DESIGN AND IMPLEMENTATION OF SUPERCAPACITOR BASED RTC MODULE

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Abstract. *This paper presents the design and implementation of a supercapacitor-based real-time clock (RTC) module for memory backup systems. The study explores the advantages of utilizing supercapacitors over traditional lithium-ion batteries, including infinite cycle life, rapid charging, and environmental safety. The design process involves selecting suitable supercapacitors based on factors such as leakage currents and time retention formulas. Practical steps for integrating supercapacitors into RTC and memory backup circuits are provided, with a focus on efficiency and longevity. A case study examines the charging time of a specific supercapacitor model, considering resistor and equivalent series resistance (ESR) effects. Additionally, the paper addresses the operational duration of RTC modules solely powered by supercapacitors after the main power supply is disconnected, providing insights into capacitor discharge characteristics. The implementation phase emphasizes the importance of component selection and circuit optimization for maximizing performance. The study showcases the practical application of supercapacitors in memory backup systems and highlights their potential for enhancing reliability and sustainability in various electronic devices.*

Keywords: *supercapacitors, real-time clock (RTC), design, implementation, sustainability.*

Introduction

In the realm of energy storage, the imperative of maintaining precise timekeeping, particularly during power interruptions, necessitates robust solutions. Conventional batteries, while reliable, are beset by slow charging times. Capacitors, on the other hand, offer swift charging but falter in their energy retention capabilities. Bridging this gap in functionality are supercapacitors, hailed as the superheroes of energy storage owing to their unique attributes.

The Energy Storage Dilemma

The necessity for rapid energy storage juxtaposed with the limitations of traditional battery technologies underscores a prevalent dilemma. While batteries exhibit stability, their protracted charging cycles render them unsuitable for exigent scenarios. Conversely, capacitors, although capable of swift charging, suffer from inadequate energy retention capacities, resembling a choice between sluggish behemoths and fleet-footed but diminutive entities [1].

Enter Supercapacitors

Supercapacitors, colloquially termed ultracapacitors, emerge as the paradigm-shifting solution to the energy storage conundrum. Characterized by their amalgamation of rapid charging and substantial energy retention capabilities, they revolutionize conventional notions of energy storage efficiency. Bigger Plates, Smaller Gap: Distinctive to supercapacitors is the augmentation of plate surface areas accompanied by diminutive interplate gaps. This architectural refinement facilitates rapid energy exchange akin to a commodious penthouse serviced by expeditious elevators [2]. Static Electricity Magic: In contrast to the electrochemical processes of batteries, supercapacitors harness electrostatic principles for energy storage. With two metal plates separated by an insulating dielectric, the buildup of positive and negative charges upon charging imbues the system with stored energy, analogous to the static cling phenomenon.

What Makes Supercapacitors Special

Energy Storage Boost: Supercapacitors boast a remarkable enhancement in energy storage capacity, exceeding conventional capacitors by factors ranging from 10 to 100-fold, akin to transitioning from a modest coin purse to a capacious backpack [3].

Flywheel Vibes: Their functionality parallels that of energy flywheels, adept at seamlessly buffering power supplies for electronic devices. Analogous to a hybrid bus equipped with supercapacitors for energy storage, the provision of instantaneous power augmentation underscores their utility [4].

The Retention Time Formula (Not as Scary as It Sounds).

The determination of a supercapacitor's retention time, denoting its ability to maintain charge, is facilitated through a mathematical formula (1):

$$T = \frac{C(V_1 - V_2)}{I_1} \qquad (1)$$

Where:

- (T): Retention time.
- (C): Capacitance.
- (V_2): Initial charge voltage.
- (V_2): Minimum allowable discharge voltage.
- (I_1): Load current.

Implementing a supercapacitor for an RTC (Real-Time Clock) module involves ensuring that the RTC module continues to function during power outages or interruptions[4]. Given:

Supercapacitor capacitance ©: 10 Farads (10F)

Supercapacitor voltage (V): 2.7V (assuming fully charged)

DS3231 standby current draw (I): Let’s assume a typical standby current draw of around 200nA (0.2µA).

We can use the formula for the discharge of a capacitor:

Time=I*C/V

Where:

Time is the time in seconds that the supercapacitor can maintain the voltage above the minimum required for the DS3231.

C is the capacitance of the supercapacitor in Farads.

V is the initial voltage of the supercapacitor in Volts.

I is the discharge current in Amperes.

