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Design and construction of dancing fountains controlled by pic16f877a

Diseño y construcción de fuentes danzarinas controladas por pic16f877a

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Abstract

This article shows the design and construction of some dancing fountains controlled by a pic16f877a. It also shows the code programmed inside this microcontroller, which was made using a PIC-C-Compiler for C language. The simulation and preliminary tests were performed in ISIS PROTEUS; the program converts the frequency signal to voltage. After the conversion, voltage ranges were assigned to activate each pump of the fountains' jets. The height that can be reached depends on how high the frequency is; then, the audio signal was coupled to an amplifier to improve the power of the audio signal to hear the music clearly, at par with the spectacle of the fountains working. In addition, the electronic designs of each board used are shown in detail. Finally, a vumeter was designed and installed to improve the visualization of the jets with illumination with LED lights changing to the rhythm of the music and the power of the output sound.

Resumen

En el presente artículo se muestra el diseño y construcción de unas fuentes danzarinas controladas mediante un pic16f877a. También se muestra el código programado dentro de este microcontrolador, el código se realizó empleando un compilador PIC-C-Compiler para lenguaje C. La simulación y pruebas preliminares se realizaron en ISIS PROTEUS; el programa convierte la señal de frecuencia a voltaje, posteriormente, cuenta con una serie de rangos los cuales cuentan con un voltaje definido por el código para activar cada una de las bombas de las fuentes, el orden en que encienden las bombas depende de la frecuencia a la cual este la música, posteriormente cuenta con un acoplo donde la señal de audio entra hacia un amplificador para mejorar la potencias de la señal de audio para escuchar la música en forma clara, a la par con el espectáculo de las fuentes funcionando. Además: se muestran a detalle los diseños electrónicos de cada una de las tarjetas empleadas. Finalmente, se diseñó e instaló un vúmetro con el propósito de mejorar la visualización de los chorros con iluminación con luces LED cambiantes al ritmo de la música y la potencia del sonido de salida.

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State of the Art

Water sources have been built and developed throughout history. The first fountains provided access to water provided by nature, to meet the basic needs of man and domestic animals.

Water fountains have been used for thousands of years for climate control, beautification, entertainment and as a means of relaxation. Among the most popular fountains are those that incorporate elements of surprise and/or special effects. These fountains elegantly combine engineering and artistic features. They are now a major tourist attraction because of the variety of lights, designs, heights and colours of the water jets.

Dancing fountains are an extraordinary tourist attraction when using a variety of frequencies that operate through various electronic devices. Today they are used to decorate parks and squares; to honour people or events that create an aesthetic design. Some musical water fountain projects consist of Arduino UNO, sound sensor with external MIC, submersible motors, LCD, relay modules, mobile sound generation, ARGB LED strip lights and adapters [1].

Musical waterscape control technology is an important part of the whole system, in the back accurately through music information retrieval technology to extract musical characteristics, and musical waterscape according to these musical characteristics to make the rhythm of the action change [2].

The system can design the performance programme of the musical source reflecting the musical connotation according to the characteristics of different songs. Through the comprehensive use of computer animation, automatic control, and other technologies, it greatly improves the efficiency of the development of the music source performance programme [3]. The artificial music fountain usually has two compositions of the system, one is the control program system, the main control of the style and flow of water, the other is the music control system, mainly through computer programming code, and according to the different music, programming, so as to achieve the synchronous form of music and water combined to send a different style of artistic effect [4].

In all kinds of modern fountains, the musical fountain can integrate human's sense of sight and hearing in real time, and plan the perfect environmental artistic effect in the urban landscape. On this basis, the theory of musical feature recognition was proposed, and the fountain shapes and the main points of the arrangement and layout were analysed in different environments [5].

In this paper, the design and implementation of a musical sound driven water fountain is addressed. The scenario is to decompose the adopted sound signal into four frequency bands, where each band occupies a narrow frequency range and represents the output signal of its IIR (Infinite Impulse Response) filter and allow each band to drive a submersible pump. The filter is Arduino-based, controlling the analogue voltage to control the magnitude and frequency of the voltage supplied to the pumps in order to determine the height of the water and the luminous intensity of the coloured light bulbs. [6].

