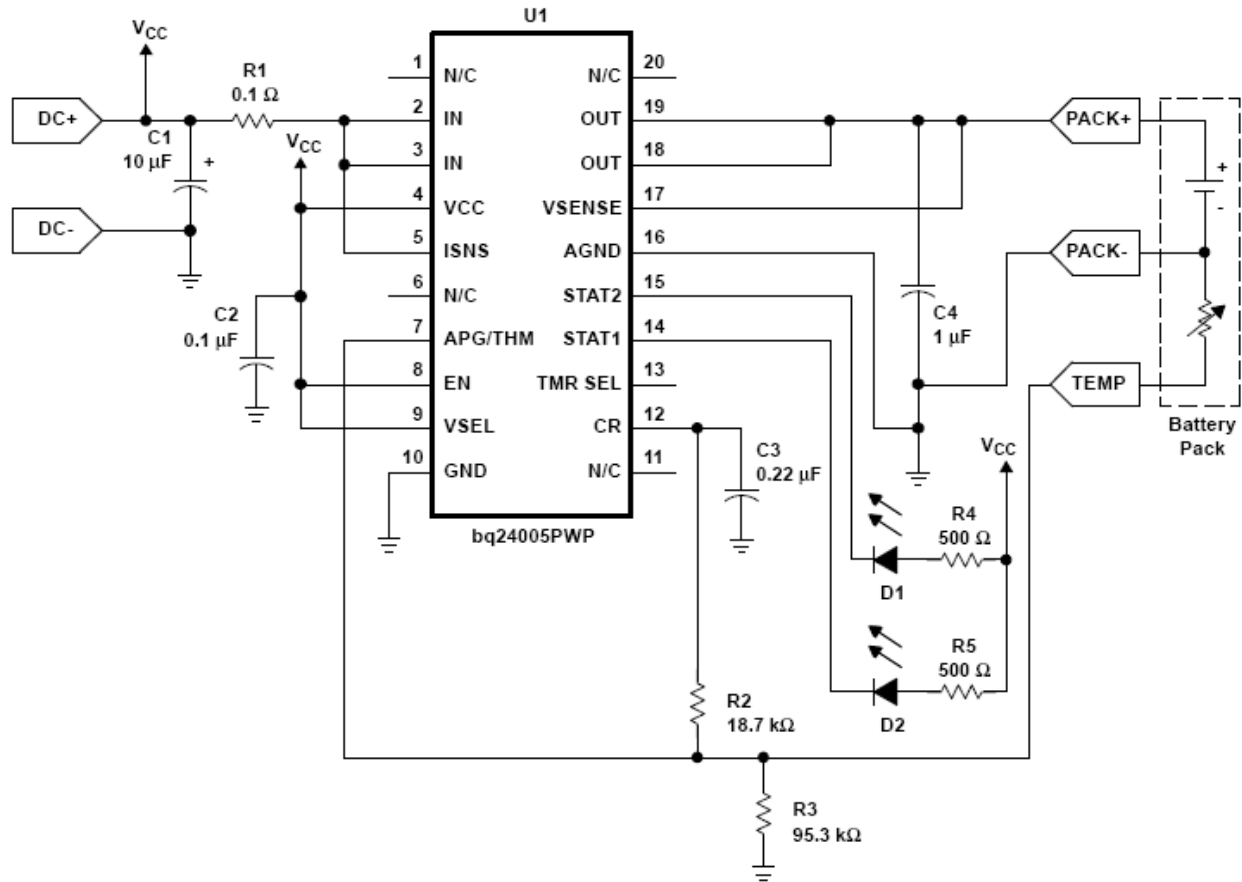
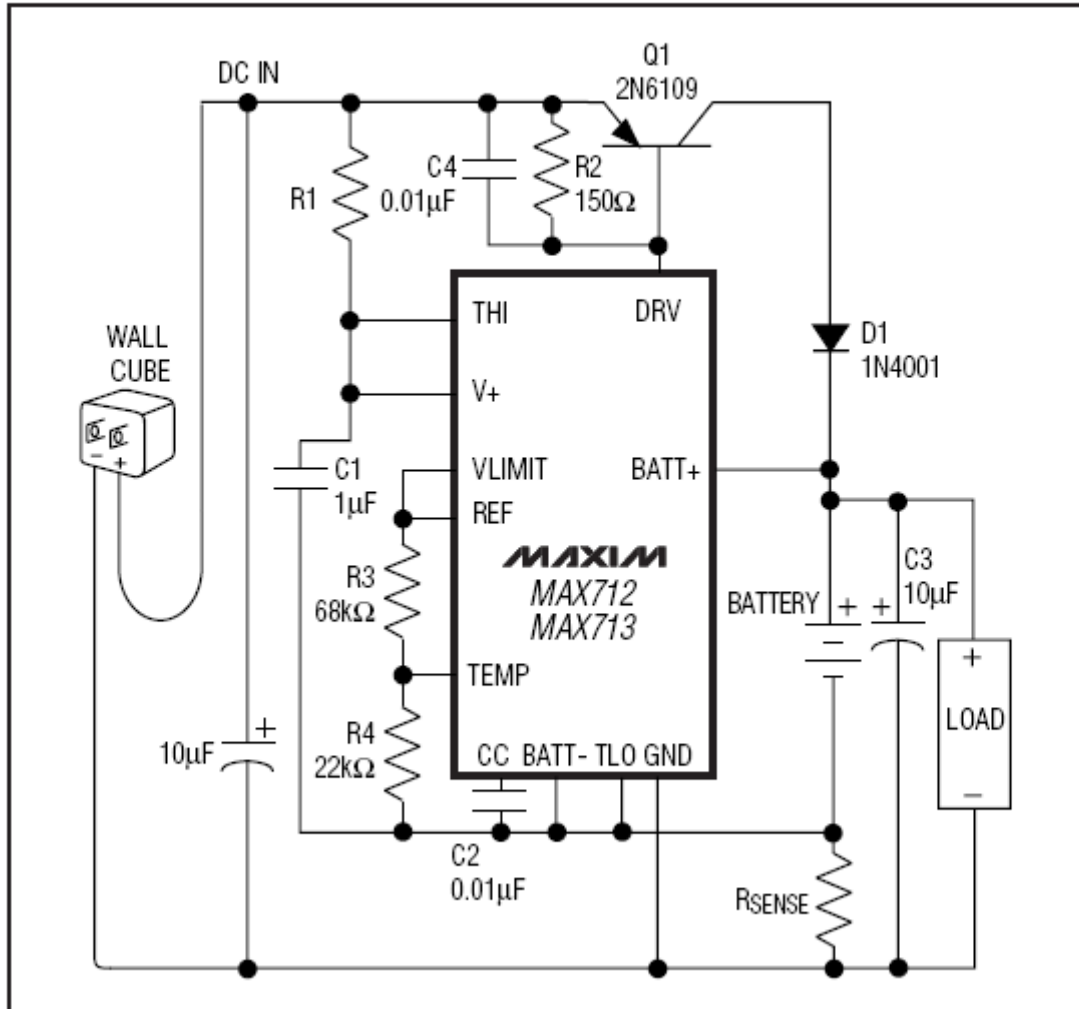


