Embedded Systems Hardware Interfacing

Notes from AN2834

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AN2834
Application note

How to get the best ADC accuracy in STM32 microcontrollers

My Own Preface

ADC is Hard (compared to digital)

Analog Input Signal Noise Elimination

- Averaging Method - Simple Technique
  - Sample Analog Input Multiple Times
  - Take the Average of the result
- Useful to eliminate the case of noise
  - Assuming analog input voltage does not change often
- Important: The average has to be made on readings that correspond to the same analog input voltage
  - You do NOT want to average values corresponding to different ADC levels

STM32 Oversampling

- STM32 Oversampling can be used for averaging
- Hardware performs a sum of a given number of ADC raw samples into one final sample
  - Hardware then right bit-shifts final value
  - Can process up to 1024 input samples

Three Ways To Read ADC

- Polling / Blocking Mode
  - Start conversion, then check when done
- Interrupts / Non-Blocking Mode
  - Start conversion, interrupt when done
  - Be careful of “interrupt flood” if you are taking lots of samples
- DMA / Non-Blocking Mode
  - Start conversion, DMA does transfer

Reference - Application Note

- https://www.st.com/resource/en/application_note/cd00211314-how-to-get-the-best-adc-accuracy-in-stm32-microcontrollers-stmicroelectronics.pdf

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Intro

- STM32 MCUs and ADC
  - 12-bit and 16-bit (depending on model)
  - Self-calibration
- ADC Accuracy can be hard with ADC
  - My project example: reading water level sensor in waste-water pipe and widely varying readings even when water level not changing
  - We want to know hardware and software techniques to minimize ADC errors