1. Control block

A microcontroller was used, which is basically an integrated circuit that is used as a small computer or brain. It has a RAM memory where orders are stored to be able to carry out actions or processes in an electronic circuit. It has analogue or digital inputs.

Microcontrollers can have either of two types of memory, either the Von Neumann architecture which says that the data bus and memory are in the same place, therefore, it makes them slower. On the other hand, there is the Harvard architecture which is divided in two, data and instructions. The microcontroller used has a Harvard architecture.

In this part is where the analogue to digital conversion is done by means of the code loaded in the microcontroller, the ranges are determined - with which the pumps will switch on if the voltage reaches them. There are 6 pumps in which two are defined for each range, number 1 and number 4 are the low ones because they have a range from 2.55 Volts to 2.60 Volts; while pumps 2 and 5 are the medium ones with a range from 2.61 Volts to 2.7 Volts; finally there are 3 and 6, whose range are the high ones that have by definition 2.71 Volts to 4.0 Volts.

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2. Programation

For this particular project "CCS C Compiler" was needed because it was the tool that was available, here all the programming is done and then the file is saved and passed to "Master Prog", the language used to make the code is C language because the program required it.

Step-by-step explanation of the code:

C programming code (libraries and declarations)

```
#include <16f877a.h>
#device ADC = 10
#fuses
HS,NOWDT,NOPROTECT,NOPUT,NOLVP,BROWN
OUT
#use delay(clock=4M)
#use standard_io(D)
#define led_1 PIN_D3
#define led_2 PIN_D4
#define led_3 PIN_D5
long valor_adc;
float voltaje (1)
```

Table 1

In this part of the code you can see the libraries and commands required to program a microcontroller such as NOWDT which means that there is no watchdog (as it is usually called). This is in charge of the blocking inside an application in case you want to open it to be used in another pic or application, it only allows it to be used in the microcontroller. In addition to this, the ADC converter is also observed. In this same part is the declaration of the microcontroller model that is being used which is the 16f877a and the ports needed to operate the pumps, in this case, were called as LEDs because, for practical purposes, LEDs were used to see if it worked properly. Finally, two variable declarations can be seen, the voltage it receives and the ADC value of the one it has. (1)

C code (main)

```
void main()
{
  //lcd_init();
  setup_adc_ports(ALL_ANALOG);
  setup_adc(adc_clock_internal);
  //a0 bajos
  while(true)
  {
    set_adc_channel(0);
    delay_us(2);
    valor_adc = read_adc();
    voltaje = (valor_adc*5.0) /1023.0 (2)
```

Table 2

It is observed what is a while cycle which is divided into three sections. We can see the procedure of an operation that includes 3 values, the first is the value received from the upset, the second is 5 because it is the maximum value to which the voltage can reach in the microcontroller, all this is divided by 1023 which would be the equivalence to 8 bits (2).

C code (if-cycle, high frequency section)

```
//high
if((voltage >= 2.71)&&(voltage <= 4.0))
     {
       output_high(led_1);
       delay_ms (2000);
     }
    else
     {
       output_low(led_1);
     } (3)
```

Table 3

In this part there is a conditional "if" which in this first part covers the section where the frequencies or high voltages are, which have a range from 2.71 to 4.0 volts, but this case will only occur with songs with very high notes (3).

C code (if-cycle, average frequency section)

```
//means
    if((voltage >= 2.61)&&(voltage <= 2.70))
     {
       output_high(led_2);
       delay_ms(500);
     }
    else
     {
       output_low(led_2);
     } (4)
```

Table 4

In this part we continue with the if cycle but in this case the conditional is that the voltage is between 2.61 and 2.70 volts which is reached in a more frequent way because it is an average voltage and most songs can have it. (4)

C code (if-cycle, average frequency section)

```
//low
     if((voltage >=2.55 )&&(voltage <= 2.60))
      {
        output_high(led_3);
        delay_ms(500);
      }
      else
      {
        output_low(led_3);
      }

   }

} (5)
```

Table 5

In the final part of the code you can find the part of the bass, which are defined by a range between 2.55 to 2.60 volts, this because any song generates enough voltage to enter that range. This range starts from 2.55 volts because if it is lower the sources would always be on because it always enters a minimum voltage of 2.50 volts (5).

