ECE 224

Design Project
Recommendation Report

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Problem Name: Selection of Analog-to-Digital Converter for Problem #1

Design Problem #1: Infrared thermometer

In this design problem, your team must design a handheld infrared thermometer to be deployed at university residences throughout the country. You are responsible for selecting an ADC to convert the analog signal read from an infrared sensor into a digital value. The infrared sensor has already been chosen for the project. The ADC requirements have been specified to guarantee a 0.1°C precision for the temperature reading. The complete design must fit in a portable device that will be battery powered. Low power consumption is essential to maximize the operation time between battery charges.

Recommendation

1.1 Establishing Criteria Breakdown For Each Design Goal

As described in the project scope, the two factors that will determine which ADC is optimal are low-power consumption and cost-effectiveness. Prior to completing the decision matrix and the multi-criteria decision analysis, the weights of these two criteria (a.k.a their ratios) need to be determined. Additionally, the composition of factors that define each of these two criteria must also be established. An unused but potential example is:

(e.g, <u>50%</u> cost per unit

+ <u>30%</u> cost in bulk of size x

+ <u>20%</u> cost of development, etc.

all composing the overall = <u>100%</u> of cost effectiveness).

1.2 Low-Power Consumption Criteria

Low-power consumption is defined as the primary design goal. It can be measured with a functional requirement defined in the Selection Report: **maximum/peak** power consumption (quantified as <=500 mW @ 2.75 V). Moreover, other power consumption values such as **typical** and **idle** can be observed as well. These three consumption values will provide a more vivid idea of how much power is being used in all possible circumstances and which model mitigates consumption. When being used for hours straight (e.g, checking in students on move-in day), then values closer to peak power consumption are crucial. When not being used (e.g, holidays when most students go home), knowing the idle power consumption is important as one would not want them to waste power (i.e, use a significant amount of battery without being on). For typical usage, typical/operational power consumption is a useful detail to know as the majority of time will be spent in this status (i.e, day-to-day usage). Since all of these requirements are critical, they will each be weighted equally.

<u>33.3%</u> maximum/peak power consumption

+ <u>33.3%</u> idle/standby power consumption

+ <u>33.3%</u> typical power consumption

= <u>100%</u> of the low-power consumption criteria

(1:1:1 ratio).

1.3 Cost-Effectiveness Criteria

Cost-effectiveness is defined as the secondary design goal. This constraint requirement can be measured in multiple manners. Examples include cost per ADC unit, cost per bulk size of y ADCs, cost per interface for each ADC, cost per bulk size of x interfaces for y ADCs, and overall cost of development and maintenance.

The ADCs will be placed in university residences across the nation of Canada.

$$Assuming\ there\ is\ldots$$

$$\frac{1\ thermometer}{1\ floor}\cdot\frac{3\ floors}{1\ residence\ building}\cdot\frac{3\ residence\ buildings}{1\ Canadian\ university}\cdot 97\ Canadian\ universities$$

$$+\frac{10\ extra\ thermometers\ (extra\ for\ rooms\ like\ gym,\ lounge,\ etc)\ and\ broken/lost/faulty}{1\ residence\ building}\cdot\frac{3\ residence\ buildings}{1\ Canadian\ university}\cdot 97\ Canadian\ universities$$

$$=3783\ thermometers\ is\ how\ many\ that\ are\ required.$$

Therefore, the bulk size selected is y=**4000** (**3783** rounded upwards to the nearest 500). The importance of its cost per bulk (both the ADCs and interfaces) are the most significant of these criteria. The cost of development and maintenance are the next-most important since they need to last long-term in the residences. The remaining two criteria are less significant but should be measured as they may be needed for replacements (e.g, few faulty ADCs). Therefore, the composition of these criteria will be:

25% cost per bulk size of 4000 ADCs

+ 25% cost per bulk size of x interfaces for 4000 ADCs

+ 20% cost of development and maintenance

+ 15% unit cost of ADC

+ 15% unit cost of interface for 1 ADC

= 100% of the overall cost-effectiveness criteria

(5:5:4:4:3 ratio).

1.4 Weight of Each Design Goal

Because low-power consumption is the primary design goal, its weight will be greater than that of cost effectiveness. The ratio between these two factors will however be of similar weight:

60% low-power consumption

+ 40% cost-effectiveness

= 100% of overall design goal weights

(3:2 ratio).

2.1 How Each Criteria Will Be Scored in the Decision Matrix/Multi-Criteria Decision Analysis

To justify how scores will be assigned to the converters, a table has been created to display the ranges of values that correspond with each score.

(**DARK GREEN** = Low-power consumption design goal, **BLUE** = Cost-effectiveness design goal)

Criteria	Score = 3	Score = 2	Score = 1
Criteria 1: Peak power consumption	< 1.5 mW @ 2.75 V	1.5 mW ≤ x ≤ 2 mW @ 2.75 V	> 2 mW @ 2.75 V
Criteria 2: Idle power consumption	< 5 µW	5 µW ≤ x ≤ 10 µW	> 10 µW
Criteria 3: Typical power consumption	< 0.6 mW	0.6 mW ≤ x ≤ 0.8 mW	> 0.8 mW
Criteria 1: Cost per bulk size of 4000 ADCs	< $0.85*4000	$0.85*4000 ≤ x ≤ $0.95*4000	> $0.95*4000
Criteria 2: Cost per bulk size of x interfaces for 4000 ADCs	< $2.90*4000	$2.90*4000 ≤ x ≤ $3.10*4000	> $3.10*4000
Criteria 3: Cost of development and maintenance	N/A: See Note 1	N/A: See Note 1	N/A: See Note 1
Criteria 4: Unit cost of ADC	< $1.00	$1.00 ≤ x ≤ $1.20	> $1.20
Criteria 5: unit cost of interface for 1 ADC	< $2.20	$2.20 ≤ x ≤ $2.50	> $2.50

Notes:

1. Information regarding Cost of Development & Maintenance was not mentioned in the datasheets, and reviews online were too few for an objective assumption to be made. Hence, no valid scoring/assumptions can be made.

