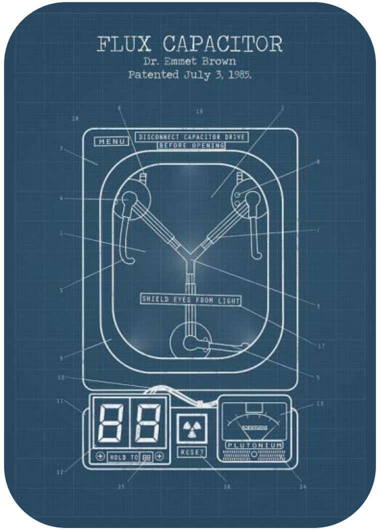
- Flux Capacitor -

A State of Charge (SOC) and State of Health (SOH) estimator for Batteries with Improved Coulomb Counting Technique



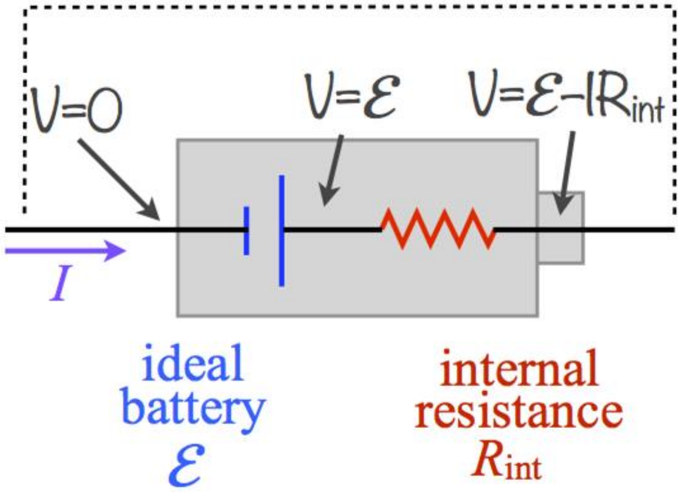
A thesis by Frank Li
Flux
2020-06-12

Abstract

Flux capacitor is meant to efficiently monitor use and storage of energy.