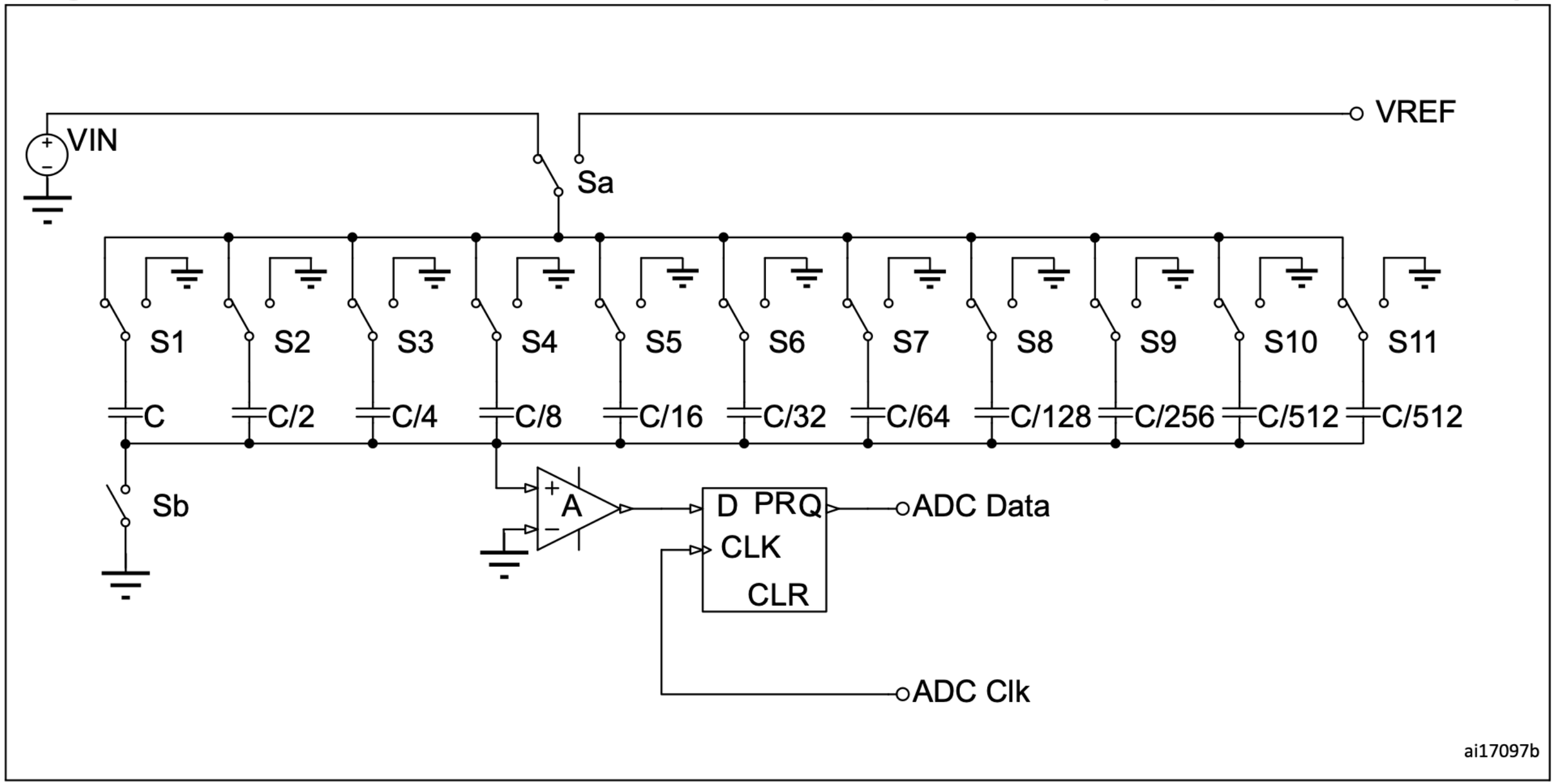
ADC Internal Operation

ADC Internal Operation

- STM32 ADC uses SAR
  - Successive Approximation Register
    - Conversion performed in several steps
      - Steps equal to number of bits in the ADC
