USING THE Si1141 FOR TOUCHLESS LAVATORY APPLIANCES

1. Introduction

The Si1141 is a single-channel, reflectance-based proximity detector with an integrated ambient light sensor and can be used as a touchless sensor IC in lavatory appliances. As a proximity detector, the Si1141 has two infrared photodiodes, flexible ADC integration time, and multiple signal ranges. In addition to the configurable ADC sensitivity configuration settings, the Si1141 can dynamically drive an irLED with anywhere from 6 to 400 mA. This high level of flexibility in the ADC, photodiode choice, and irLED drive strength all contribute to allow the end product to operate under various ambient light conditions.

In general, lavatory appliances operate indoors, typically under CFL lighting. However, it is common for these appliances to be exposed to direct sunlight when the product is near a window. Therefore, having the flexibility to allow operation under various light sources is key to making a robust product and helps provide end product differentiation.

Another product feature that makes the Si1141 compelling in touchless lavatory appliances is the low system power. Most touchless lavatory appliances, such as flushers and faucets, are battery operated since power mains are typically unavailable in most lavatory stalls. A lavatory appliance spends much of its time waiting for the target to enter its proximity. Minimizing the current draw from the battery benefits the end product by extending its lifetime use.

The Si1141 achieves this low power by taking proximity measurements using a single 25.6 µs irLED pulse instead of performing the multiple pulses commonly used in discrete photodiode approaches.

In addition to the Si1141 Proximity and Ambient Light Sensor, Silicon Labs offers an array of low-power MCU devices (C8051F9xx series). When combined, these devices offer best-in-class, low-power operation.

In general, lavatory appliances are subdivided into the following categories:

- Lavatory Flushers
- Lavatory Faucets
- Soap Dispenser

Toilet flushers, faucets, and soap dispenser assemblies are typically battery powered since a power plug is generally not available nearby. Toilet flushers generally aim to detect the presence of a human body, while faucets and soap dispensers are designed to detect the presence of hands. All of these application uses are similar in that the proximity detector generates an action, typically the driving of a motor.

2. Lavatory Flushers

Lavatory flushers are typically side-mounted or top-mounted. The mechanical topology generally determines the choice of the irLED packaging. Lenses are often used to direct the light from the irLED to the target and usually refract light from the target to the IR sensor. The top-mounted flusher has an advantage in that the human body is directly in front of the PCB plane, while, in a side-mounted configuration, the target is offset to one side, which necessitates specialized optics to direct the light to and from the target.

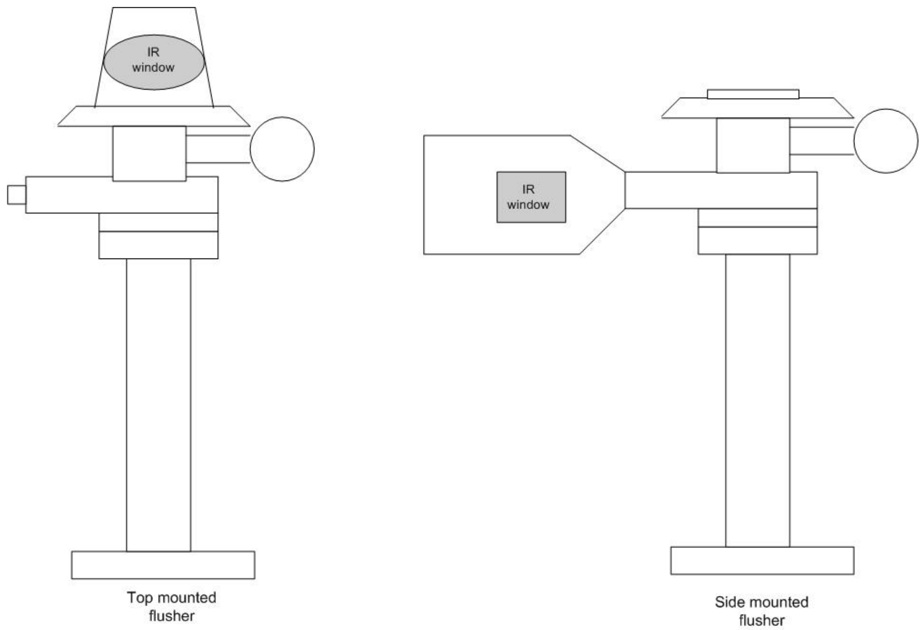


Figure 1. Top Mounted (Left) and Side Mounted (Right) Flushers

The top-mounted flusher typically requires a PCB perpendicular to the main board, while the side-mounted flusher can have the optical components mounted directly on the main board. Figure 2 shows typical system partitioning between the main board and optics PCB for the two flusher topologies.