Design of System

$$\Delta V = \mathcal{E} - IR_{int}$$



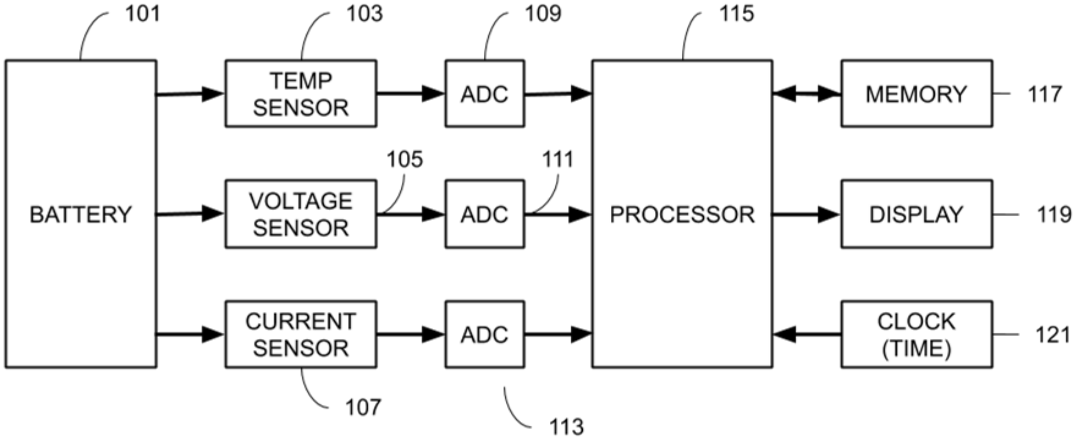
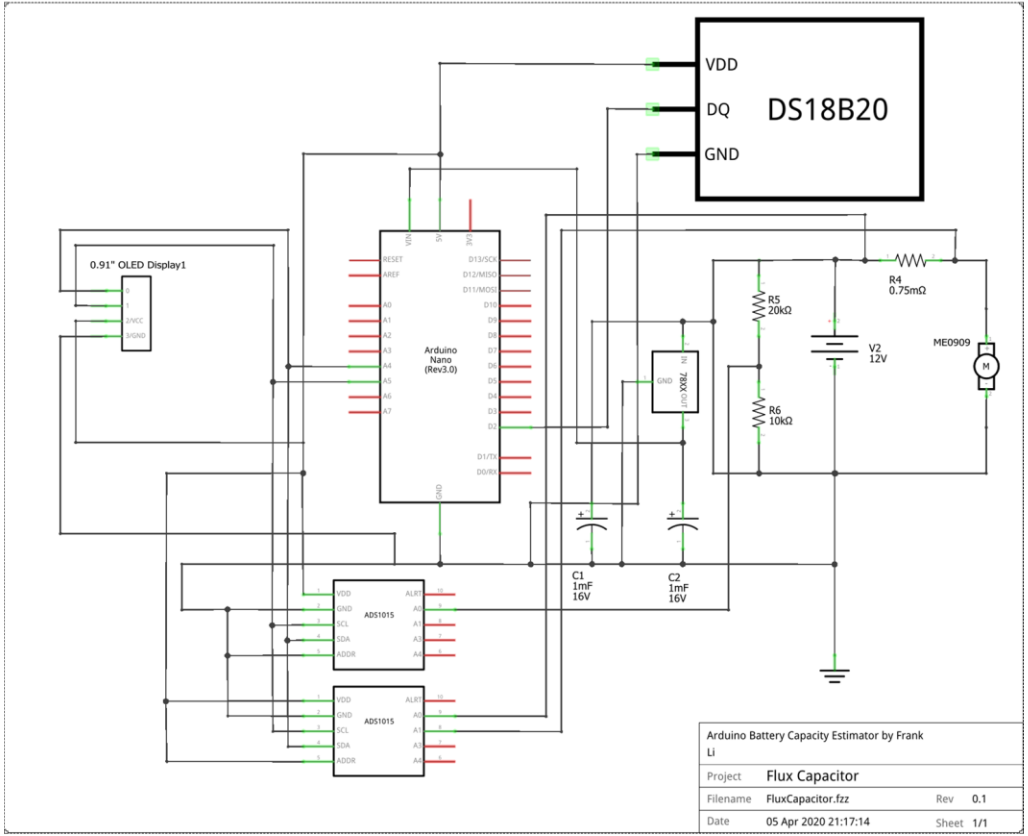


FIG. 1

Hardware



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TEXAS INSTRUMENTS

ADS1013, ADS1014, ADS1015

SBAS473E – MAY 2009 – REVISED JANUARY 2018

ADS101x Ultra-Small, Low-Power, I²C-Compatible, 3.3-kSPS, 12-Bit ADCs With Internal Reference, Oscillator, and Programmable Comparator

1 Features

- Ultra-Small X2QFN Package: 2 mm × 1.5 mm × 0.4 mm
- 12-Bit Noise-Free Resolution
- Wide Supply Range: 2.0 V to 5.5 V
- Low Current Consumption: 150 µA (Continuous-Conversion Mode)
- Programmable Data Rate: 128 SPS to 3.3 kSPS
- Single-Cycle Settling
- Internal Low-Drift Voltage Reference
- Internal Oscillator
- I²C Interface: Four Pin-Selectable Addresses
- Four Single-Ended or Two Differential Inputs (ADS1015)
- Programmable Comparator (ADS1014 and ADS1015)
- Operating Temperature Range: –40°C to +125°C

2 Applications

- Portable Instrumentation
- Battery Voltage and Current Monitoring
- Temperature Measurement Systems
- Consumer Electronics
- Factory Automation and Process Control

3 Description

The ADS1013, ADS1014, and ADS1015 devices (ADS101x) are precision, low-power, 12-bit, I²C-compatible, analog-to-digital converters (ADCs) offered in an ultra-small, leadless, X2QFN-10 package, and a VSSOP-10 package. The ADS101x devices incorporate a low-drift voltage reference and an oscillator. The ADS1014 and ADS1015 also incorporate a programmable gain amplifier (PGA) and a digital comparator. These features, along with a wide operating supply range, make the ADS101x well suited for power- and space-constrained, sensor measurement applications.

