

# **Progress Report For An Automated Dog Ball Throwing Machine**

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## **Executive Summary**

The project goal is to create a dog toy, while gaining knowledge of the circuitry, software, and hardware design process. The dog toy is an automated tennis ball throwing machine, it will throw a ball and feed the dog via a TCP/IP network. Users can call the dog using recorded messages. The process can be seen via a camera mounted on the mechanism. All of the control will be done through a webpage interface.

Embedded Ethernet and web applications are a developing area in the technology sector. Ethernet is ideal because of its ability to transmit data over large distances. Trends indicate that more households are utilizing broadband internet connections and local area networks. Users can connect the dog toy to their home network and interact with it via a web browser. Web applications are independent of operating systems. Users only require a web browser and a network interface card (standard on new computers for the last 4 years) to connect to the dog toy.

The team is currently in their second month of development. A number of technologies have been researched and two prototypes have been created. Electronics are currently developing; however, they are a step behind the mechanical systems. Changes in actuator technologies keep the circuitry from being finalized. Currently a web enabled microcontroller is running and a number of “proof of concept” applications that have been created.

The project has had a couple set backs. Lead times for the microcontroller were excessively long. This slowed down the initial application development. The development of the mechanical components is lengthy because of limited access to a machine shop, thus slowing the prototyping process.

Over all, the project is progressing and is not far behind schedule. The proposed features list will be revised in coming weeks, illustrating the final functionality of the dog toy. The project should be completed on time for the presentations (March 28th).

## **Table of Contents**

|  |     |
|--|-----|
| Executive Summary .....                    | i   |
| Table of Contents .....                    | ii  |
| List of Tables .....                       | iii |
| List of Figures .....                      | iv  |
| 1. Background .....                        | 1   |
| 2. Progress .....                          | 2   |
| 2.1 Work Planned .....                     | 2   |
| 2.2 Work Completed .....                   | 2   |
| 2.2.1 Electrical .....                     | 2   |
| 2.2.2 Software .....                       | 5   |
| 2.2.3 Mechanical systems .....             | 6   |
| 2.2.4 Ball Launch Tests .....              | 13  |
| 2.2.5 Ball Launcher Design Selection ..... | 17  |
| 2.3 Problems .....                         | 18  |
| 2.4 Work in Progress .....                 | 18  |
| 2.5 Work remaining .....                   | 19  |
| 3. Plans and Recommendations .....         | 20  |
| 4. References .....                        | 21  |
| Appendix A .....                           | 22  |
| Appendix B .....                           | 24  |

## **List of Tables**

|  |    |
|--|----|
| Table 2.1: Microcontroller Comparison .....        | 3  |
| Table 2.2: Ball launchers for dogs .....           | 8  |
| Table 2.3: Required starting power.....            | 12 |
| Table 2.4: Spring design analysis .....            | 12 |
| Table 2.5: Rat trap (spring test) calculation..... | 14 |

## **List of Figures**

|   |    |
|---|----|
| Figure 1.1: Project Components .....                  | 1  |
| Figure 2.1: Interface Circuitry .....                 | 4  |
| Figure 2.2: ISD1400 Block Diagram .....               | 5  |
| Figure 2.3: One and two disc baseball throwers .....  | 6  |
| Figure 2.4: Lever arm operated baseball throwers..... | 7  |
| Figure 2.5: Air powered tennis ball thrower .....     | 7  |
| Figure 2.6: Single belt system.....                   | 9  |
| Figure 2.7: Dual belt configuration.....              | 9  |
| Figure 2.8: Spring design .....                       | 10 |
| Figure 2.9: Prototype 1 .....                         | 15 |
| Figure 2.10: Prototype 2 .....                        | 15 |
| Figure 2.11: Motor and PVC tubing assembly .....      | 16 |

## 1. Background

The ultimate goal of this project is to create an automated machine that throws tennis balls for a dog. The premise of the project is that the owner of the machine will be able to play with their dog remotely, whether it is from work, or around the world. The machine should also be able to feed the dog, either on the return of the ball, or by remote control. The remote user will also be able to see their dog through the digital camera. To call the dog to the machine, a voice recorder chip will be used. The user will be able to record their voice on the chip and play it back remotely. The project has been broken down into the following blocks (Figure 1.1). The lower blocks are the hardware or lower level tasks. Each task builds on the task below it.