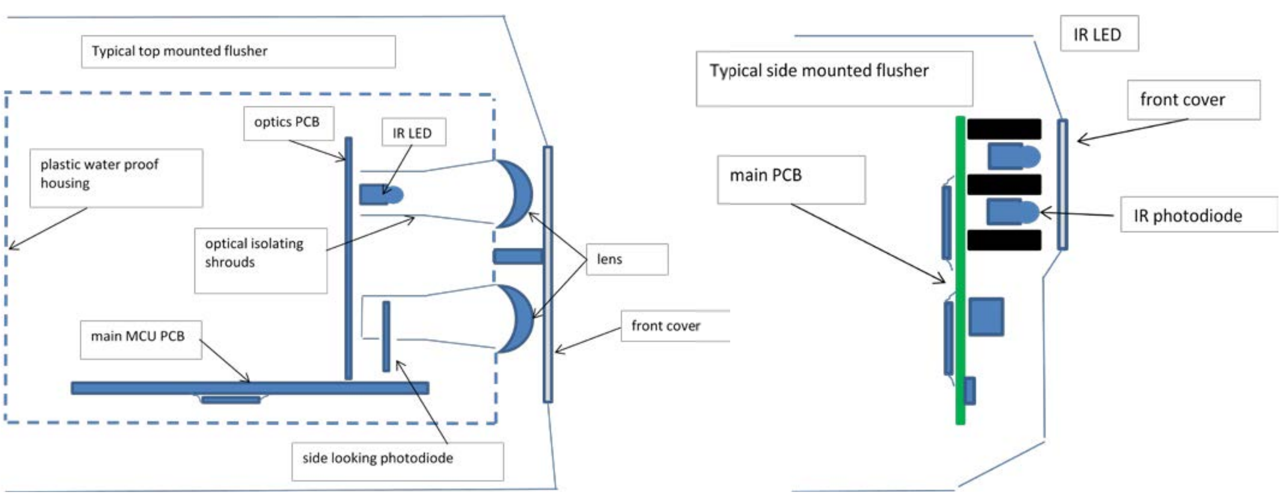


Figure 2. Top Mounted (Left) and Side Mounted (Right) Flushers PCB Placement

A typical block diagram for a lavatory flusher is shown in Figure 5. This block diagram can be implemented using the Si1141 and C8051F9xx series MCU shown on Figure 6. The C8051F9xx series MCUs have a built-in 20 MHz crystal, which makes an external crystal unnecessary. Although the Si114x has an internal sequencer, it too has an internal clock source.

The top-mounted flusher usually has a preamplifier on the optical PCB since the relative distance from the discrete photodiode and MCU on the main board goes through a connector. The combination of using the Si1143 and the C8051F9xx MCU lends itself well to system partitioning since the communication interface is purely digital, resulting in additional BOM saving. The C8051F9xx MCU also has a built-in regulator and can operate directly with a 2-cell battery.

2.1. Lavatory Faucets

Touchless lavatory faucets typically have the proximity sensor on the base of the faucet. Some faucets have an additional proximity sensor on the sides of the faucet for selection of hot and cold water.

Proximity detection for lavatory faucets is designed to detect the presence of a human hand to within 10 cm of the system. Due to mechanical constraints, lavatory faucets and soap dispensers make use of light collection and light piping to bring the light to and from the PCB hosting the optical components and main host controller.

It is sufficient to say, however, that the generalized block diagram in Figure 5 still applies. Figure 6 also generally illustrates the block diagram of a similar system making use of the C8051F9xx and the Si1141.