        - Each Step driven by the ADC Clock
          - Each ADC clock produces 1 bit of output

10-bit SAR - Overview

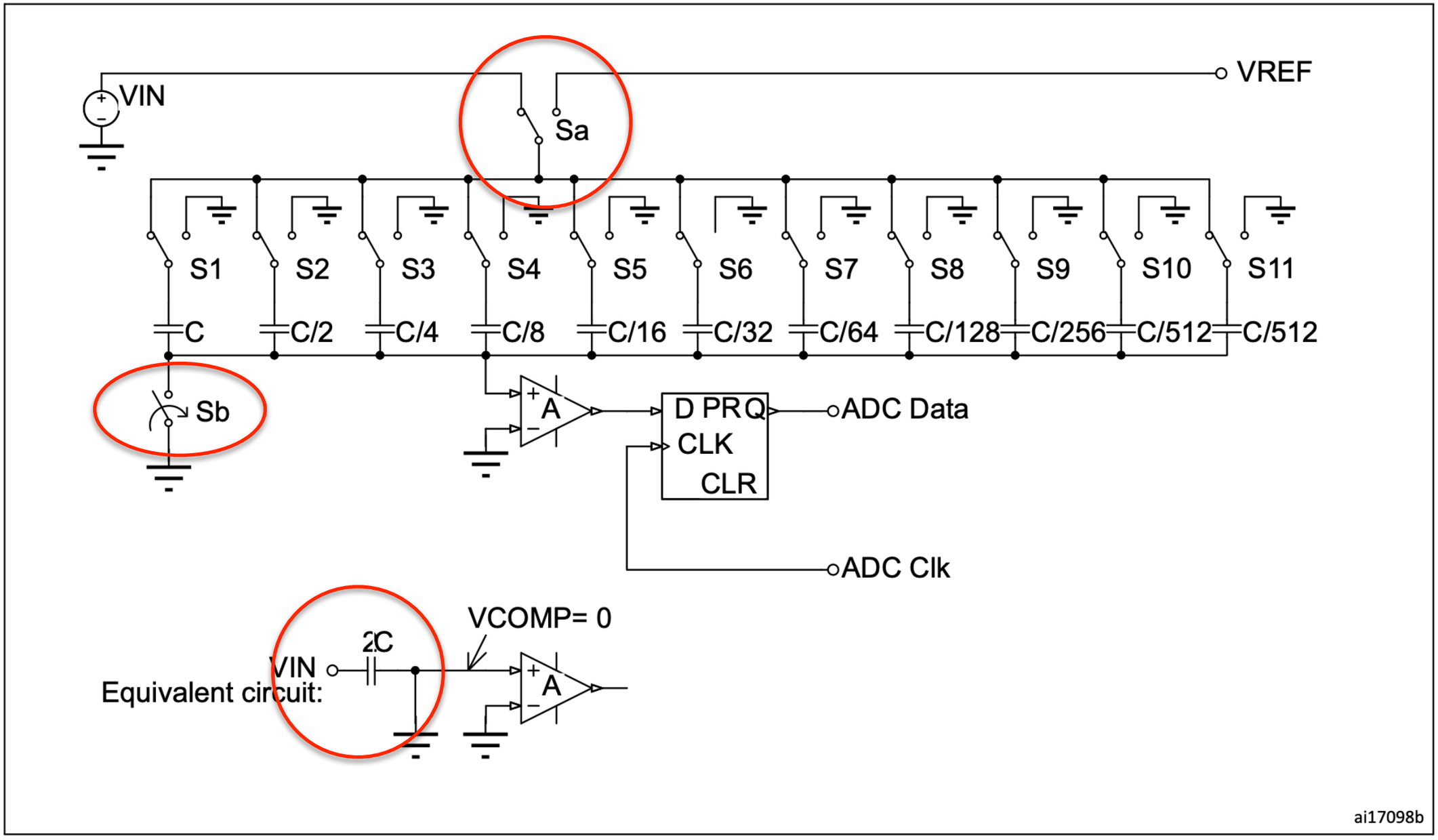
Figure 1. Basic schematic of SAR switched-capacitor ADC (example of 10-bit ADC)