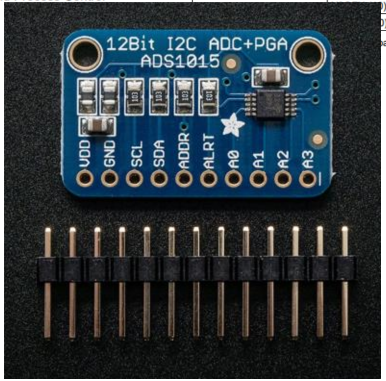
The ADS101x perform conversions at data rates up to 3300 samples per second (SPS). The PGA offers input ranges from ±256 mV to ±6.144 V, allowing precise large- and small-signal measurements. The ADS1015 features an input multiplexer (MUX) that allows two differential or four single-ended input measurements. Use the digital comparator in the ADS1014 and ADS1015 for under- and overvoltage detection.

The ADS101x operate in either continuous-conversion mode or single-shot mode. The devices are automatically powered down after one conversion in single-shot mode; therefore, power consumption is significantly reduced during idle periods.

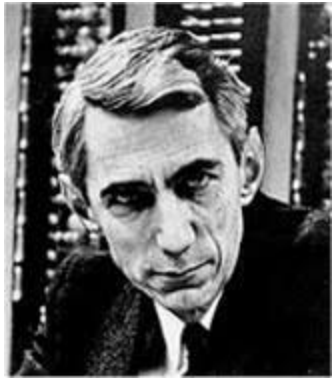
Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
	)	1.50 mm × 2.00 mm
	)	3.00 mm × 3.00 mm

ackage option addendum



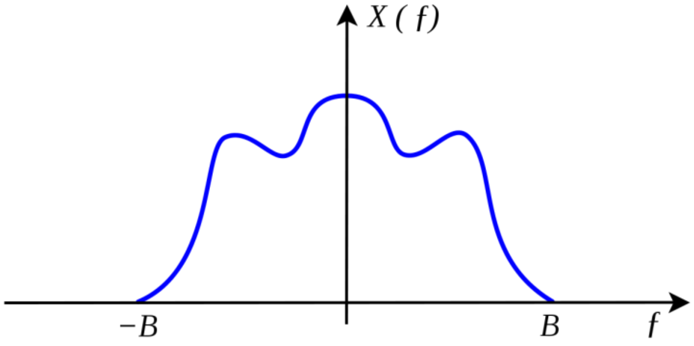
```
// configuration variables for the ADS1015
byte I2C_Voltage = 0x48;        // the I2C address of the device
byte I2C_Current = 0x49;        // the I2C address of the device
const byte Voltage_inputSelect  =  B11111111; // input enable configuration (all 8 input modes enabled)
const byte Current_inputSelect  =  B11111111; // input enable configuration (all 8 input modes enabled)
unsigned long ADS1015_inputGain = 0x55555555; // set the gain for each input
byte ADS1015_autoGainAdjust     =  B11111111; // enable/disable Auto Gain Adjust (all 8 enabled)
byte resultV;
byte resultI;
```