The flexibility of the Si1141 is convenient in these systems. With the Si1141, the irLED current and ADC sensitivity settings make it possible for the system designer to fine-tune the performance of the electrical system once the mechanical and optical system has been designed.

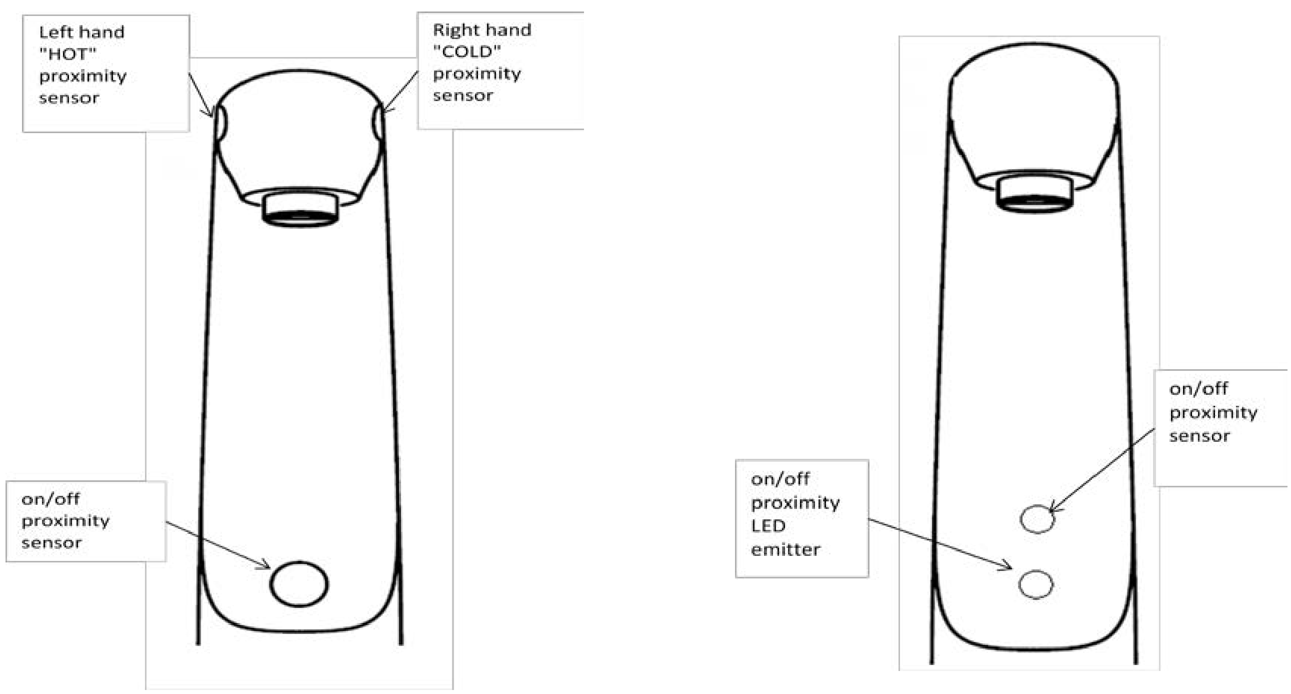


Figure 3. Faucet with Temperature Control (Left) and Proximity-Only Faucet

3. Lavatory Soap Dispensers

Touchless lavatory dispensers can be implemented with forward-looking or downward-looking proximity sensors. In both cases, the proximity detector is set for a much shorter detection range relative to a touchless faucet application. In general, most soap dispensers are implemented such that the controller and the optics are all on a single PCB.

The generalized block diagram in Figure 5 also describes a lavatory soap dispenser, and Figure 6 still describes a block diagram for an equivalent soap dispenser using the C8051F9xx and Si1141. The mechanical enclosure is still the dominating factor that differentiates the various lavatory systems.