1. Basic ADC schematic with digital output.

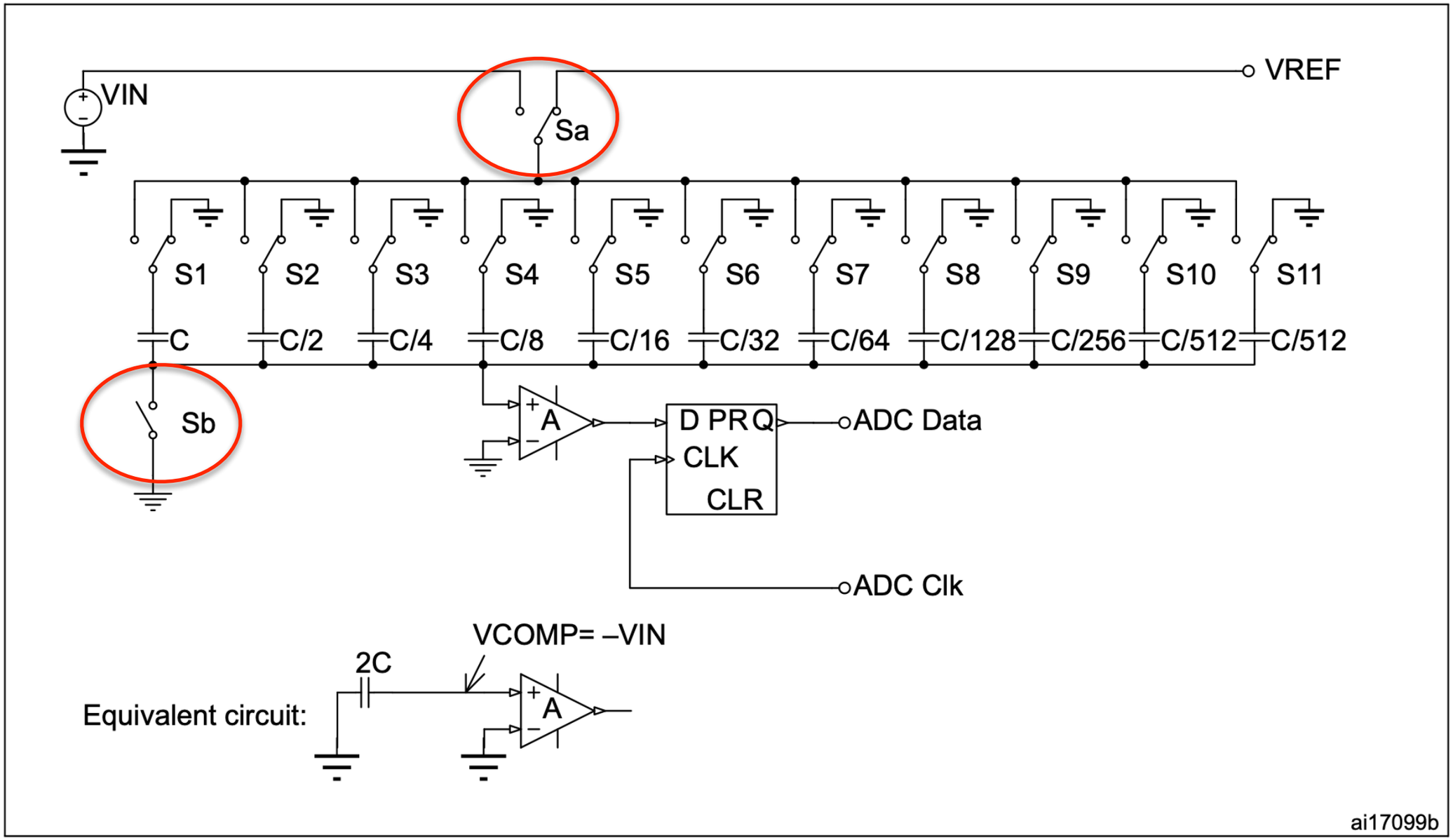
Sample State

Figure 2. Sample state



Hold State

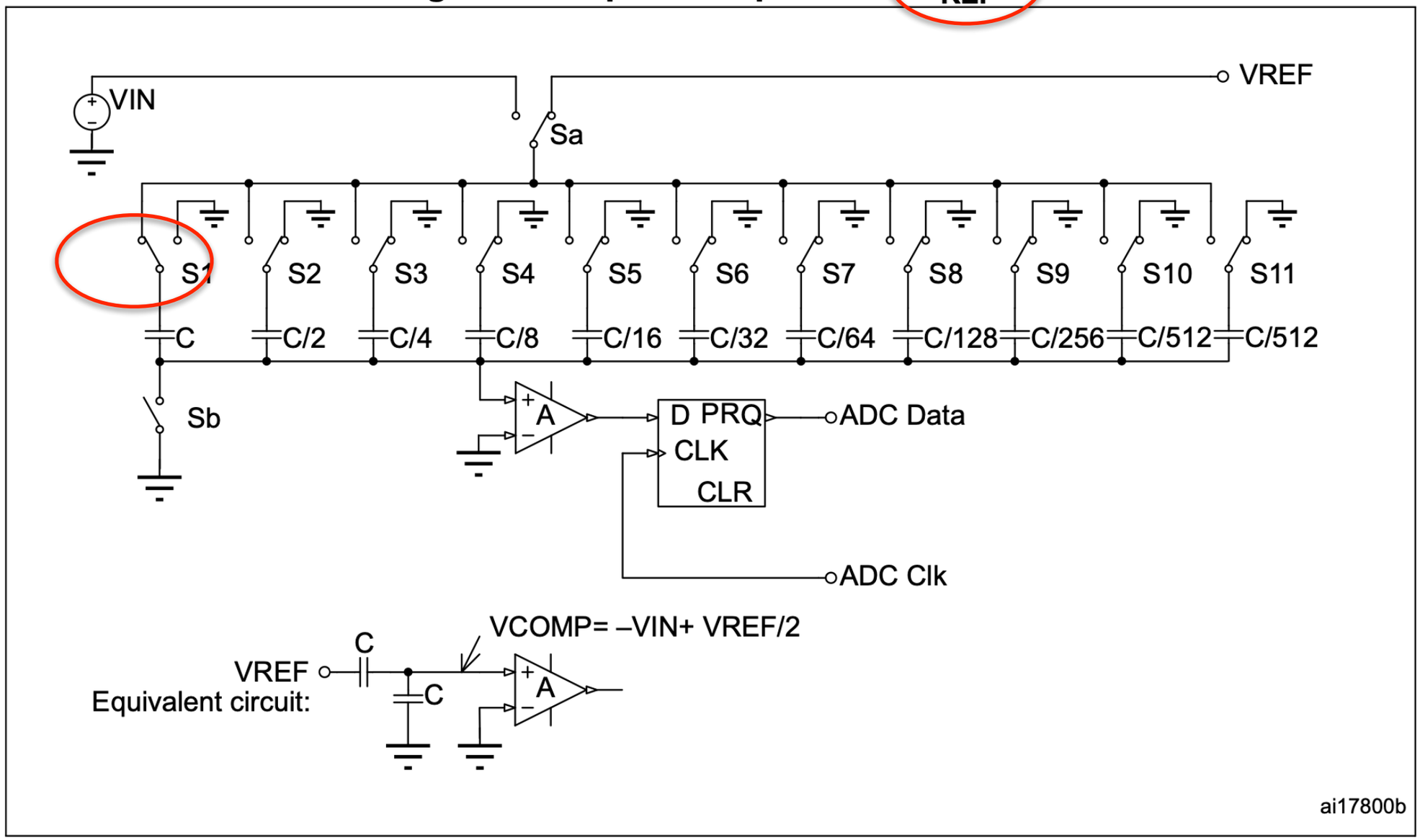
Figure 3. Hold state