2.2 Decision Matrix/Multi-Criteria Decision Analysis

(DARK GREEN = Low-power consumption design goal, BLUE = Cost-effectiveness design goal)

Alternatives / Criteria (with Weight)	ADC 1	ADC 2	ADC 3	ADC 4
Criteria 1: Peak power consumption (0.13)	Score: 3 (1.4 mW is the lowest peak power consumption of the options)	Score: 1 (5.62mW)	Score: 1 (4.3mW)	Score: 2 (1.8mW. Can be found on page 3 of the datasheet)
Criteria 2: Idle power consumption (0.13)	Score: 1 (14 µW is small but much larger than other options)	Score: 3 (3.1µW is a very small amount lost)	Score: 3 (2.6 µW)	Score: 3 (3.3µW is a very small amount lost. The value could be found on Page 3 of the datasheet)
Criteria 3: Typical power consumption (0.13)	Score: 3 (0.517 mW is a small amount but greater than other options)	Score: 2 (0.734mW is a very small amount of power consumed)	Score: 1 (1.5mW)	Score: 3 (0.4 mW is a very small amount of power consumed) (Note 5)
Criteria 1: Cost per bulk size of 4000 ADCs (0.15)	Score: 1 ($1.60 * 4000) (Note 8)	Score: 2 ($0.0886*4000) (Note 1)	Score: 2 ($0.924*5000)	Score: 1 ($1.65*4000) (Note 6)
Criteria 2: Cost per bulk size of x interfaces for 4000 ADCs (0.15)	Score: 3 (4 * ($0.7) * 4000) (Note 1)	Score: 3 (3*($0.89)*4000) (Note 1)	Score: 1 ((4 * $0.7 + $0.314) * 4000) (Note 7)	Score: 3 (3*($0.7)*4000) (Note 1)
Criteria 3: Cost of development and maintenance (0.12)	Score: N/A (Note 1 in Section 2.1)	Score: N/A (Note 1 in Section 2.1)	Score: N/A (Note 1 in Section 2.1)	Score: N/A (Note 1 in Section 2.1)
Criteria 4: Unit cost of ADC (0.09)	Score: 1 (Second most expensive per unit cost)	Score: 2 (2nd-cheapest option)	Score: 3 (Cheapest per unit)	Score: 1 (Most expensive per unit cost)
Criteria 5: unit cost of interface for 1 ADC (0.09)	Score: 1 ($0.7*4 = $2.80)	Score: 3 ($0.7*3 = $2.10) (Note 1)	Score: 1 (4 * $0.7 + $0.314)	Score: 3 ($0.7*3 = $2.10) (Note 1)

Total	13	16	12	16
Weighted total	1.60 (3rd place)	1.98 (1st place)	1.44 (4th place)	1.73 (2nd place)

Notes:

1. According to Note 3 on Page 3 of the device datasheet, three decoupling capacitors are recommended for AVDD, DVIO and VREF. The average price of decoupling capacitors is around $0.7 each under mass purchase (https://www.mouser.ca/c/passive-components/capacitors/feed-through-capacitors/?product=X2Y%20Filtering%20and%20Decoupling%20Capacitor%20MLCCs).
2. According to Page 11 of the device datasheet, four decoupling capacitors are required to achieve optimal performance of the ADC. The average price of decoupling capacitors is around $0.7 each under mass purchase (https://www.mouser.ca/c/passive-components/capacitors/feed-through-capacitors/?product=X2Y%20Filtering%20and%20Decoupling%20Capacitor%20MLCCs).
3. Peak consumption calculated under the assumption of throughput rate of 500ksps at 2.75V
4. Stand-by power consumption not listed in datasheet, calculation made based on Power-Down mode at 2.75V
5. 0.4 mW is used as the typical power consumption here. The value corresponds to the total power consumption at 100 ksps on page 3 of the datasheet
6. Can be purchased directly from the manufacturer: (https://www.microchip.com/en-us/product/MCP33141-05#buy-from-store). When the amount is lower than 5000, the price per unit increases to $1.65.
7. According to note 10.2 of Page 15 of the device datasheet, a dedicated linear voltage regulator ($0.314 for the example) is necessary to reduce noise. According to note 10.2.2 on Page 16, a single pole low-pass anti-aliasing filter is required on the input to satisfy the Nyquist criterion. This involves a recommended 100Ω resistor and a capacitor in the -nF range.
8. Can be purchased directly from the manufacturer at a price per unit of $1.60, no bulk discount is provided.

3.1 Recommendation Decision

Based on the decision matrix and multi-criteria decision analysis, the ADCs ranked from highest to lowest are

1. **ADC 2**,
2. ADC 4,
3. ADC ADC 1, and
4. ADC 3

respectively. The established sub-criteria of both design goals, low-power consumption and cost-effectiveness, and their justified weightages enabled these comparisons to be made and help determine which ADC is optimal. Therefore, ADC 2, Maxim Integrated MAX1396, is recommended due to the highest weight total value at 1.98.