Figure 1.1: Project Components

This project will allow the developers to learn and apply theory about control systems, interfacing, and design. Since both electrical and mechanical systems are involved, the project will teach mechanical and electrical engineers how to work together in the design and the realization of the project.

The goal of this project is to learn about the following concepts:

- Working with multiple discipline engineers
- Interfacing electrical systems to mechanical
- Creating a web browser based configuration tool
- Using analytical problem solving to find the optimal design
- Java applications and Java enabled controllers

## **2. Progress**

There have been a number of bumps in the realization thus far. A large amount of time was taken to decide on the actuators. Since controlling a stepper motor, AC motor, DC motor, and a solenoid are all very different; the electrical design could not be fully developed until decisions were made on the actuators. This caused a large bump in development.

### **2.1 Work Planned**

The work planned for this project was presented in the proposal and is included on the new Gantt chart, Appendix A.

Planned work consisted of:

- A literature search
- Creating project specifications
- Comparing design alternatives
- Testing alternative designs
- Testing the microcontroller
- Mechanical modeling
- Electrical circuit design
- Mechanical simulation
- Component procurement

The following sections will clarify what has been done and what will be done.

### **2.2 Work Completed**

The current state of the project is not as far along as was originally planned. The Circuit schematics are very close to complete, however, certain circuitry still needs to be built for the dog feeder. The hardware for the dog feeder is also being designed.

Completed tasks consist of:

- Literature search
- Comparison of design alternatives
- Creation of design specifications
- Testing alternative designs
- Testing the microcontroller
- Camera testing

#### **2.2.1 Electrical**

A microcontroller was needed to control the electrical systems in this project. As per the proposal's specifications, a micro controller with a TCP/IP stack was required. There are not a lot of microcontrollers with TCP/IP stacks that are in the appropriate price range for this project. The following table shows the microcontrollers that were researched.

Table 2.1: Microcontroller Comparison

| Controller              | Pros   | Cons  | Cost                     |
|-------------------------|--|---|--------------------------|
| Jstik [2]               | Real Time Processor, TTL outputs, large memory space (2MB) | Limited IO, Small Community, Not yet available                                    | \$300 USD DevKit         |
| TINI [1]                | Large Community, numerous open source projects, Low Cost   | External addressing hardware needed   | \$80 USD for 1MB version |
| Rabbit 2000, AVR or PIC | Very low cost  | IP stack is not fully compatible, lack of examples, Incomplete software libraries | Roughly \$12 USD         |
| PicoWeb [3]             | Small, low cost  | Low memory, limited I/O, limited power  | \$75 USD                 |

The TINI microcontroller by Dallas Semiconductor [1] was chosen to control this project. One of the larger factors in choosing the TINI was that the community is very friendly and friendly. TINI has also been out for 2 years and is currently releasing their third version. This means that there are a large number of articles on how to use TINI.

To interface the TINI to the inputs and outputs, an address decoder and bus latches are used. Figure 2.1 shows the circuitry used to create TTL level outputs and inputs. The TINI has a free address range from 0x300000 to 03FFFFFF excluding 0x300000 to 0x307FFF and 0x310000. For this project 8 addresses are used and ghosted over the balance of the memory. The address range used is from 0x38XX2X to 0x38XXEX where the odd numbers of the second digit and any digit marked with an X are irrelevant.

To throw the ball a number of systems were researched. The mechanical section will cover the choice of an AC motor for this project. Three motors were tested to throw the ball. The first motor was a synchronous motor from a vacuum. The Vacuum motor spun too fast, required 1000Watts, and was less than 33% efficient. The second motor was from a washing machine. This motor spun at roughly 3000RPM and was controllable by a dimmer switch. The problem with the washing machine motor was that it was under powered and experienced severe vibration. Recently a radial arm saw motor was implemented. The radial arm saw motor can launch balls between 28 and 58 ft (depending on the pressure in the ball) and has no vibration problems.

