Power Calculation

To calculate the power consumption of all the electrical components of this project, firstly it will be separated into two main parts: Those components that are fed by the Power Supply and the DC/DC converter.

1. DC/DC Converter required power analysis

The DC converter supplies power to the following components: RGB LEDs, Ultrasonic sensors, Display and the microcontroller. Passive components that are part of the circuit such as resistors, capacitors and the crystal, will not be taken into account to calculate the power consumption, since they do not need external power to help it work properly.

1.1 RGB LEDs power calculation.

To make the RGB LED illuminate evenly for the three colors, it is needed to calculate the resistance according to the datasheet that suggest 20mA per color (Inolux HV-5RGB60, o. D.). According to Kirchhoff's voltage law, the voltage source must be equal to the sum of the voltage drop around a closed loop. Therefore, we derive equation 1.

$$V_{pin} = V_{red} + R_{red} I_{pin}$$

Equation 1

Where V_{pin} is the voltage provided by the output pin of the microcontroller (5.0V) , V_{red} is the voltage drop across the red LED (2.0V according to datasheet), R_{red} is the desired resistance and I_{pin} is the current desired (20mA) (*Microchip ATMEGA640-16AU*, o. D.). Replacing the values into the equation.

$$R_{red} = \frac{5.0V - 2.0V}{20mA} = 150\Omega$$

Repeating the same procedure for green and blue, knowing that they have the same voltage drop (3.4V) according to the datasheet.

$$R_{green} = R_{blue} = \frac{5.0V - 2.0V}{20mA} = 80\Omega$$

For costs purposes, the resistance for green and blue will be chosen to 100Ω, which will imply that the current on the green and blue LED will be reduced to 16mA.

Table 1 describes the power calculation for each LED of the whole circuit.

LED	Quantity	Voltage (V)	Current (mA)	Power (W)
Red	8	2	20	0.32
Green	8	3.4	16	0.43
Blue	8	3.4	16	0.43
			P_{RGB} (W)	1.18

Table 1

Therefore, it is known that only the RGB LEDs will draw **P_{RGB} = 1.18W** of power

1.2 Ultrasonic sensor power calculation.

According to the datasheet of the HC-SR04 sensor, the current consumption during measurement is 15mA (Adafruit Industries LLC, 2018). Since in our design the 8 sensors will be constantly measuring the level of the containers, connected at the pins of the microcontroller with a 5V source, we simply calculate according to equation 2.

$$P_{US} = N * V * I$$

Equation 2

Where P_{US} is the Power drawn by the ultrasonic sensor, N is the number of sensors on the whole circuit, and I is the current consumption during measurement.

Therefore, it is calculated that the Ultrasonic sensors draw **P_{US} = 0.6W** of power.

1.3 Display power calculation.

The technical features of the resistive touchscreen display, says that the power consumption is the product of the input voltage and the 65mA (*ITEAD Studio Nextion NX3224T028 - Generic 2.8" HMI LCD Touch Display*, o. D.).

Therefore, it is calculated that the Display needs **$P_{display}$ = 0.325W** of power.

1.4 Microcontroller power calculation.

Since our microcontroller will be operating at 5V with a frequency of 16MHz, a helpful graph taken from the datasheet shows how much current the microcontroller will draw while on its active state (*Microchip ATMEGA640-16AU*, o. D.).

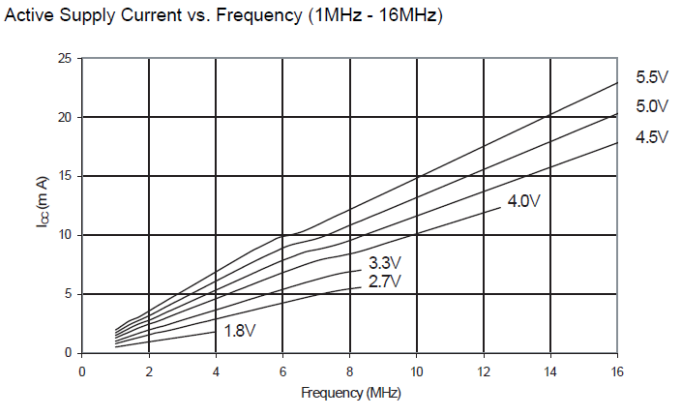

Figure 1: taken from ATmega640 datasheet

Approximately we can see that from the mentioned frequency and voltage, the current drawn will be I_{cc} = 20mA. Once again, we multiply the current and voltage to get that the microcontroller consumes **P_{MCU} = 0.1W** of power.

