1 Current Consumption When Off (1 month)

- The latch IC (MAX16054) consumes $7\,\mu A$.
- The LDO consumes less than $1\,\mu A$.
- 1 month is 720 hours, we will ignore the fact that during some of this duration the device will be active
- $I_{off} = 8\mu A \times \frac{1mA}{1000\mu A} \times 720\,\text{hours/month} = \boxed{5.75 \quad \text{mAh/month}}$

2 Active Current Consumption Per Interaction

- The latch IC (MAX16054) consumes $0.4\,mA$.
- The MCU consumes at most $4\,mA$ for running code from flash memory with 48 MHz clock, SPI requires $0.2\,mA$, the GPIOs will require $0.1\,mA$ each and there are 4.
- The LDO efficiency is calculated as $\frac{V_{out}}{V_{in}} = \frac{2.8}{3} = 0.93$. This means that the current requirement for the MCU and RF transceiver combined should be multiplied by 1.075.
- The RF transceiver consumes $14.7\,mA$ in RX mode and $30\,mA$ in TX mode.

We estimate the total time of operation for one interaction to be 2 seconds, or 0.0006 hours. This consists of:

- 0.6 seconds (0.0002 hours) in RX mode.
- 1.4 seconds (0.0004 hours) in TX mode.

The total current consumption per interaction is:

$$I_{\text{latch}} = 0.4\,\text{mA} \times 0.0006\,\text{hours} = 0.00024\,\text{mAh}$$

$$I_{\text{MCU}} = 1.075((4 + 0.2 + 0.4)\,\text{mA} \times 0.0006\,\text{hours}) = 0.002967\,\text{mAh}$$

$$\begin{aligned} I_{\text{transceiver}} &= 1.075 \times ((14.7\,\text{mA} \times 0.0002\,\text{hours}) + (30\,\text{mA} \times 0.0004\,\text{hours})) \\ &= 0.00294 + 0.012 = 0.0160605\,\text{mAh} \end{aligned}$$

$$I_{\text{interaction}} = I_{\text{latch}} + I_{\text{MCU}} + I_{\text{transceiver}}$$

$$I_{\text{interaction}} = 0.0192675\,\text{mAh} \approx \boxed{0.0193 \quad \text{mAh/interaction}}$$

3 Monthly Consumption

Assuming 10 interactions per day, the monthly current consumption is:

$$I_{\text{month}} = (I_{\text{off}}) + (10\,\text{interactions/day} \times 30\,\text{days/month} \times I_{\text{interaction}})$$

$$= 5.75\,\text{mAh/month} + 5.79\,\text{mAh/month}$$

$$I_{\text{month}} = \boxed{11.54 \quad \text{mAh/month}}$$

4 Battery Life Estimation

Our target is for the fob to last at least one month on a single battery. We have identified batteries with a capacity greater than 200 mAh. Therefore, the estimated battery life is at least:

$$t_{\text{life}} = \frac{200\,\text{mAh}}{11.54\,\text{mAh/month}} \approx \boxed{17 \quad \text{months}}$$

This is 17x longer than our goal

5 Modular Group Example

The group G consists of the non-zero integers in $\mathbb{Z}_7$, i.e., $G = \{1, 2, 3, 4, 5, 6\}$.

We choose $g = 3$ as the generator. Now, let's compute the powers of g mod 7:

$$\begin{aligned}
g^1 &= 3^1 \mod 7 = 3, \\
g^2 &= 3^2 \mod 7 = 9 \mod 7 = 2, \\
g^3 &= 3^3 \mod 7 = 27 \mod 7 = 6, \\
g^4 &= 3^4 \mod 7 = 81 \mod 7 = 4, \\
g^5 &= 3^5 \mod 7 = 243 \mod 7 = 5, \\
g^6 &= 3^6 \mod 7 = 729 \mod 7 = 1.
\end{aligned}$$

Thus, the powers of $g = 3 \mod 7$ generate the set $\{1, 2, 3, 4, 5, 6\}$, which means $g = 3$ is a generator of the group $G \mod 7$.