

# MSP430 Advanced Technical Conference 2006



## Battery Charging and Chemistry Detection with the MSP430

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# Agenda

- Battery Charging Basics
- Li-Ion Charging
- NiMH Charging
- Chemistry Detection
- Hardware and Software Overview
- Demo

# Battery Chemistries

<b>Chemistry</b>	Alkaline	Ni-Cad	NiMH	Li-Ion
<b>Rechargeable</b>	No	Yes	Yes	Yes
<b>Memory Effect</b>	N/A	Large	Small	None
<b>Self Discharge</b>	Medium	High	High	Low
<b>Current Output</b>	Medium	High	High	Low
<b>Capacity</b>	Low	Low	Medium	High
<b>Cost</b>	Low	Low	Medium	High

- **Li-Ion is potentially dangerous to charge**
- **Ni-Cad is very environmentally unfriendly**

# Battery Charging Basics

- Battery Capacity is expressed in mAh
- Charge rate is expressed in terms of C
- $C = \text{Battery Capacity} / 1 \text{ hour}$
- Example: 2500mAh battery
  - $C = 2.5A$
  - $2C = 5A$
  - $C/2 = 1.25A$
  - $C/10 = 250mA$
  - Etc.
- A battery charged at 1C should charge in ~1 hour, at C/2 in ~2 hours

# Agenda

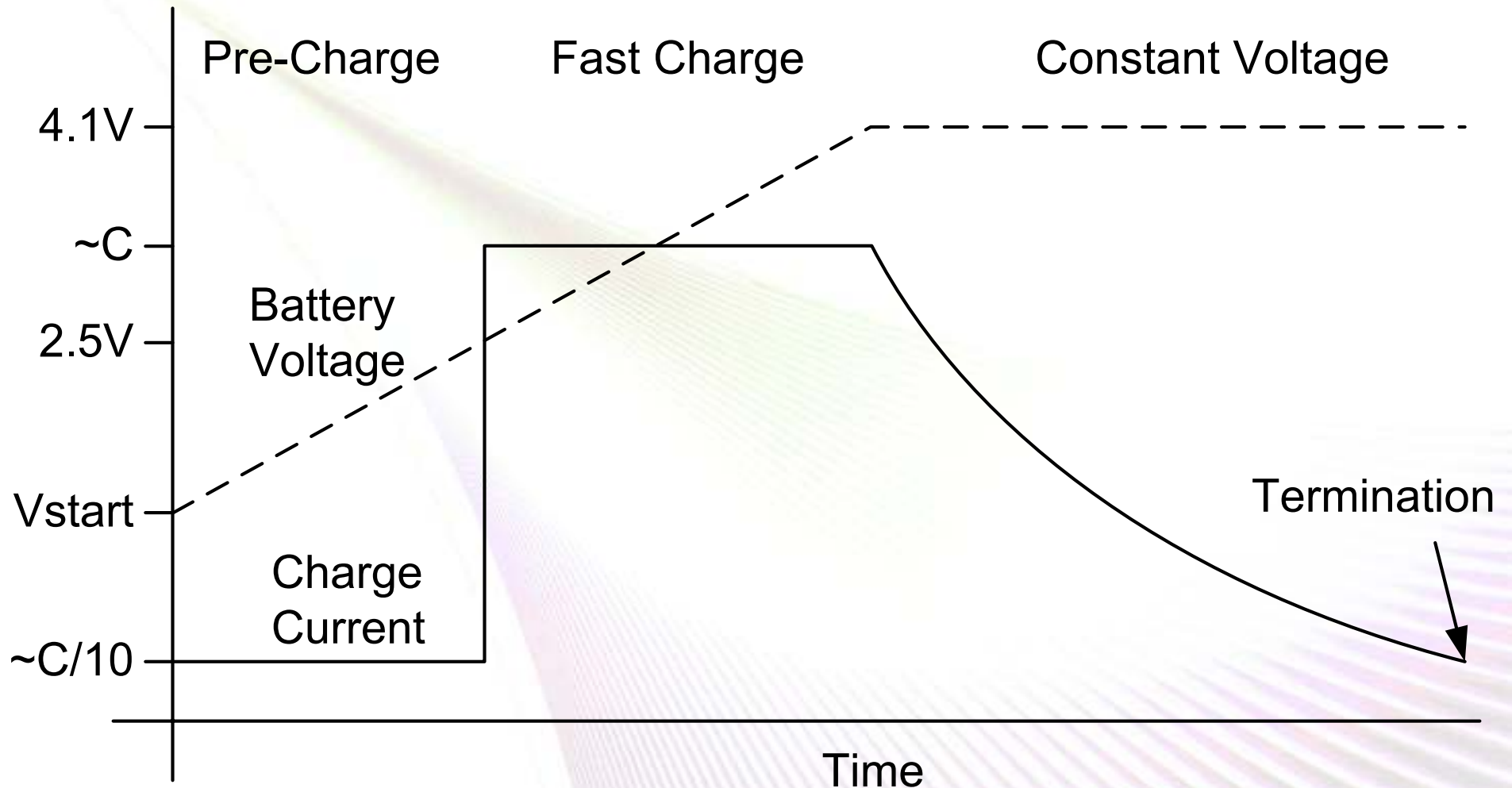
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# Li-Ion Charging Stages