A triac is used to control the motor. Since there cannot be a common ground between the microcontroller and the motor, an optically coupled triac is used to trigger the high current triac. This trigger is recommended by the triac manufacturer; ST Electronics. Their Application note is provided in Appendix B. With motor speed control there are a couple different possibilities. Most motors are synchronous and speed control has to be done with a frequency varying controller. This is very difficult to build and will not be implemented in this project. AC Induction motors and universal motors can be controlled

by slicing the sign wave with the triac. The output circuitry can be found in Figure 2.1. A 200ohm resistance is used between the triacs to keep the current through the opto-triac low in the case of a stalled motor.

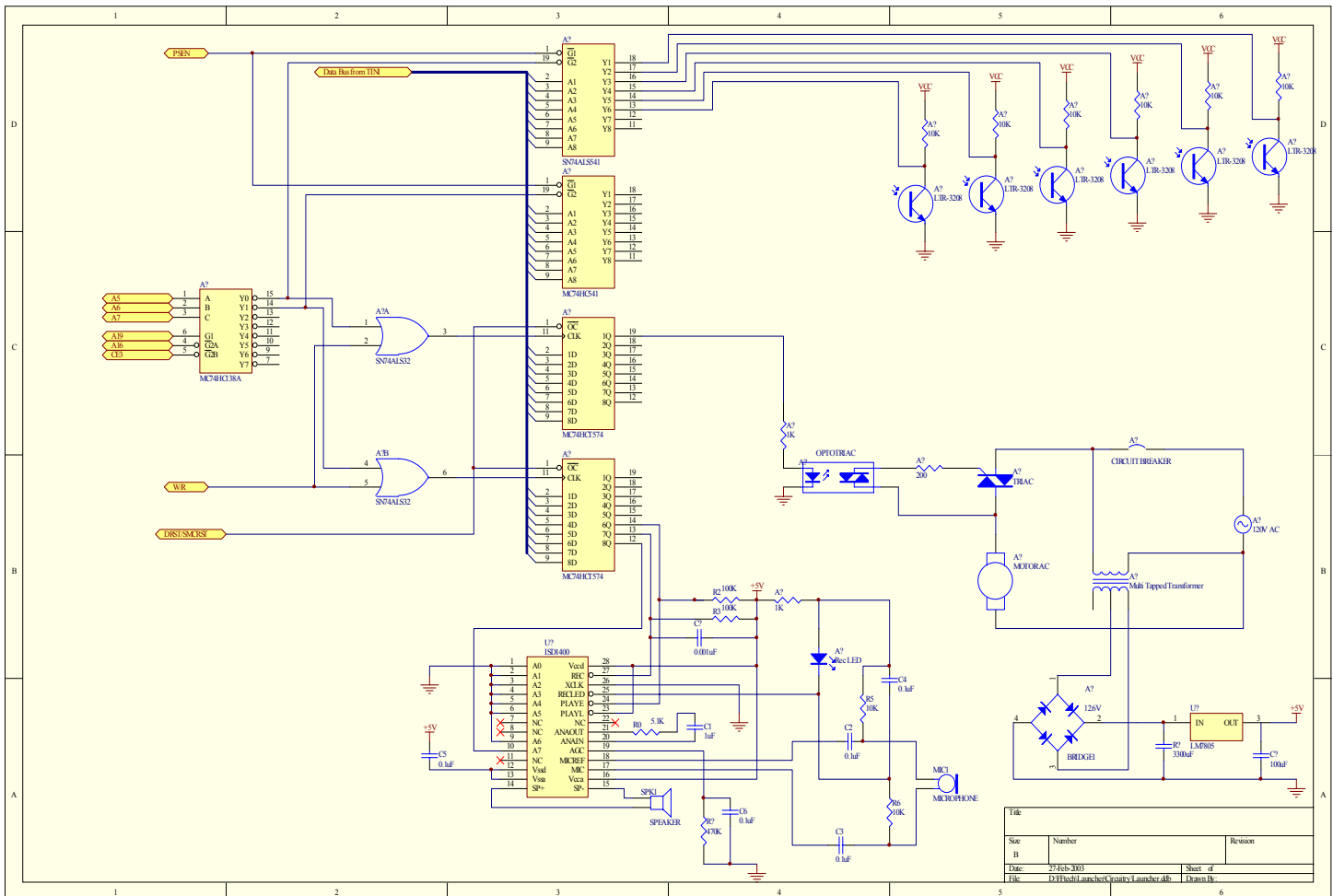


Figure 2.1: Interface Circuitry

To detect the balls, and the amount of food, optical sensors will be used. Three types of sensors were considered; a mechanical switch, an optical emitter and detector, and a capacitive sensor. There are several problems with a mechanical switch. The balls that go into the machine will not be clean, and will most likely be wet. A mechanical switch can easily be jammed and is vulnerable to rain and mud. Sensing optically is cheap and effective; however, there is the possibility that mud will cover an emitter. Capacitive sensors would be ideal if it was not for the pricing of the sensors. The only places that carry capacitive sensors are Omron, Allen Bradley, and other large scale control companies. In the end a set of optical emitters and detectors were chosen. LiteOn's LTE - 2872 and LTR-3208 are a set of paired infrared detectors and emitters. The emitters have a beam spread of  $16^\circ$ . In the 3inch pipe the total spread at the emitter will be 1.5 inches. Since the balls are roughly 2.5 inches in diameter, they will effectively block the light source. Since the pipe is white and fairly shiny there could be a problem with reflecting light hitting the sensors. There are two ways to solve this; the first is to paint the inside of

the pipe with a matte black, the second is to adjust the biasing of the collectors so that reflected light will not trigger the input.