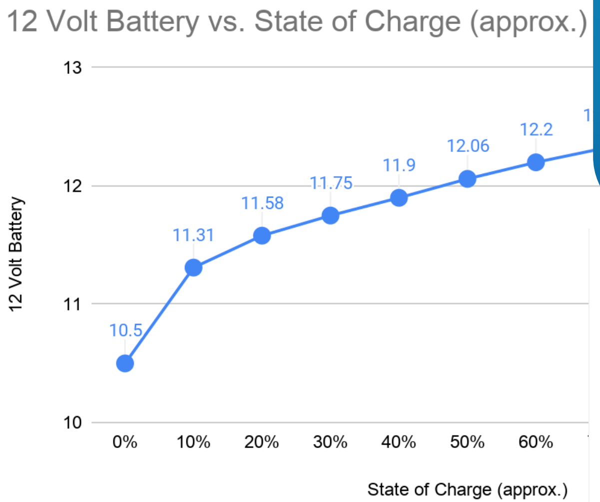
```
while(i < period){
    secondSample = millis();
    if(secondSample - firstSample >= samplePeriod){
      sample += getCurrent();
      //Serial.println(sample);
      i += samplePeriod;
      firstSample = secondSample;  //IMPORTANT to save
    }
}
```

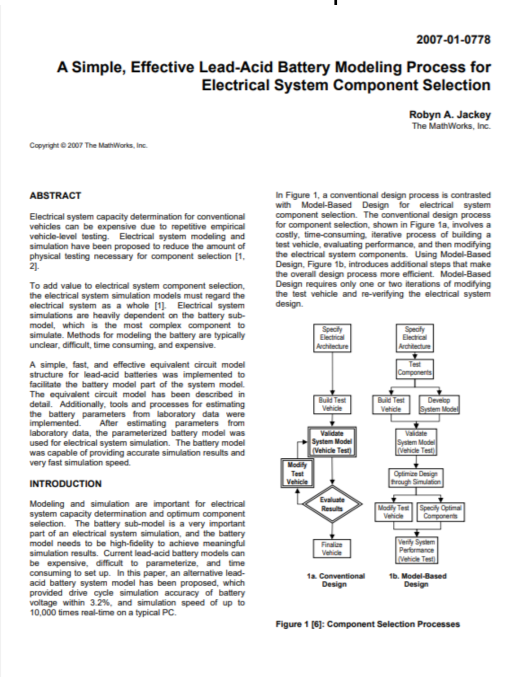
```
float getVoltage() {//units: V
    float voltage;
    voltage = (ADSV.getVoltage()*2.55);
      //Serial.println(voltage);
    return (ADSV.getVoltage()*2.55);
}

float getCurrent() { //units: A
    float current;
    current = (ADSI.getVoltage()/0.75);
    //Serial.println(current);
    return current;
}
```



References





2007-01-0778

A Simple, Effective Lead-Acid Battery Modeling Process for Electrical System Component Selection

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The MathWorks, Inc.

ABSTRACT

Electrical system capacity determination for conventional vehicles can be expensive due to repetitive empirical vehicle-level testing. Electrical system modeling and simulation have been proposed to reduce the amount of physical testing necessary for component selection [1, 2].

To add value to electrical system component selection, the electrical system simulation models must regard the electrical system as a whole [1]. Electrical system simulations are heavily dependent on the battery sub-model, which is the most complex component to simulate. Methods for modeling the battery are typically unclear, difficult, time consuming, and expensive.

A simple, fast, and effective equivalent circuit model structure for lead-acid batteries was implemented to facilitate the battery model part of the system model. The equivalent circuit model has been described in detail. Additionally, tools and processes for estimating the battery parameters from laboratory data were implemented. After estimating parameters from laboratory data, the parameterized battery model was used for electrical system simulation. The battery model was capable of providing accurate simulation results and very fast simulation speed.

INTRODUCTION

Modeling and simulation are important for electrical system capacity determination and optimum component selection. The battery sub-model is a very important part of an electrical system simulation, and the battery model needs to be high-fidelity to achieve meaningful simulation results. Current lead-acid battery models can be expensive, difficult to parameterize, and time consuming to set up. In this paper, an alternative lead-acid battery system model has been proposed, which provided drive cycle simulation accuracy of battery voltage within 3.2%, and simulation speed of up to 10,000 times real-time on a typical PC.