3. Electronic design

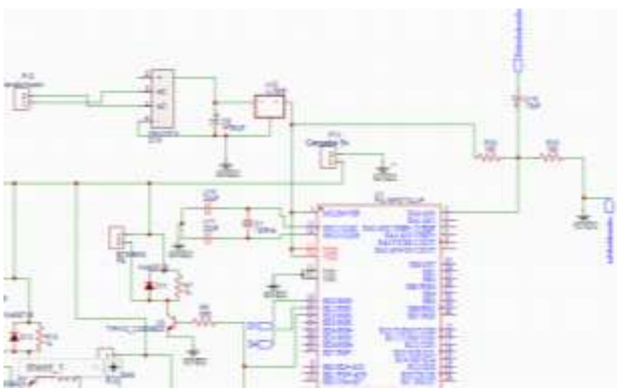

Figure 1 Circuit diagram (control part)

The circuit is divided into four parts.

In figure 2 is a 5v source, in this source can be seen a diode bridge which is responsible for changing the alternating current entering the transformer to direct current, followed by the diode bridge is a capacitor which functions as a filter that eliminates noise and finally reaches a voltage regulator to control the output voltage of the source.

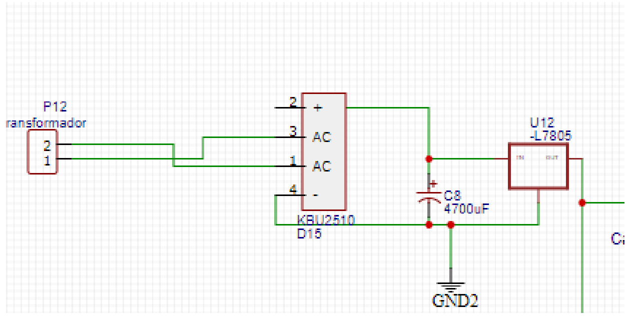

Figure 2 Power supply to feed the microcontroller

Figure 3 shows an upset, which is used to raise the voltage coming from the audio input because the microcontroller must receive a voltage of 0-5v, otherwise it may burn out.