- **Pre-Charge (Conditioning)**
  - If battery voltage  $< 2.5V$
  - Constant current of  $C/10$
- **Fast Charge**
  - Constant current of  $1C$
  - While battery voltage in between  $2.5V$  and  $4.1V$
- **Constant Voltage Charge**
  - Constant voltage at  $4.1V$
- **Termination**
  - When current drops below  $C/10$

# Li-Ion Charging



# Agenda

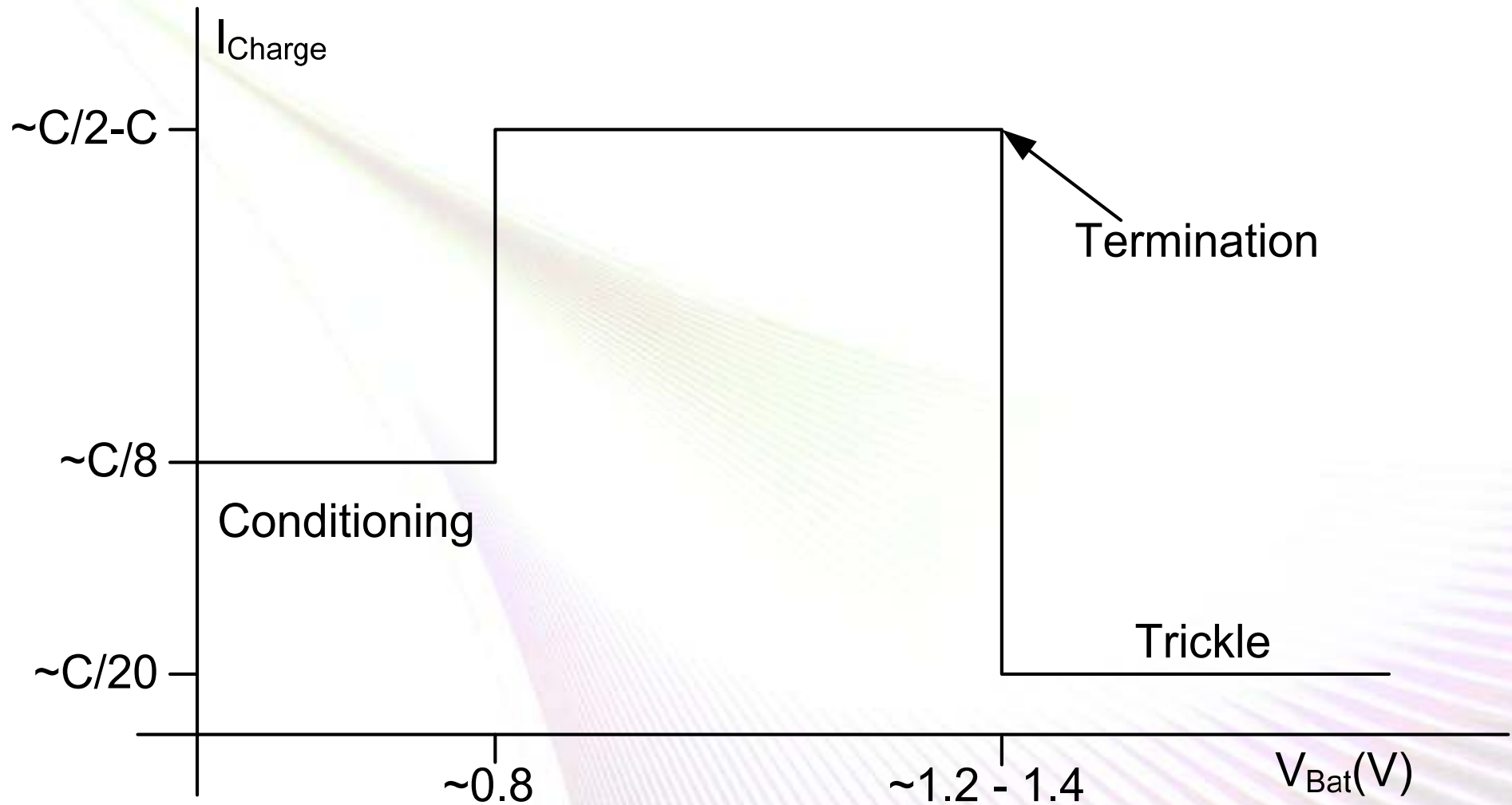
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# NiMH Charging Stages