1. Hold state: the input is disconnected, capacitors hold input voltage. Sb switch is open, then S1-S11

Step 1 Approximation

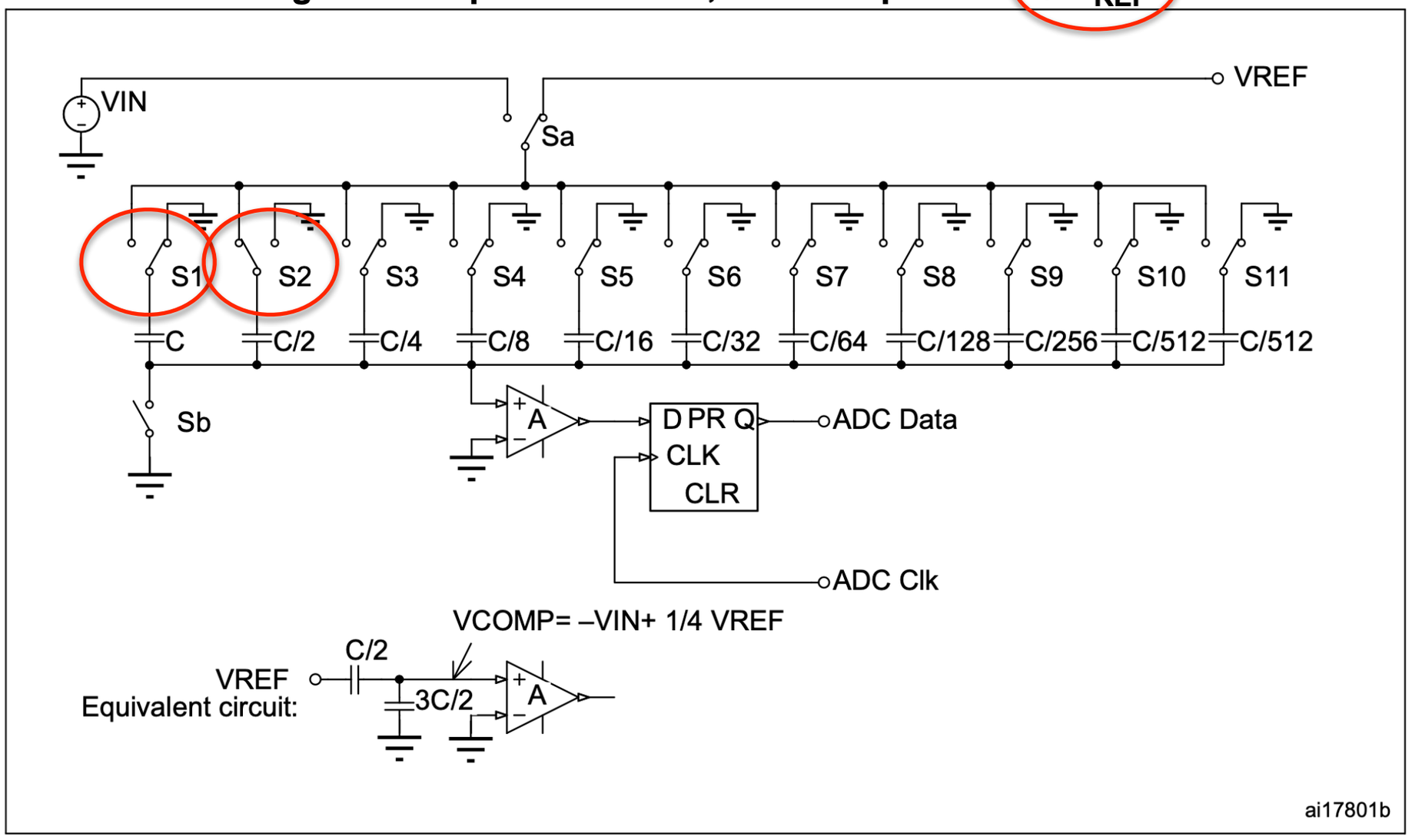
Figure 4. Step 1: Compare with $V_{REF}/2$