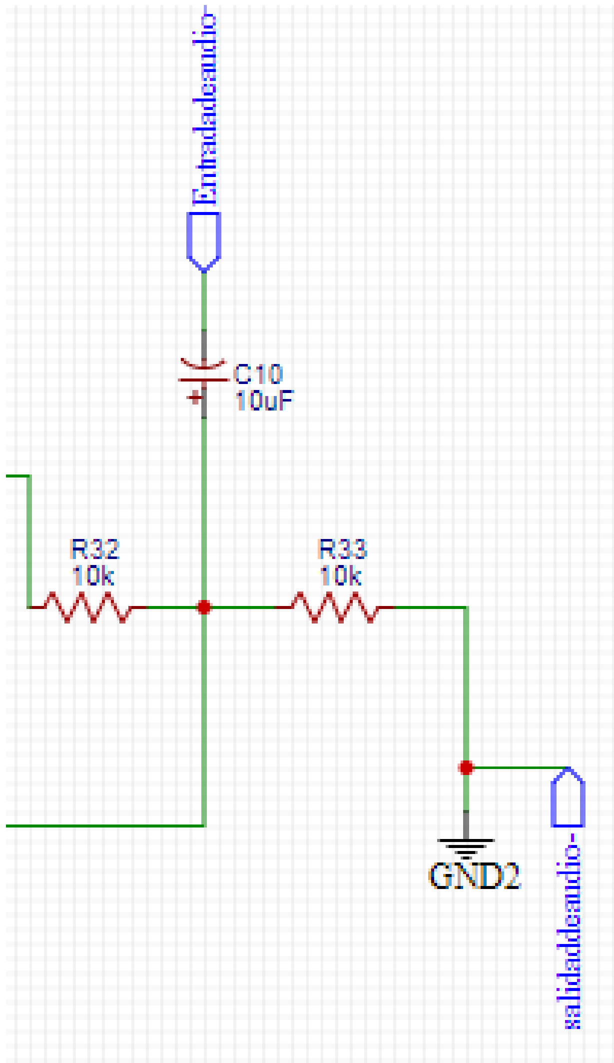

Figure 3 Diagram of the upset

Finally there is the PIC with its crystal and two capacitors (black box) that work as a filter in the case of the capacitors and the crystal is that it helps the microcontroller to oscillate, inside the microcontroller is already loaded the code that controls the operation of the sources (Figure 4).

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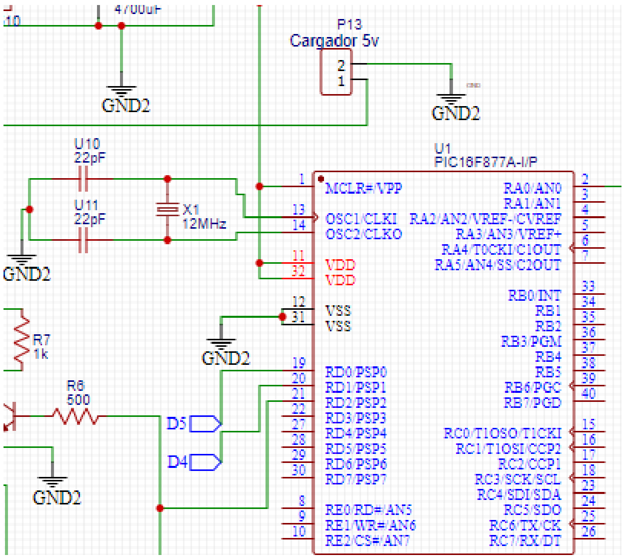

Figure 4 PIC16F877A microcontroller diagram

Figure 2 shows an arrangement consisting of a diode (1N4007) reverse biased to prevent the flow of current from the terminal block where the sources are connected to the PIC, there is also a resistor that goes one part to the terminal block and the other part is connected to a transistor (TIP441) that is used to give more power to the pumps, because if they demand all the power to the PIC can be damaged or heat up.

4. Power block

In this block is the arrangement of a transistor (TIP 41) which helps the pumps do not demand all the current to the microcontroller, in addition to the transistor, an inverted diode was added, which helps when the pump stops the current does not return to the PIC, finally has a resistor to protect the pump from a higher voltage than it is designed.

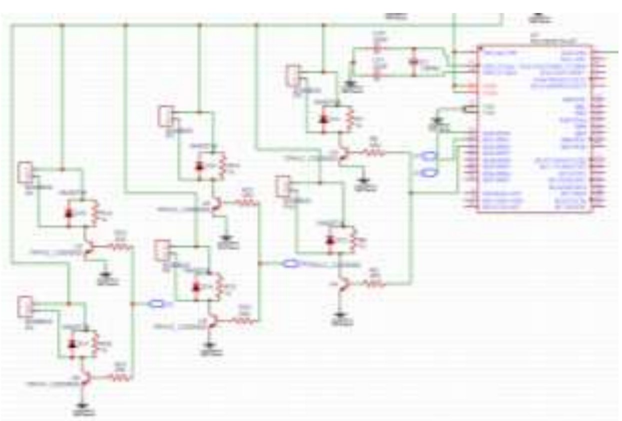

Figure 5 Decoupling part and pump swich

The transistors (TIP 41) support a maximum current of 6 Amperes so they are widely used in power amplifiers either in low power audio amplifiers or power supplies because they can dissipate up to 65 watts and withstand a temperature of up to 150 ° Celsius. The diode (1N4007) that accompanies the transistor was chosen due to its capacity to dissipate a power of 3 watts and its resistance to temperatures up to 150°, besides being a protection because it is inversely polarized and this prevents the pump from returning the current generated when it is turned off. Finally, there is a 100 ohms (Ω) resistor to protect the pumps in case a voltage higher than they can withstand reaches them.