- **Pre-Charge (Conditioning)**
  - If battery voltage  $< 0.9V$
  - Constant Current of  $C/10$
- **Charge**
  - Constant current of  $C/2 - 1C$
  - When battery voltage  $> 0.9V$
- **Termination**
  - 3 different methods
- **Trickle Charge**
  - After termination constant current of  $C/20$  to maintain charge

# NiMH Charging



# NiMH Charge Termination

- **3 Methods**

- $-\Delta V/\Delta t$  (primary)
- $\Delta T/\Delta t$  (secondary)
- Timer (secondary)

- **Use all 3 for robust charge termination**

- **$\Delta T/\Delta t$**

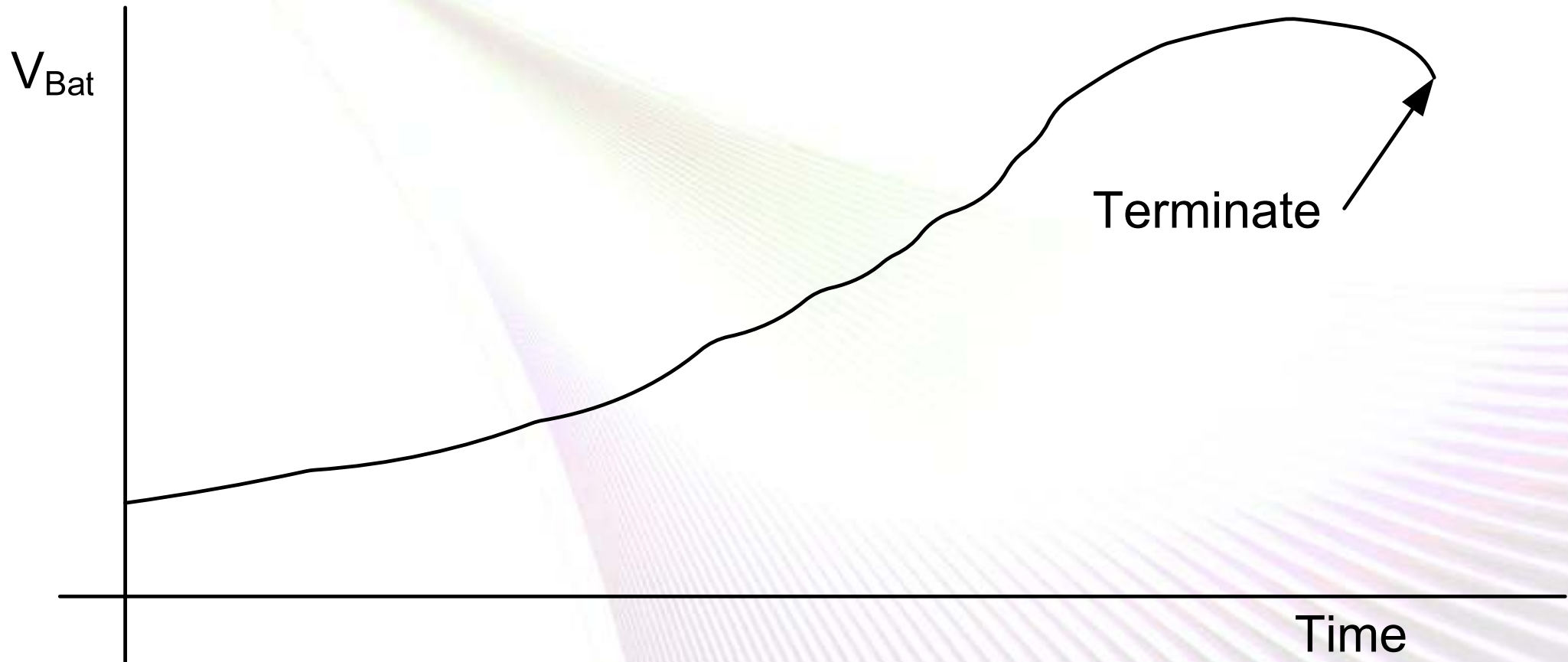
- Look for sharp increase in battery temperature over ambient or absolute safety temperature