The last electrical component is the voice record/playback processor. The Winbond ISD1400 [4] was chosen to store and playback voice messages. This was one of the only processors on the market devoted to voice playback. The chip is a self contained record, store, and playback system. Figure 2.2 shows a block diagram of the ISD1400's systems, Figure 2.1 shows how the recording and playback device will be connected to the microcontroller. This configuration will allow the user to record two messages, up to 8 seconds in length. A button may be added so that the person can record the audio without the use of the computer. Playback will available through the web based control application.

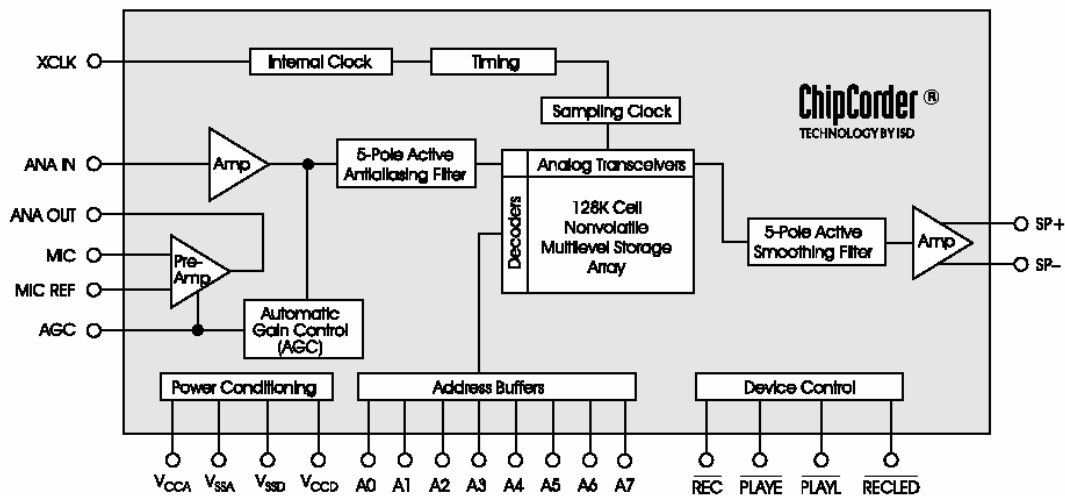


Figure 2.2: ISD1400 Block Diagram

### 2.2.2 Software

Thus far a number of testing applications have been built for the TINI microcontroller. Currently the controller is running an application that turns on and off the lights on a desk at a remote location. The program is slow and bulky; however, it serves as a proof of concept. The controlling servlet is built on top of the Tynamo [6] free source Web Server. The server comes with a number of iButton analysis servlets. These were used as a reference for creating the blinking light servlet.

Picture taking software has also been implemented. The NickClick children's digital camera was used to interface to the TINI through the serial port. This camera was used because of the number of projects [5] that have been created with it. The camera has a very small resolution and communicates to the TINI through RS232. The current program creates a PNG image from the camera and posts it to a webpage. The system is very slow because of the creation of the PNG image. There is also a problem with an infinite loop in one of the processes, this triggers Watch Dog timer after a certain amount of time. (roughly two pictures)

### **2.2.3 Mechanical systems**

The ball launcher is the mechanism that is to launch the ball 40 ft. Ideally the ball range would be variable to accommodate for different size yards and to vary the game for the dog. A number of other commercially available products launch balls and these were investigated as a starting point for this design.