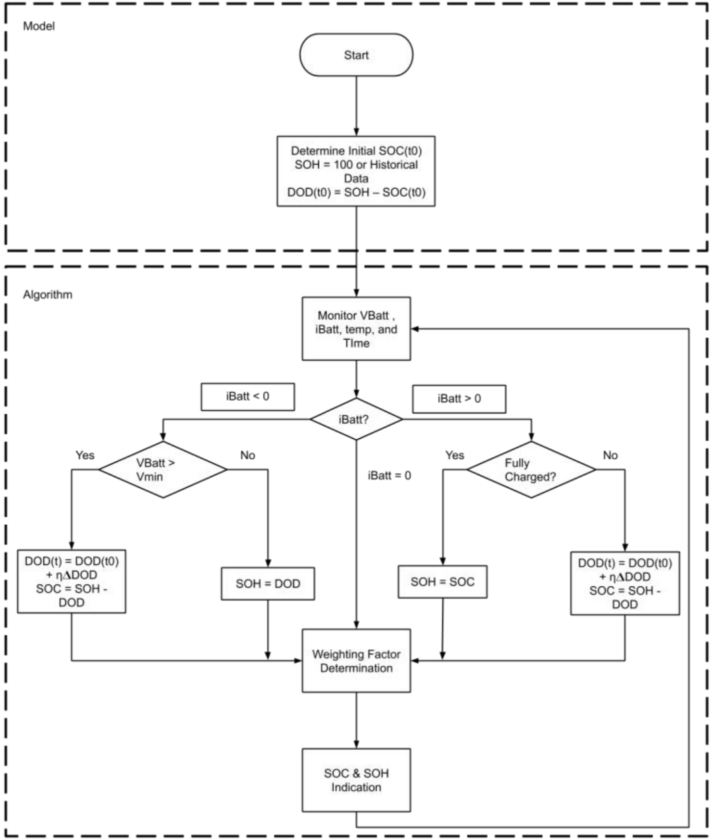
In Figure 1, a conventional design process is contrasted with Model-Based Design for electrical system component selection. The conventional design process for component selection, shown in Figure 1a, involves a costly, time-consuming, iterative process of building a test vehicle, evaluating performance, and then modifying the electrical system components. Using Model-Based Design, Figure 1b, introduces additional steps that make the overall design process more efficient. Model-Based Design requires only one or two iterations of modifying the test vehicle and re-verifying the electrical system design.

Specify Electrical Architecture
Build Test Vehicle
Validate System Model (Vehicle Test)
Modify Test Vehicle
Evaluate Results
Finalize Vehicle
1a. Conventional Design
Specify Electrical Architecture
Test Components
Build Test Vehicle
Develop System Model
Validate System Model (Vehicle Test)
Optimize Design through Simulation
Modify Test Vehicle
Specify Optimal Components
Verify System Performance (Vehicle Test)
1b. Model-Based Design

Figure 1 [6]: Component Selection Processes

ge	12 Volt Battery	Volts per Cell	Linear Equation
	12.70	2.12	Y = 2x + 10.7
	12.50	2.08	Y = 0.8x + 11.78
	12.42	2.07	Y = x + 11.62
	12.32	2.05	Y = 1.2x + 11.48
	12.20	2.03	Y = 1.4x + 11.36
	12.06	2.01	Y = 1.6x + 11.26
	11.90	1.98	Y = 1.5x + 11.3
	11.75	1.96	Y = 1.7x + 11.24
	11.58	1.93	Y= 2.7x + 11.4
	11.31	1.89	Y = 8.1x + 10.5
	10.50	1.75	

Firmware



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A Closer Look at State of Charge (SOC) and State of Health (SOH) Estimation Techniques for Batteries

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Solar PV Systems, Analog Devices, Inc.
Adel Ghazel
Chief Technology Officer, EBSYS Technology Inc./WEVIOO Group

Introduction

Battery stacks based on lithium-ion (Li-ion) cells are used in many applications such as hybrid electric vehicles (HEV), electric vehicles (EV), storage of renewable energy for use at a later time, and energy storage on the grid for various purposes such as grid stability, peak shaving, and renewable energy time shifting. In these applications, it is important to measure the state of charge (SOC) of the cells, which is defined as the available capacity (in Ah) and expressed as a percentage of its the internal structure of batteries. However, since battery discharge and charge involve complex chemical and physical processes, it is not obvious to estimate the SOC accurately under various operation conditions.