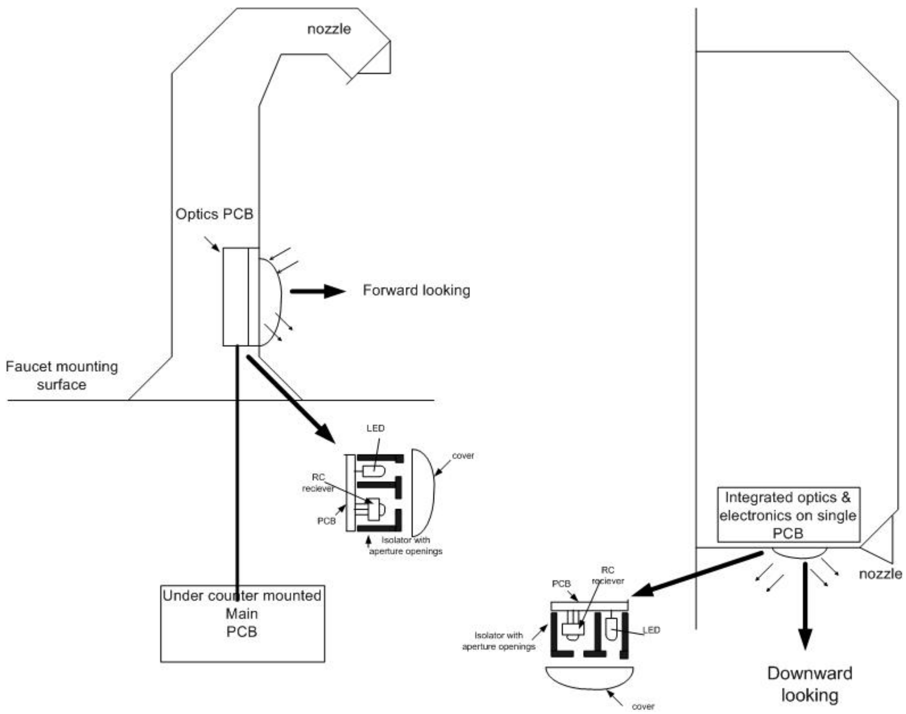


Figure 4. Forward-Facing Soap Dispenser (Left), Downward-Facing Soap Dispenser (Right)

4. General Lavatory System Block Diagram

In general, many of the various lavatory systems follow the block diagram shown in Figure 5. The systems essentially differ in the proximity detection range. This is obvious since the object size and distance are the main differentiating factors among these systems. Figure 6 shows an equivalent system implemented using the C8051F9xx and the Si114x.