In this same block is the PIC, which is programmed to make the switching of the pumps (turn them on and off) depending only on the frequency, has an analog-to-digital converter because the pumps need a digital signal to be driven in the right way.

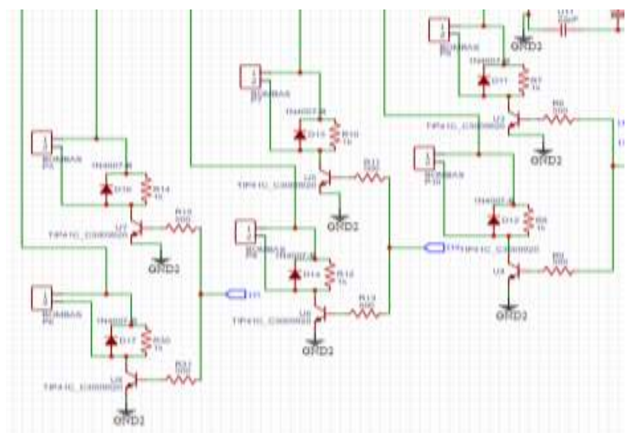

Figure 6 Diagram of the power stage

5. Amplifier

The diagram used for the amplifier was consulted on the internet which consumed up to 3 effective watts. This amplifier was selected because we have a very large speaker, therefore, an amplifier that supports more power is necessary.

A potentiometer was added to control the volume at which the music is needed to be heard, besides this inside the same circuit is added the power supply of this, which is 32 volts positive and at the bottom has a power supply of 32 volts negative.

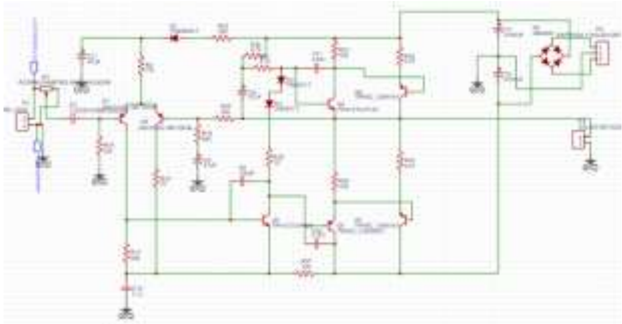

Figure 7 Diagram of the amplifier

It can be seen in the diagram the diode bridge, which is responsible for rectifying the sine wave received from the transformer, because the circuit needs direct current for optimum performance.

At the input of the amplifier there is a capacitor, which is in charge of filtering the stray noises that could reach the amplifier.

In this model of amplifier some diodes are used, which are reverse biased to protect some of the parts of the circuit where it should not enter much voltage, because the horn has a winding and could return some current, therefore, protection is necessary (Figure 7).

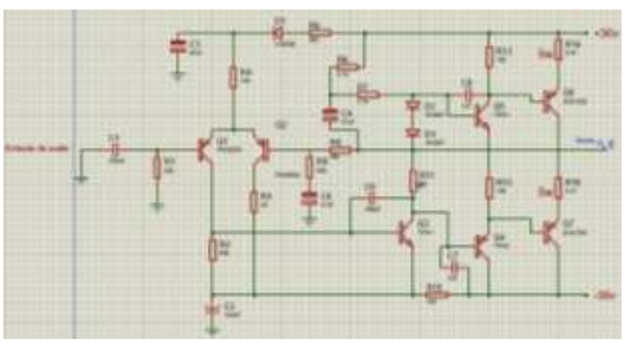

Figure 8 Proteus amplifier

The diagram of the amplifier made in proteus can be seen, which was helpful at the time of testing, to know its operation and then pass that same amplifier to the final boards (Figure 8).