- **Timer**

- Set timer for appropriate charge time + 10% to 20% (to account for inefficiencies)
- Example: if charging at C/2, set timer for 2 hours + 12 to 24 minutes

# **$-\Delta V/\Delta t$ Termination**

- Look for battery voltage dip



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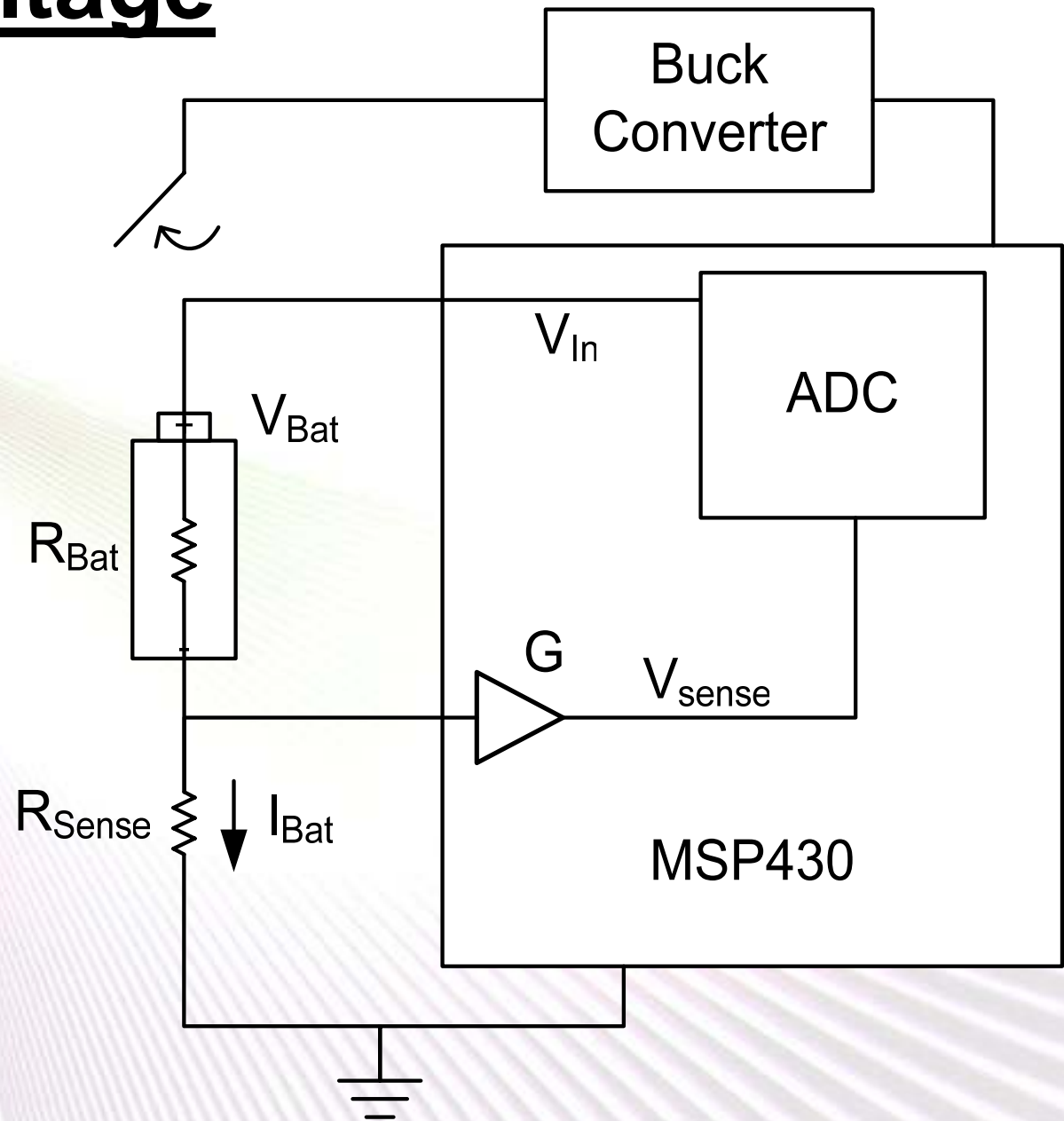
# About Chemistries Detection