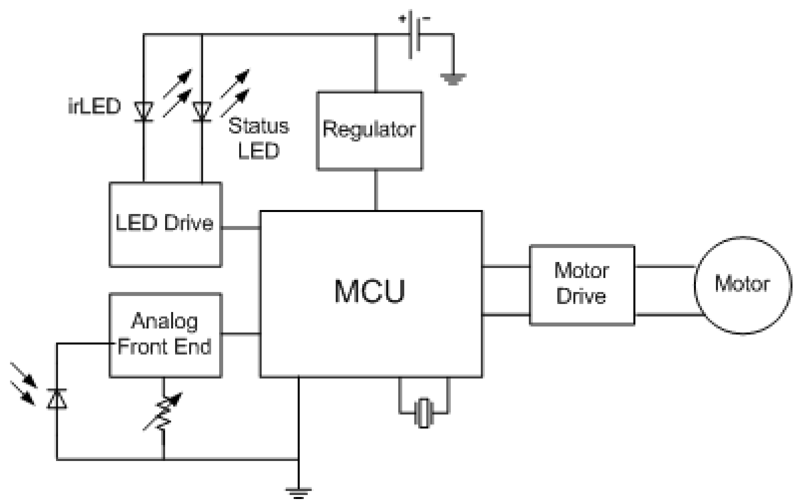


Figure 5. General Lavatory System Block Diagram

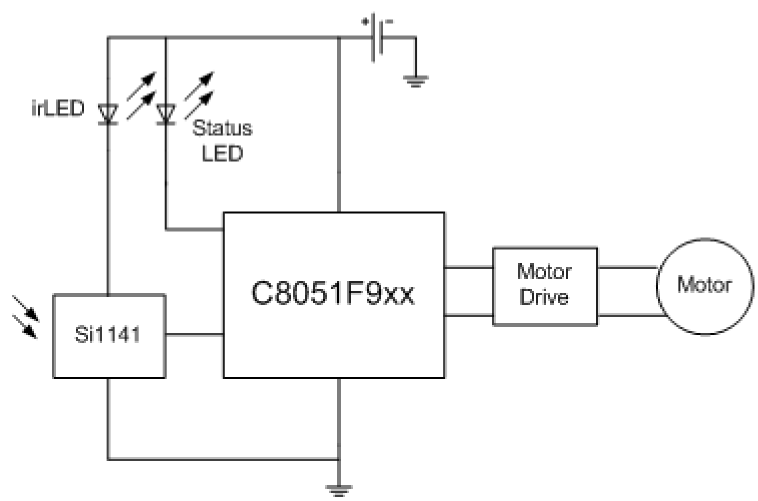


Figure 6. Lavatory System Block Diagram Using C8051F9xx and Si1141

5. Power Consumption

A lavatory appliance generally spends much of its time waiting for an object to enter its proximity. In Table 1, the Proximity Polling Period is measured by examining the period of the irLED current pulses when no object is in range. The irLED current and on-time is also measured. In most systems, the irLED on-time consists of multiple pulses. For these systems, the reported on-time is the accumulation of the irLED on-time within one Proximity Polling Period. The System Current is defined as the amount of current drawn through the System Power Source.

The F9xx and Si114x combination offers the best-in-class system current draw under the no-proximity condition. To best show this, an irLED current is estimated based on the detection distance and the size of the object. The estimated irLED current is then run through a calculator to achieve an estimated current consumption for the Si114x plus the irLED. Next, 1.2 µA is added to this to simulate the expected current drawn by the F9xx. It is important to note that the Si114x supports “interrupt on threshold”. This means that the Si114x can be set up so that the F9xx only wakes up from its sleep state if the reflectance reaches a certain level. The F9xx can then be woken up only when there is a proximity event. The 1.2 µA sleep current F9xx assumes that the Si114x interrupt pin is connected to a Port Match interrupt, allowing the F9xx to stay in its sleep state and only wake up when the Port Match interrupt is triggered.

6. Summary

The C8051F9xx and Si114x combination can provide significant power reduction in lavatory appliances.

The Si1141's high ADC sensitivity and flexible current sink capability provide the ability to adapt to different systems using a single hardware design. The Si1141 includes an ambient light sensor. This allows for the detection of high levels of IR ambient levels and can be used to change the ADC and irLED current parameters to best suit the ambient light conditions. The Si114x has excellent immunity to flicker noise due to the fast sampling single-pulse measurement system.