#### ***2.2.3.1 Ball Launch Alternate Designs***

Most of the machines found for automatically throwing balls were trainers for baseball and tennis. There were a variety of designs and price ranges available in these products. Three automatic tennis ball launchers for dogs were found.

#### **The baseball throwers:**

- One or two wheel design (each wheel is separately driven) (Figure 2.3)
- Rubber or grooved wheels
- Typical motor: ½ hp, 110 VAC,
- Lever arm type machines were also available (Figure 2.4).

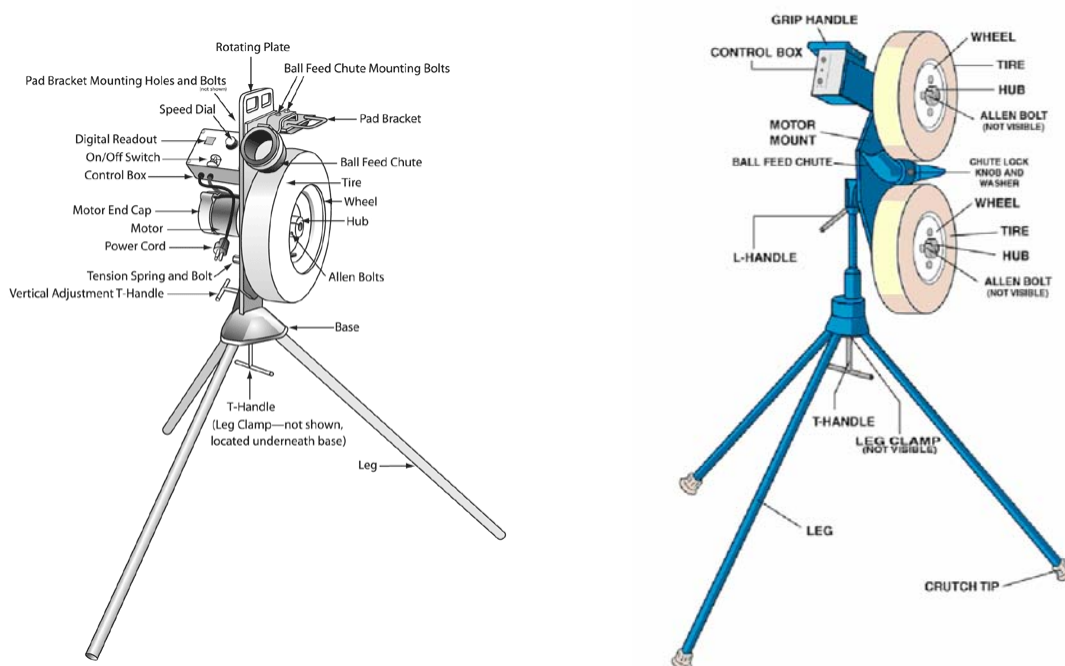


Figure 2.3: One and two disc baseball throwers



Figure 2.4: Lever arm operated baseball throwers



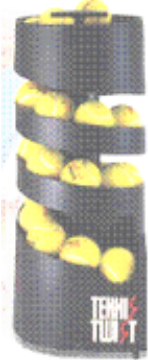
**Tennis ball thrower:**

- One or two wheel designs were available – typically two wheel
- Less expensive versions were air powered (Figure 2.5 below).