1. First approximation step. S1 switched to V_{REF}.

Step 2 (if MSB = 0) Approximation

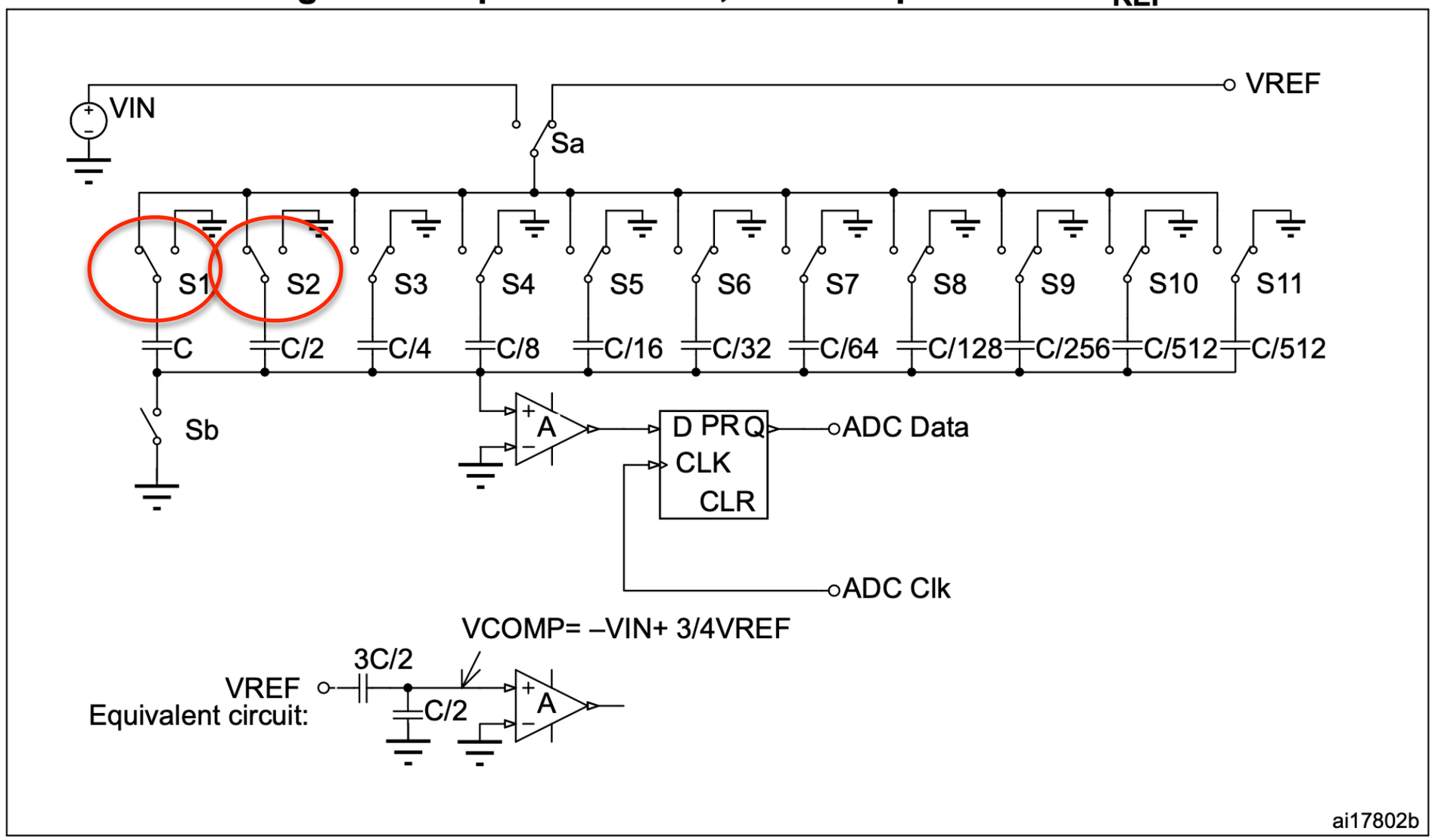
Figure 5. Step 2: If MSB = 0, then compare with ¼V_{REF}