- Different battery chemistries have different internal impedances
- These impedances change over temperature, charge state, and life of the battery
- Goal: only charge the battery if it is definitely a NiMH (or NiCad)
- *Never attempt to charge different chemistries (Alkaline, Lithium, etc.)*
- NiMH has lowest impedance of all AA battery chemistries
- Impedance =  $R_{\text{Bat}} = \frac{V_{\text{Bat(Closed)}} - V_{\text{Bat(Open)}}}{I_{\text{Bat(Closed)}}$



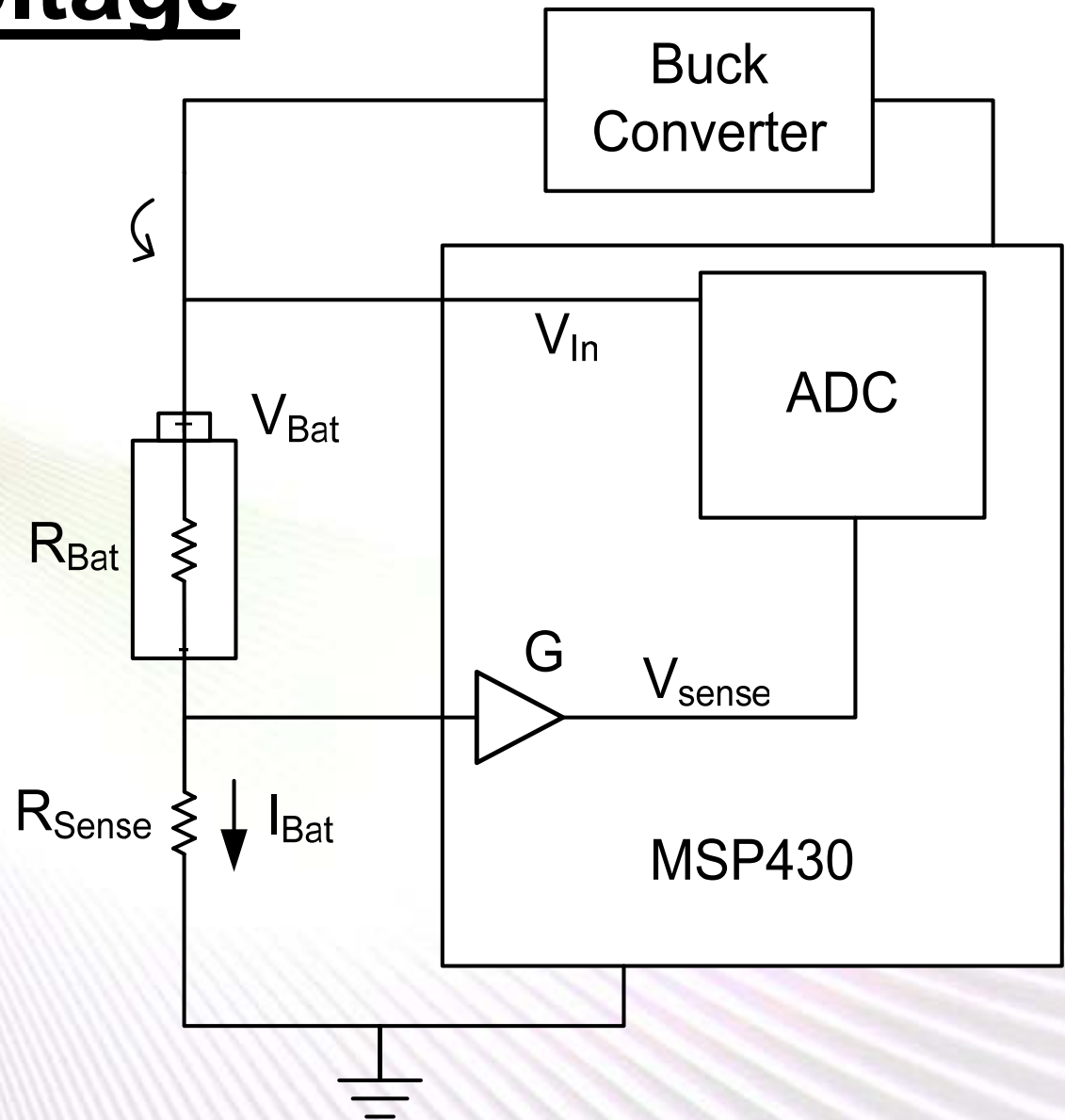
# Open Loop Voltage

- $I_{\text{Bat}} = 0\text{mA}$
- $V_{\text{sense}} = 0\text{V}$
- $V_{\text{Bat}} = V_{\text{In}}$



# Closed Loop Voltage

- $I_{\text{Bat}} < 150\text{mA}$
- $V_{\text{sense}} = G \cdot I_{\text{Bat}} \cdot R_{\text{Sense}}$
- $V_{\text{Bat}} = V_{\text{In}} - (I_{\text{Bat}} \cdot R_{\text{Sense}})$



# Impedance Calculation

- $V_{\text{Bat(Closed)}} = V_{\text{In}} - (V_{\text{sense}} / G)$
- $I_{\text{Bat(Closed)}} = V_{\text{sense}} / (G \cdot R_{\text{Sense}})$
- $R_{\text{Bat}} = \frac{V_{\text{Bat(Closed)}} - V_{\text{Bat(Open)}}}{I_{\text{Bat(Closed)}}$

# How to Identify a NiMH AA Battery

- We use the battery's impedance calculation along with its open circuit voltage (estimate of its charge state) to determine whether it is a NiMH battery
- This method will sometimes fail to identify very old NiMH batteries correctly
  - Impedance increases over the life of a battery
- Conditioning charge of 150mA for some time often allows NiMH to recover to low impedance
- Example Impedance cutoffs for AA batteries

<b>Voltage</b>	<b>1.5V</b>	<b>1.2V</b>	<b>0.9V</b>
<b>Cutoff Impedance</b>	<b>100mOhm</b>	<b>150mOhm</b>	<b>200mOhm</b>