Figure 2.5: Air powered tennis ball thrower

Table 2.2: Ball launchers for dogs

|  |   |
|--|---|
| <ul style="list-style-type: none"> <li>The Lobster 202 Economy Ball Bucket is a machine made as a tennis trainer but also marketed to the dog owner. It is air powered and has a large ball capacity and velocity capability.</li> </ul>   |  <p><b>Lobster 202 Ball Bucket</b></p> |
| <ul style="list-style-type: none"> <li>The Go Dog Go tennis ball thrower is designed for dogs and has a launch adjustment of 15 to 30 ft and a 15 ball capacity. The ball launch is impact driven.</li> </ul>  |  <p><b>Go Dog Go ball thrower</b></p>  |
| <ul style="list-style-type: none"> <li>The Tennis Twist by Sportstutor is a machine for small dogs with an adjustable range of 10 to 20 feet and a 28 ball capacity. The Tennis Twist can be powered by AC or using “D” size batteries. The ball launch is most likely impact driven.</li> </ul> |  <p><b>Tennis Twist</b></p>          |

### 2.2.3.2 Spinning Disc Designs

#### One motor driving two spinning discs:

By using belt, pulley and gear systems, one motor can drive two spinning discs to propel the ball. This design could be configured with one continuous belt or the motor driving two belts. Since the discs must be spinning in opposite directions, the two belt system would require a pair of gears at one disc to accomplish this.

Figure 2.6 below shows a possible configuration of the single belt driving two pulleys system.

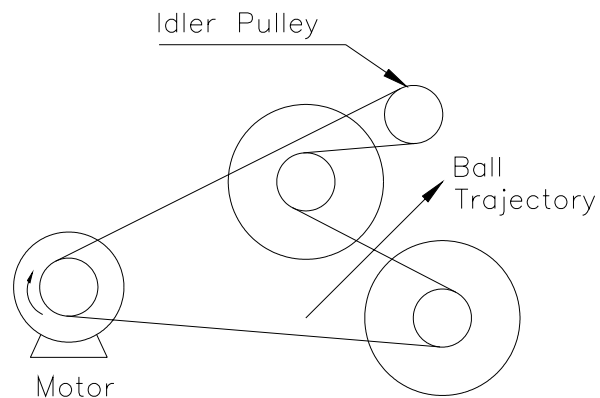


Figure 2.6: Single belt system

The advantages of this system over the dual belt system are:

- The simplicity of a single belt
- No double pulleys required
- All three pulleys can be the same
- One adjustment point for tensioning the pulley
- Belt tensioner (idler pulley) is part of system.

The disadvantages of the one belt system are:

- A flat belt is required because both sides will contact pulleys (require more belt wrap)
- More tension is required in the one belt
- Higher tension results in higher loads in the bearings.

A schematic of the dual belt system is shown below in Figure 2.7.

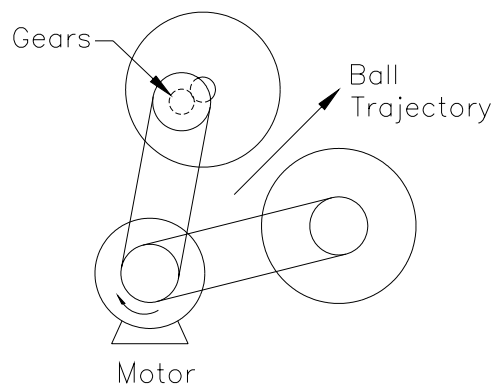


Figure 2.7: Dual belt configuration

The advantages of the dual belt system are:

- It can use a V-belt
- Better wrap around the pulleys and better power transmission
- Less belt tension is required resulting in less load on the bearings.

The disadvantages of the dual belt system are:

- More parts are required
- A double pulley is required on the motor
- A gear or twisted belt configuration must be used to change the rotation direction of one of the discs
- Adjustment of the belts is more complicated.

### **Independently driven discs:**

One or two disc designs can be independently driven by separate motors. This allows the eliminations of the belts, pulleys and all the mounting and adjustments that are associated with them. Smaller motors can be used and there will be no loss of energy between the motor and the spinning disc.

### **2.2.3.3 Spring Designs**

The spring designs would make use of the energy in the spring to launch the ball. The spring would activate an arm that would catapult the ball. The spring would have to be energized by an electric motor or solenoid, and another solenoid could release the arm to launch the ball. Figure 1 below shows a possible schematic for this design.