1. Compare with ¼V_{REF}; if MSB =1. S1 switched back to ground. S2 switched to V_{REF}.

Step 2 (if MSB = 1) Approximation

Figure 6. Step 2: If MSB = 1, then compare with ¾V_{REF}



ADC Errors

ADC Errors

- Two Categories
  - Errors due to ADC
  - Errors due to Environment

Errors due to ADC

- Offset Error
- Gain Error
- Differential Linearity Error
- Integral Linearity Error
- Total Unadjusted Error

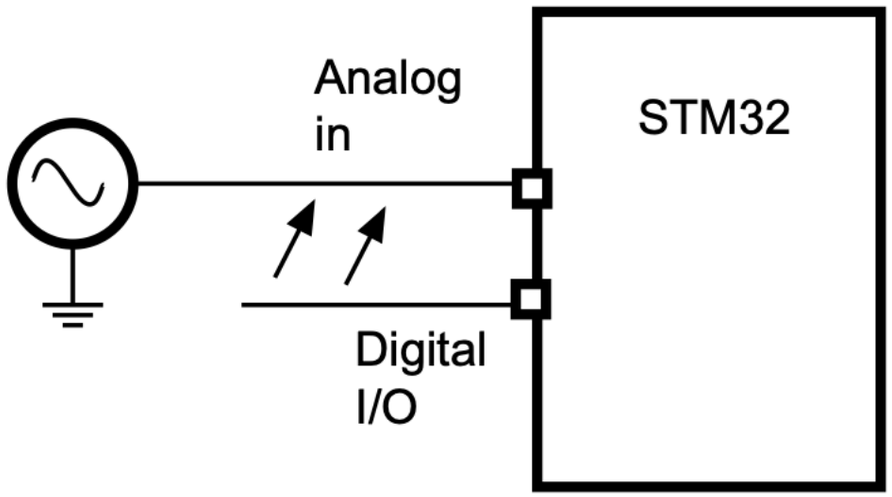
Errors due to ADC Environment

- Reference Voltage Noise
- Reference Voltage / Power Supply Regulation
- Reference Voltage Decoupling and Impedance
- External Reference Voltage Parameters
- Analog Input Signal Noise
- ADC dynamic range bad match for max input signal amplitude

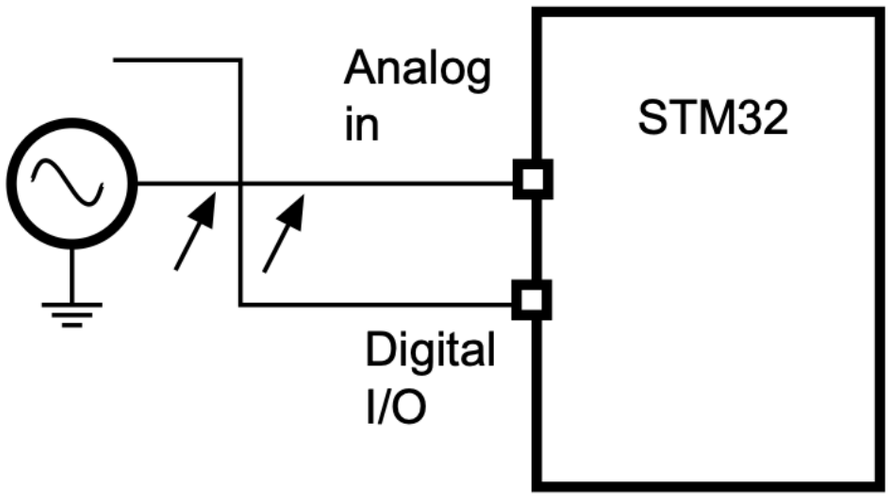
Temperature Influence

- Temperature has a major influence on ADC accuracy
  - Leads to two major errors
    - Offset Error drift
    - Gain Error Drift
- Compensate via firmware

I/O Pin Crosstalk



Case 1



Case 2

Much more in

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