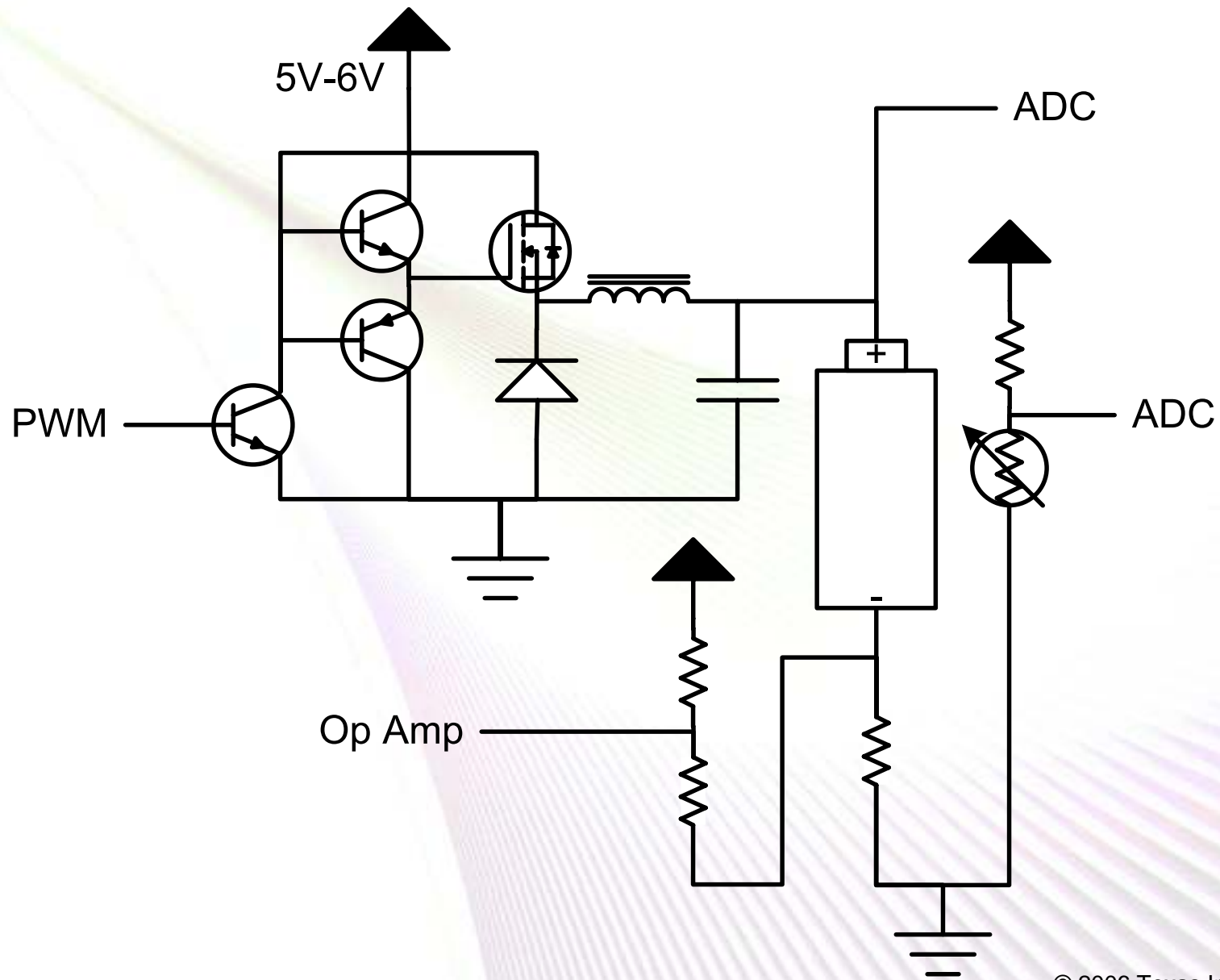
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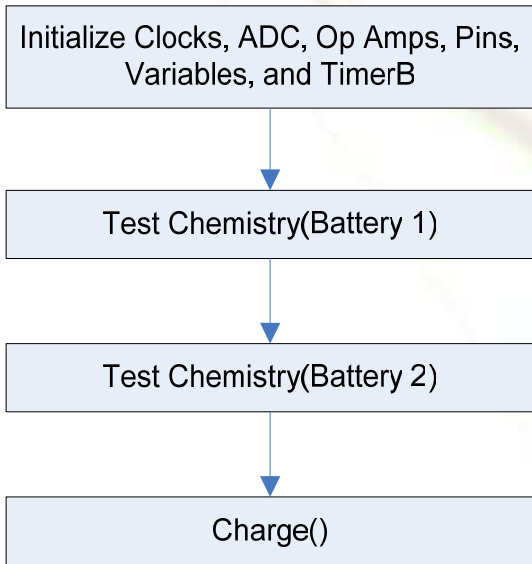
# Battery Charge Circuitry