The general approach for measuring SOC is to measure very accurately both the coulombs and current flowing in and out of the cell stack under all operating conditions, and the individual cell voltages of each cell in the stack. This data is then employed with previously loaded cell pack

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Battery capacity estimating method and apparatus

Abstract

A method for accurately estimating battery capacity based on a weighting function is provided. The disclosed system monitors battery current and uses the monitored battery current to calculate the state of charge (SOCbyAh) of the battery. The system also measures the open circuit voltage (OCV) of the battery when the system is at rest, rest being determined by achieving a current of less than a preset current value for a period of time greater than a preset time period. The state of charge of the battery is calculated from the OCV (SOCbyOCV). The weighting function is based on ΔSOCbyAh and ΔSOCbyOCV, where ΔSOCbyAh is equal to $SOCbyAh_{First\ time}$ minus $SOCbyAh_{Second\ time}$, and where ΔSOCbyOCV is equal to $SOCbyOCV_{First\ time}$ minus $SOCbyOCV_{Second\ time}$. The weighting function also takes into account the errors associated with determining SOCbyAh and SOCbyOCV.

Classifications

- G01R31/3842 Arrangements for monitoring battery or accumulator variables, e.g. SoC combining voltage and current measurements

US20100138178A1
United States

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Inventor: Anil Paryani, Scott Ira Kohn, Brian Boggs, Andrew David Baglino, Craig Bruce Carlson

Current Assignee : Tesla Inc

Worldwide applications

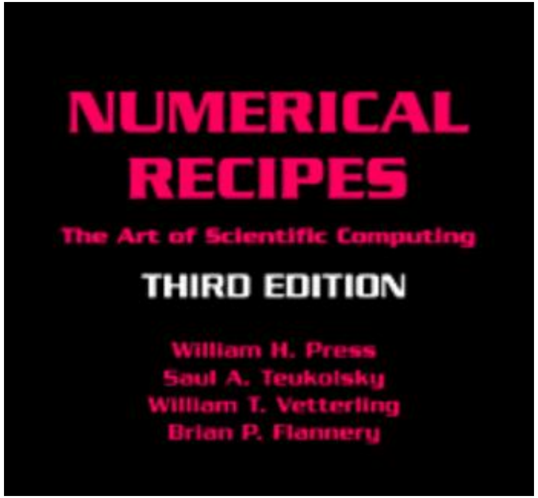
2009 · US

Application US12/384,696 events

```
//Wire.setClock(400000);

adsI.setGain(GAIN_SIXTEEN);
adsI.begin();
adsV.begin();
```

```
double integral(double(*f)(double x), double a, double b, int n) {
    double step = (b - a) / n;  // width of each small rectangle
    double area = 0.0;  // signed area
    for (int i = 0; i < n; i ++) {
        area += f(a + (i + 0.5) * step) * step; // sum up each small rectangle
    }
    return area;
}
```



$$SOC(t) = SOC(t-1) + \int_0^t \frac{I}{C_{bat}} \cdot dt$$

Where:

$SOC(t)$	Battery state-of-charge at time t [%]
$SOC(t-1)$:	Battery initial state-of-charge [%]
I	Charge/discharge current [A]
t	Time [h]
C_{bat}	Battery capacity [Ah]

Lessons learnt

- Make sure to purchase hardware that fit the requirements, try to follow them as closely as possible
- Double check circuits and collaborate
- Firmware quality is heavily dependant on understanding of the scientific background

Demo Time