6. Vumeter

It implements an integrated circuit called LM3914 which is a vumeter. The way it works is detecting voltage levels controlled by some audio input or potentiometer and displays them in a series of 10 LEDS which turn on or off depending on how high or low is the voltage at the input of the integrated circuit (VUmeter).

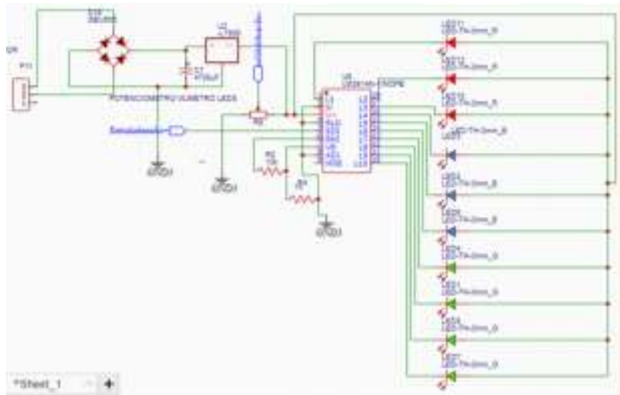

Figure 9 Vumeter and 5V source diagram

Vumeter diagram:

The diagram is made up of a series of 10 LEDS connected to a shared ground, which through the vumeter are controlled by a voltage input, either from an audio input or from a potentiometer. In addition to the LEDs, it has the vumeter, which is connected at its input to a potentiometer to control the sensitivity with which it receives the music.

To feed the vumeter, it is powered by the transformer, because the transformer gives alternating current is rectified by a diode bridge and a capacitor of 4700uF, in addition to adding a voltage regulator, which allows only 5 volts to enter the vumeter, which are necessary for its operation (Figure 9).

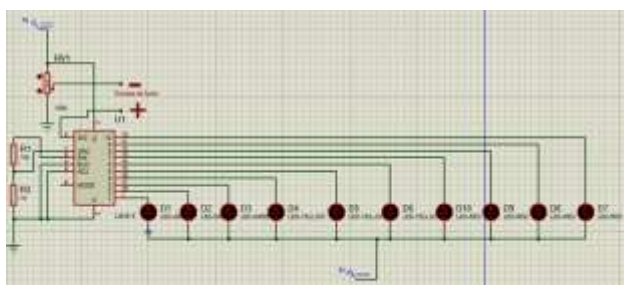

Figure 10 Vumeter in proteus

The vumeter presented in proteus is shown, in this way the voltages at which the music arrives can be observed.

The green LEDS represent the low levels, the yellow LEDS represent the high levels and finally the red LEDS represent the high levels (Figure 10).

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Results

Next, it is possible to appreciate what is everything that conforms the part of sound and visualization of the dancing sources, two sources can be observed which, one of them feeds the amplifier and the second one that is smaller feeds the vumeter.

This all in test plates because it is necessary to test its operation to later pass it to the plates that will remain as final, this to avoid any bad connection and that this generates a short circuit in the final plate, in addition to this, it also works in case you need to make any changes or something else (Figure 11).