1.5 DC/DC converter requirements.

After the calculations made from section 1.1 to 1.4, the total power output required from the DC/DC converter is according to equation 3.

$$P_{DC} = P_{RGB} + P_{US} + P_{Display} + P_{MCU} = 2.2W$$

Equation 3

Therefore, our required DC/DC converter needs to output at least 2.2W of power with 5V of voltage supply. For this reason, our chosen DC converter is the ATA02A18-L that delivers 5V ± 0.1V with an 82% power efficiency, that means that the converter will need 2.68W to deliver at the input to deliver 2.2W (*Artesyn Embedded Technologies ATA02A18-L*, o. D.).

2. Power supply power requirement analysis

The AC/DC power supply needs to power the following components: Solenoids, Pumps and the DC/DC converter. Components that are part of the circuit such as resistors, diodes and the ON/OFF switch are passive, therefore it does not need to be considered to calculate the power consumption, since they do not need external power to operate properly.

To calculate the power required, firstly we need to assume that out of the 2 pumps and 10 solenoids installed on the machine only 2 pumps, 3 solenoids and 5 MOSFETS will be used per cycle, therefore the power consumed is calculated as follows.

Component	Quantity	Voltage (V)	Current (A)	Power (W)
Solenoid	3	12	0.5	18
Pump	2	12	0.6	14.4

Table 2

Lastly, there is the power consumption that the DC/DC converter requires. Since the datasheet of the DC/DC converter states that it transforms with an 82% of efficiency, the power input needed to deliver 2.2W would be $\boldsymbol{P_{DC\ (input)} = 2.68W}$ (*Artesyn Embedded Technologies ATA02A18-L*, o. D.).

After the calculations made, we know that.

$$P_{AC\ (input)} = P_{solenoid} + P_{Pump} + P_{DC\ (input)}$$

Equation 4

Replacing the values into the equation 4, we get that the $P_{AC\ (input)} = 35.08W$.

2.1 Power supply requirements.

We need a voltage of 12V to feed all the solenoids and pumps in parallel, and a power output of 35.08W. The power supply chosen (IRM-60-12) has a 12V± 0.3V output deliver and a rated power of 60W at an 87.5% of efficiency, which would be sufficient according to our calculations made (*MEAN WELL IRM-60-12*, o. D.). With that 87.5% of efficiency extracted from the datasheet, we know that the power supply needs 40.09W as input to deliver the required 35.08W calculated on the section 2. The following picture 1 displays this information.

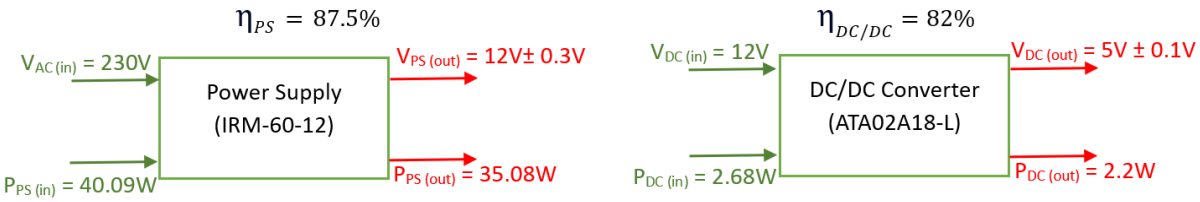

Figure 1

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Adafruit Industries LLC. (2018). *HC-SR04: 3942* [Datensatz]. https://www.digikey.de/en/products/detail/adafruit-industries-llc/3942/9658069

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