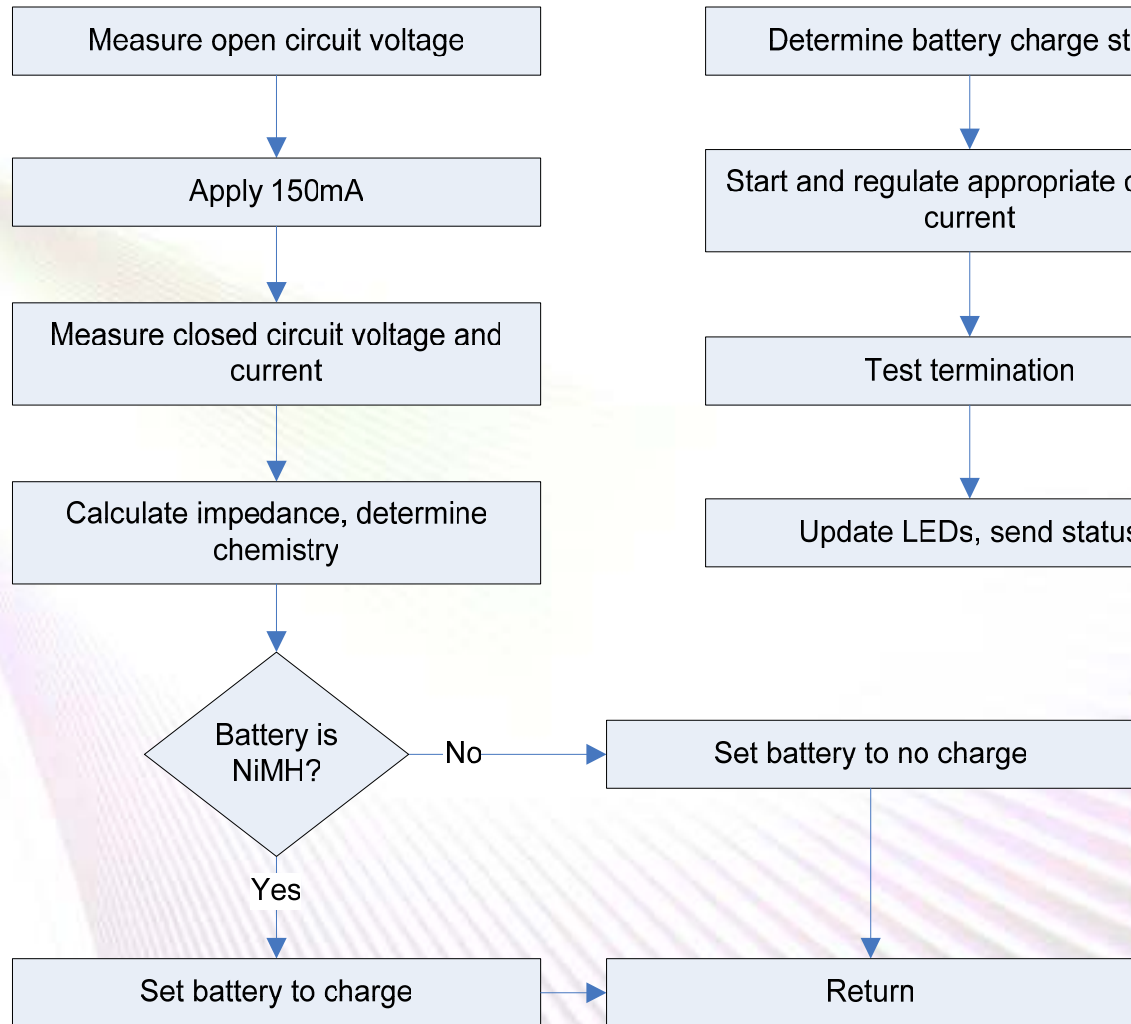
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# Software Overview

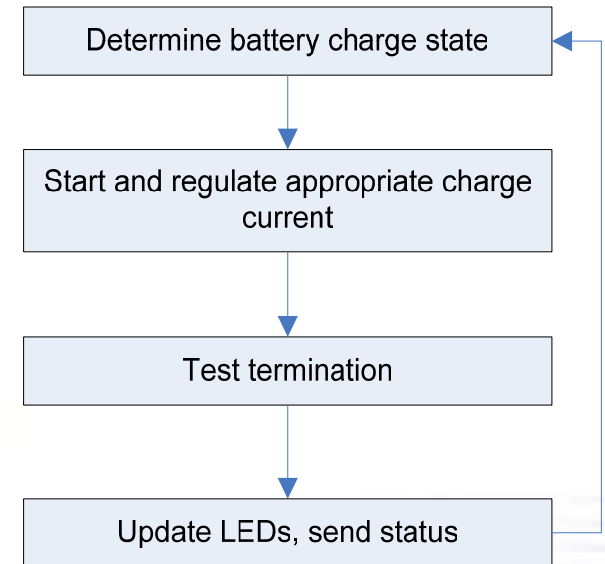
## Main Program



## Test Chemistry



## Charge



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# Demo

- Impedance Demo
- NiMH Charging Demo

# Summary

- **Li-Ion and NiMH batteries can be charged using the analog and digital control capabilities of the MSP430**
- **Non-Rechargeable batteries can be detected by measuring their open circuit voltage and impedance**

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