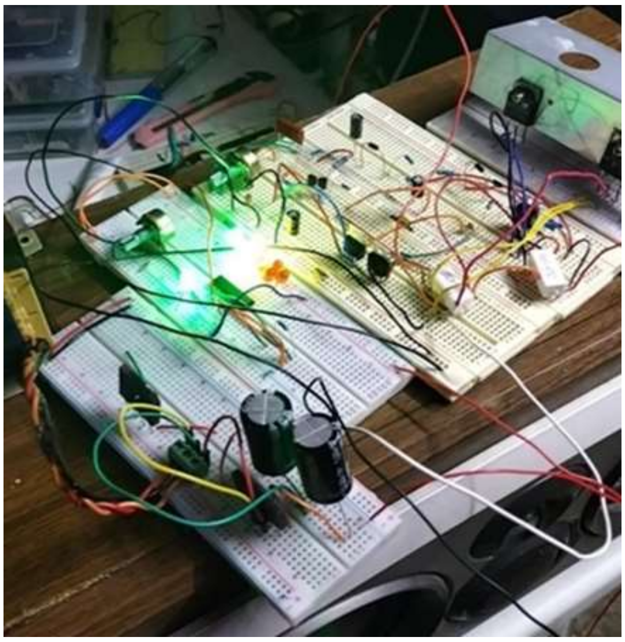

Figure 11 Combined amplifier-vumeter circuit

In this part you can see the final structure of the project, it consists of a fish tank lined at the ends with vinyl to avoid any accidental cut, in addition to this, at the base has two rubber strips to prevent any slippage. Inside the fish tank you can see 6 pumps, these pumps will be our fountains. In addition to the pumps we added 4 LED lights and some fish tank stones for aesthetic purposes.

In the lower part of the structure is where the horn and a transformer are placed, from where practically the power supply for the whole circuit is taken. In the upper right part of the structure is where the end plate with its heatsink goes, plus a small fan which serves to dissipate the heat that the power transistors generate (Figure 12).

Figure 12 Structure

Finally, the final prototype is shown, which already includes the power stage that can be seen with a red box and consists of an array of transistors, resistors and diodes.

There is also a blue box with the control part which is the microcontroller (16f877a) together with its 5v power supply.

In the black box you can see the vumeter (LM3914) with all its LEDS and its 8v power supply.

Finally, there is the amplifier with its audio output to the speaker, its audio input to the 3.0 jack, its potentiometer to control the level at which the volume is required, its source of +36v and -36v that enters the positive part to the top of the amplifier and the negative part to the bottom of the amplifier (Figure 13).

Figure 13 Structure

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In this part is the final board that was used, this is the final design with all its components already soldered, besides having a heatsink on the power transistors to prevent them from overheating.

The board was sent to be machined for aesthetic purposes, because at the time of making it there were several flaws, with the machined board only the other components are assembled and it is ready for use (Figure 14).

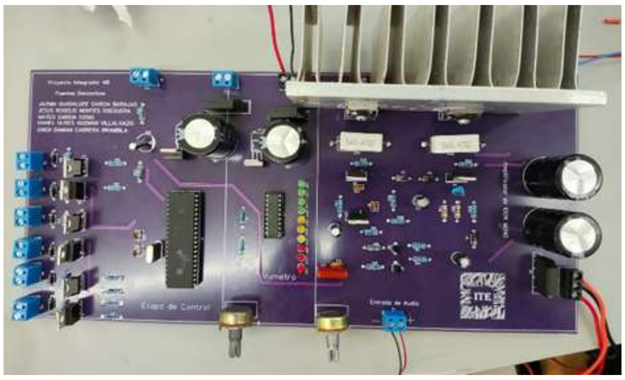

Figure 14 End plate

Conclusions

The objective of designing and creating dancing fountains was achieved, there were setbacks and errors, but they were solved in time. Several tests were performed to verify its operation and also some adjustments happened at the time of making the circuit, but in the end we tried to find a better way to make the pumps follow the rhythm of music.

This project was very beneficial for learning control through a microcontroller, design of power stages and decoupling, card design and assembly of amplifiers, also this project was beneficial to learn to work in a team and lead a team, stress management.

Team work can be a little complicated if you do not have good communication when delegating tasks, however, you learn to communicate and delegate work to other members making them see the areas of opportunity and accepting constructive criticism. The way to manage the team well is to allocate 3-4 days per week to make significant progress in the development of the team.

The project was very demanding because it had not worked with microcontrollers, so it was necessary to spend a lot of time to see how it worked and finally to implement what was learned to control the sources, then it was found with the power stage and decoupling for which it was necessary to investigate in different sources of information to make it, finally an amplifier diagram was consulted on the internet, which was modified and adapted to certain needs to use it.

This project has a great focus on electronics because it asks for a design for the board, it is necessary to know about power stages and decoupling, it is necessary to have knowledge about controlled sources as well as amplifiers. Because of this, the expected results were obtained, because the amplifier worked very well, the sources turned on according to the music, the board does not overheat and looks good aesthetically.

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