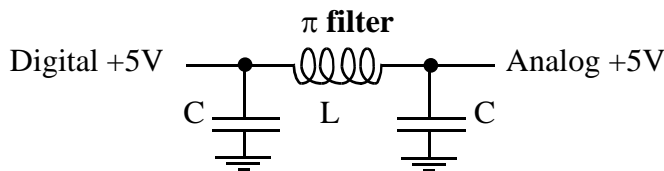
Figure 13. Li-ION/Li-POL Charger

## Typical Operating Circuit



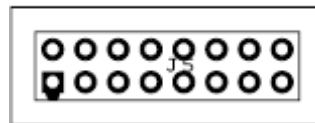
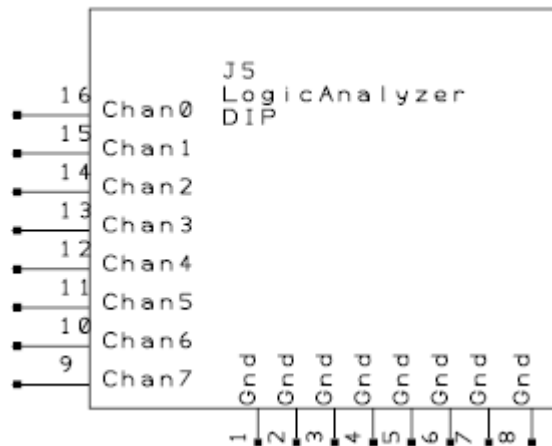
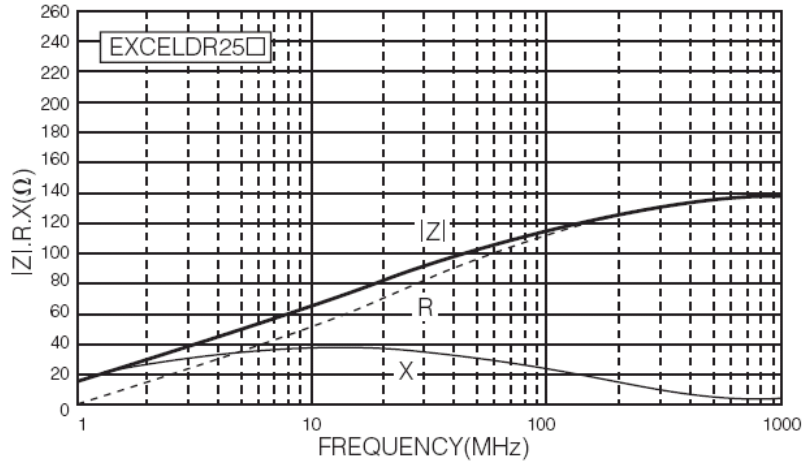
*NiMH charger*

A **CLC filter** can be used to create a blocking filter to separate current spikes generated by digital logic from becoming voltage noise on analog power lines. This filter is also called a  $\pi$  filter.



For the inductor, one can use a ferrite bead. At DC the bead is essentially a short circuit. The ferrite bead increases both its real and reactive impedance at high frequencies. The bead should be selected to have a large impedance at the digital clock frequency. Panasonic makes a series of ferrite beads. In the

following figure, X is the reactance (in  $\Omega$ ), determined by the magnitude  $|j\omega L|$ . R is the real part of the resistance (also in  $\Omega$ ), which also increase with frequency.  $|Z|$  is the overall impedance. The Panasonic EXC-ELDR25C has a DC resistance of  $0.08 \Omega$ , can conduct 7A DC, but has an  $80\text{-}\Omega$  impedance at 24 MHz.



**Testing**

- Debugging interface, JTAG, Spy-Bi-Wire
- Test points (two big clips for ground)
- Logic analyzer connector
- Heart beats (LEDs or scope test points)