Let’s plug in the values:

Time=10F×2.7V0.2×10−6ATime=0.2×10−6A10F×2.7V

Time=270.2×10−6Time=0.2×10−627

Time=272×10−7Time=2×10−727

Time=270.0000002Time=0.000000227

Time=135,000,000 secondsTime=135,000,000 seconds

Time≈1,562.5 daysTime≈1,562.5 days

So, with a 10F 2.7V supercapacitor and assuming a standby current draw of 200nA, the backup time would be approximately 1,562.5 days.

DS3231 RTC Module Overview and base circuit:

The DS3231 is an I2C-based real-time clock (RTC) module that accurately keeps track of time, even when the main power supply is interrupted.

It includes a battery input for backup power, which is essential for maintaining accurate timekeeping during power outages [5].

AT24C32 EEPROM IC for (for storing time and date data).

From the datasheet we take the basic connection of DS3231 IC to MCU.

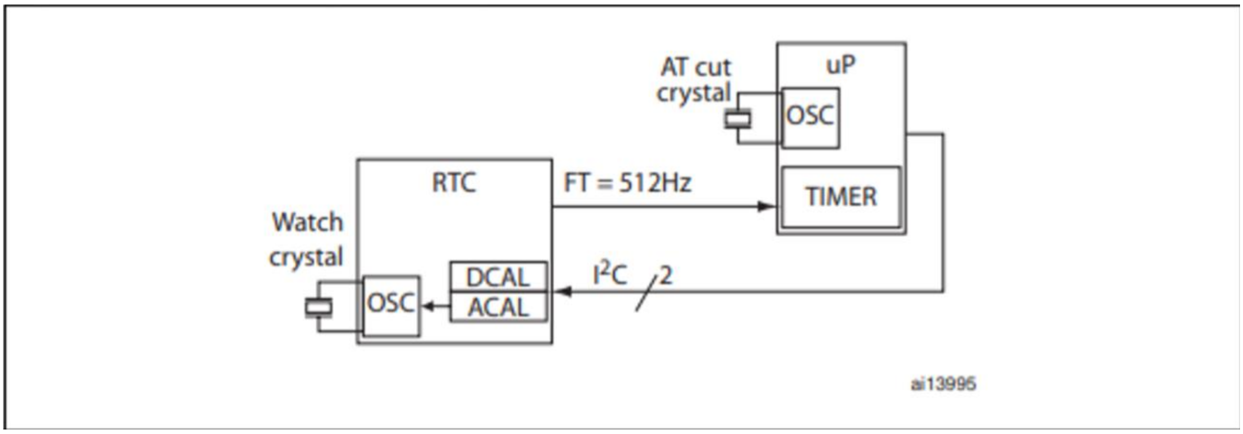

Figure. 1 Basic setup of microprocessor RTC

Supercapacitor Integration:

Researching the supercapacitor as memory backup integrations I made my based on STMicroelectronics AN4718 [6].