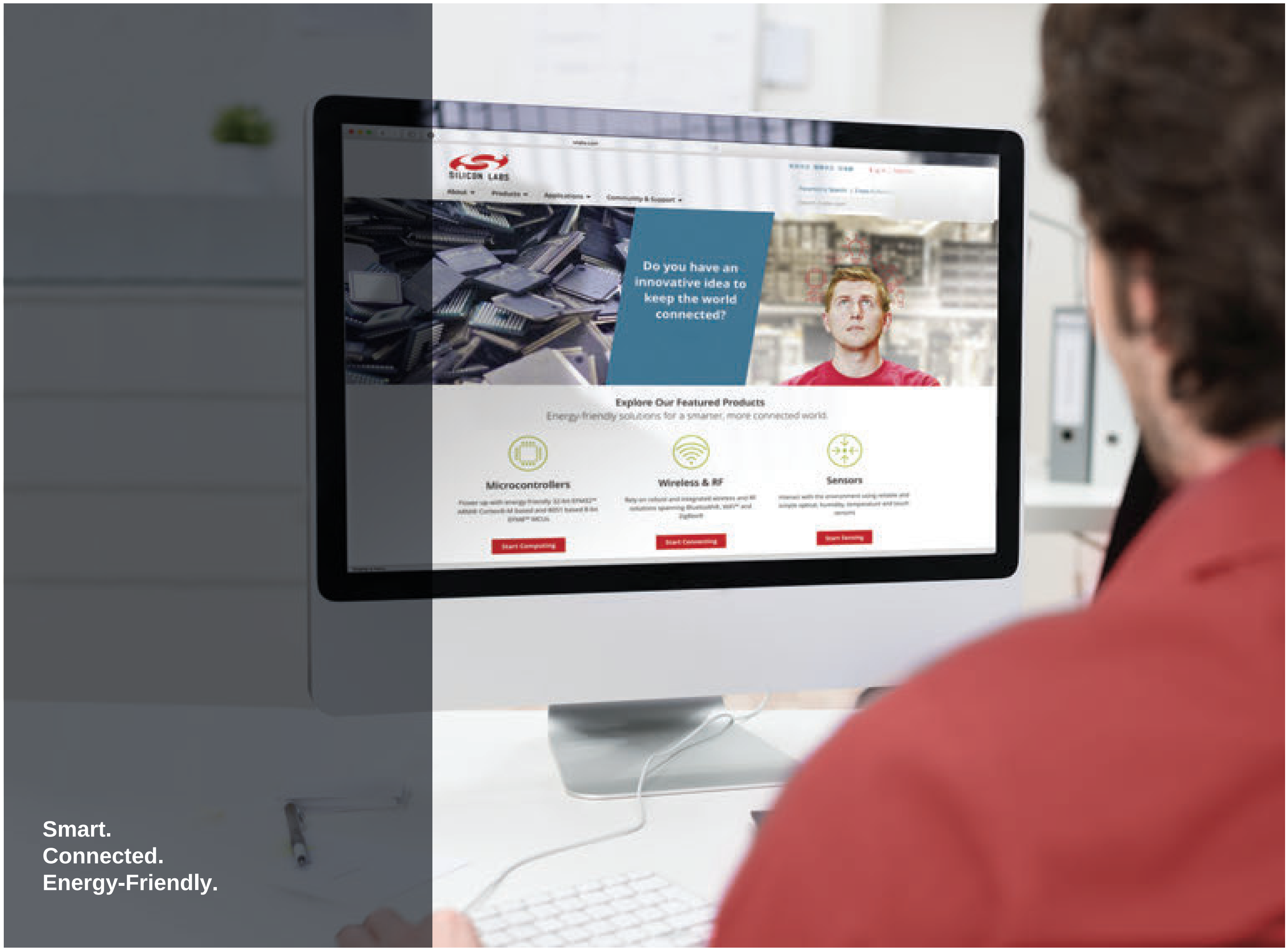
The C8051F9xx is a high-performance 8-bit MCU with best-in-class power consumption. A sleep current of 1.2 µA is easily achieved. The Si1141's use of a single-pulse of 25.6 µs and high sensitivity ADC minimize system current usage.

Both the Si1141 and C8051F9xx can operate from 3.6 V all the way down to 1.8 V. A system voltage regulator is not necessary since both devices can operate directly from the battery. In addition, neither the Si1141 nor the C8051F9xx require an external crystal to operate.

The C8051F9xx and Si114x are well-suited for use in lavatory appliances.

Table 1. Typical Lavatory Power Consumption

Appliance	Detection Distance	System Power Source	Proximity Polling Period	irLED Current - irLED on Time	System Current (No Object in Proximity)
Flushers					
Flusher A	50 cm	4 x D cell	870 ms	14 mA–59 µs	67 µA
Flusher B	50 cm	4 x C cell	1450 ms	65 mA–900 µs	41 µA
Flusher A using F9xx+Si1141	50 cm	2 cell	870 ms	400 mA–25.6 µs	14 µA
Flusher B using F9xx+Si1141	50 cm	2 cell	1450 ms	400 mA–25.6 µs	9.3 µA
Faucets					
Faucet A	10 cm	6.2 V	137 ms	7 mA–460 µs	40 µA
Faucet B	10 cm	6.0 V	129 ms	200 mA–13 µs	33 µA
Faucet using F9xx+Si1141	10 cm	2 cell	129 ms	70 mA–25.6 µs	21 µA
Soap Dispensers					
Dispenser A	5 cm	6.0 V	54 ms	6 mA–208 µs	57 µA
Dispenser B	5 cm	6.0 V	362 ms	45 mA–234 µs	58 µA
Dispenser A using F9xx+Si1141	5 cm	2 cell	54 ms	26 mA–25.6 µs	27 µA
Dispenser B using F9xx+Si1141	5 cm	2 cell	362 ms	26 mA–25.6 µs	5.5 µA



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