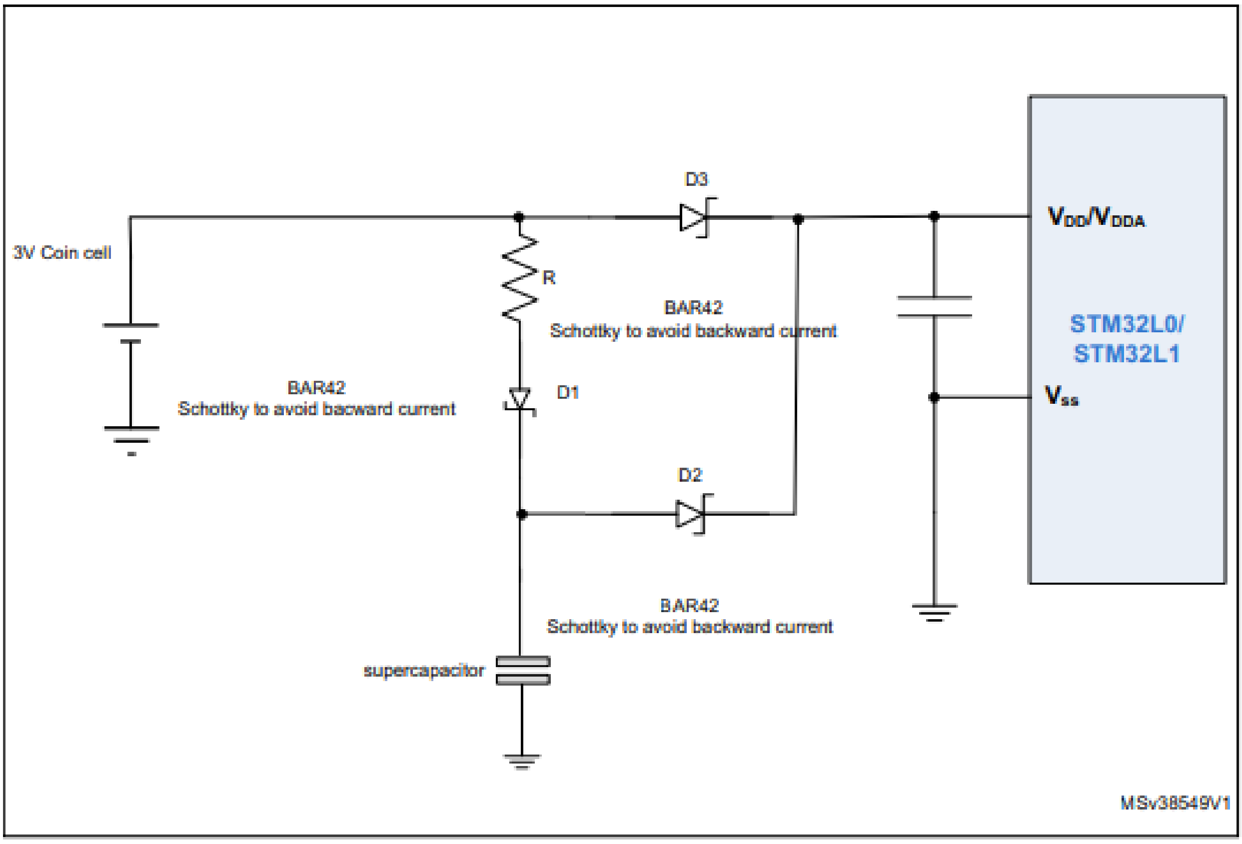

Figure 2. Suppercapacitor connection from STMicroelectronics application note

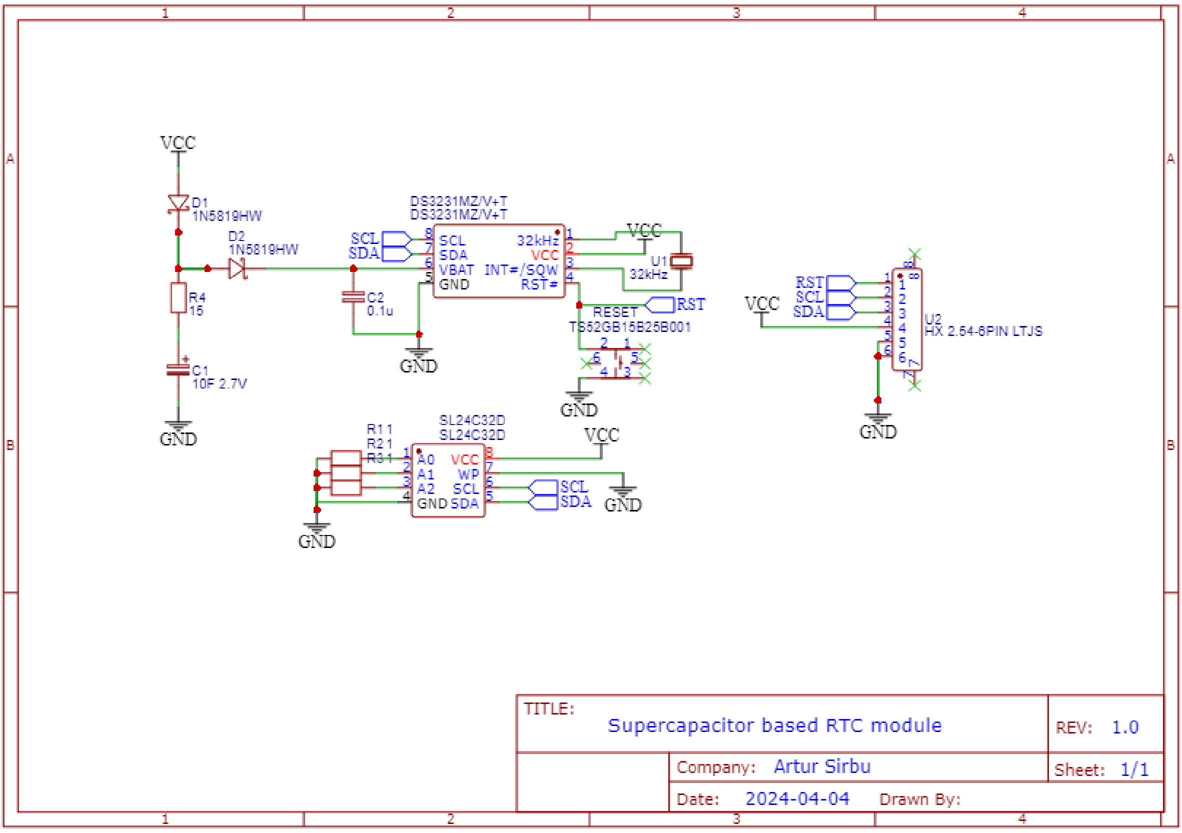

Figure 3. Circuit developed by me

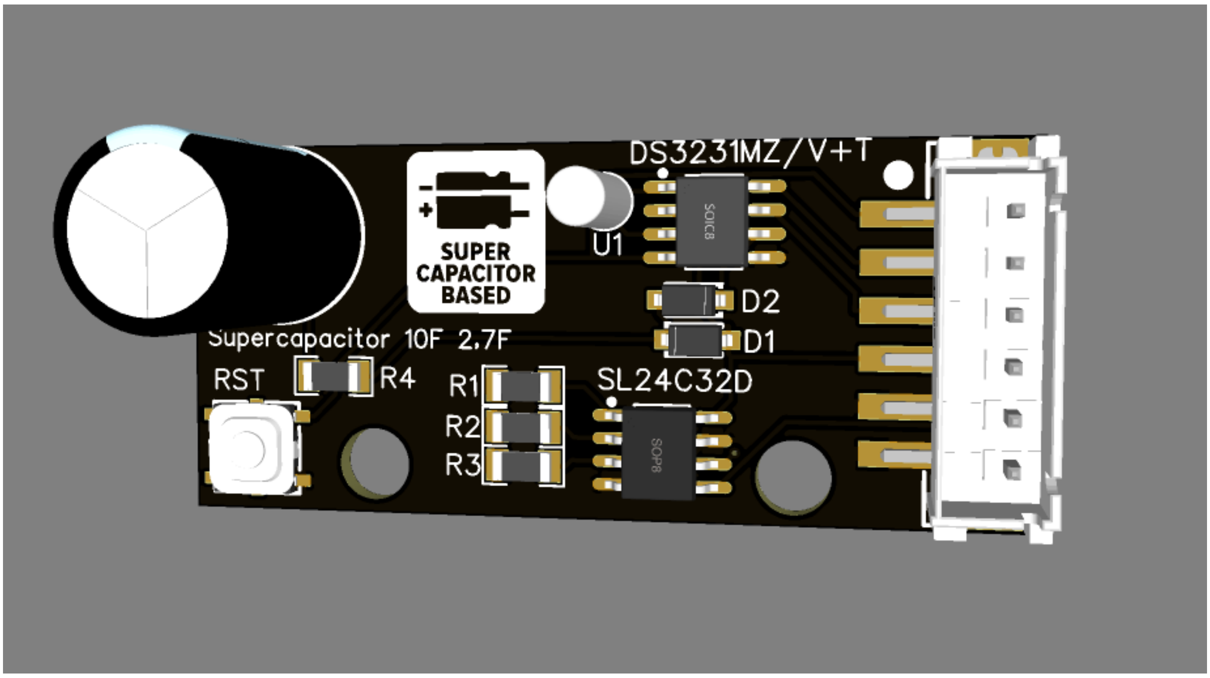

Figure 4. PCB Design

Conclusion

In conclusion, the design and implementation of a supercapacitor-based real-time clock (RTC) module for memory backup systems represents a significant advancement in energy storage technology. Through this research, we have explored the advantages of utilizing supercapacitors over traditional lithium-ion batteries, highlighting their infinite cycle life, rapid charging capabilities, and environmental safety.

The study has provided practical insights into the design process, emphasizing the selection of suitable supercapacitors based on factors such as leakage currents and time retention formulas. Additionally, we have demonstrated the integration of supercapacitors into RTC and memory backup circuits, focusing on efficiency and longevity.

References

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