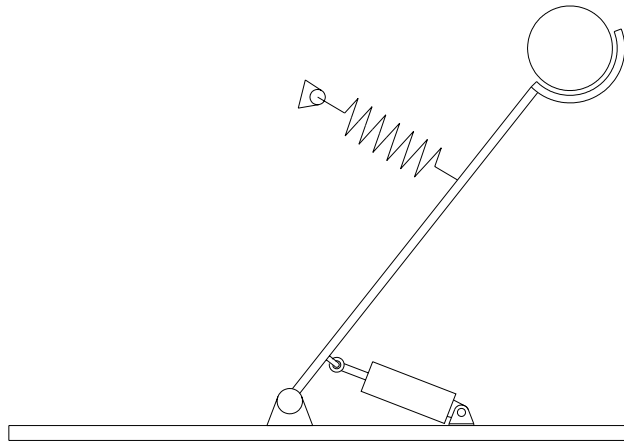


Figure 2.8: Spring design

One option that was discussed was timing the motor while energizing the spring to vary the ball distance, or using a ratcheting mechanism to hold the spring in a range of positions.

The advantages of the spring design are:

- It may not need a motor (or only needs one motor)
- It is potentially quieter (no high speed rotating masses)
- Energy only needs to be applied periodically when it is needed.

The disadvantages of the spring design are:

- It requires a high force solenoid, or a low speed high torque motor to charge the spring
- It could be difficult to engage and disengage the spring-arm system.

#### ***2.2.3.4 Pneumatic Designs***

A pneumatic design would use a compressor or fan and an accumulator or tank to store a large enough volume of compressed air to launch a tennis ball. A constriction in the exit type that is electronically controlled would be used to release the ball.

The advantages of the pneumatic design are:

- Simple design with few moving parts.

The disadvantages of the pneumatic design are:

- It is difficult to vary the ball range
- It is noisy
- It is bulky, requiring an air storage tank
- The components are expensive.

#### ***2.2.3.5 Preliminary Analysis of Launch Components***

A spreadsheet (developed by Aaron Bohnen) was used that calculates the trajectory of a spherical projectile when launched with a known angle and initial velocity. The spreadsheet takes gravity and air friction into account and is calibrated for varying air temperatures.

Based on drag coefficients for a tennis ball which are slightly lower than for a smooth sphere, an initial velocity of 11 m/s is needed to launch a tennis ball approximately 40 ft at a 45° launch angle.

A regulation sized tennis ball has the following dimensions and mass:

Diameter: 2.5" – 2.625" or 63.5 – 66.7 mm

Mass: ~ 58 grams

#### ***2.2.3.6 Spinning Disk Design Analysis***

An analysis was done on the spinning disc design to determine the rotational speed and power required by a motor to launch a ball at 11 m/s. To get an 11 m/s initial velocity a rotational speed of 2068 RPM is needed from two 4" discs or one 8" disc. The assumptions in this calculation are:

1. There is no slip between the ball and disc or fixed surface and the ball
2. The disc speed is constant while contacting the ball

3. The ball does not deform in contact with the disc.

The following table shows the starting power required from the motor to achieve a ball exit velocity of 11 m/s. The mass moment for the disc was taken from an actual pulley that will be used for initial testing.

Table 2.3: Required starting power

| DISC OF KNOWN MOMENT      |              |                    |             |                    |
|---------------------------|--------------|--------------------|-------------|--------------------|
| Disc OD                   | 8            | in                 | 203.2       | mm                 |
| Number of discs           | 1            |                    |             |                    |
| Mass Moment               | 11.27        | lb-in <sup>2</sup> | 0.003298    | kg-m <sup>2</sup>  |
| Full speed                | 2068         | rpm                | 216.5605    | rad/s              |
| Time to reach FS          | 1            | s                  |             |                    |
| Angular Accel             |              |                    | 216.5605    | rad/s <sup>2</sup> |
| <b>Starting Torque</b>    | <b>5.79</b>  | <b>ft-lb</b>       | 0.7142      | N-m                |
| <b>Starting Power</b>     | <b>0.207</b> | <b>hp</b>          | 154.6733    | W                  |
| <b>Ball Exit Velocity</b> |              |                    | <b>11.0</b> | <b>m/s</b>         |

For a time of 1 second to reach full speed 0.2 hp is required from an electric motor. This is a reasonable value and a motor of this size would be available.

### 2.2.3.7 Spring Design Analysis

Some analysis was done on the idea of using springs to launch the tennis ball. The analysis was done to determine the feasibility of the idea. The analysis assumes a configuration similar to Figure 2.8, with a solenoid charging the spring which then transfers the energy to the ball. Table 2.5 shows an approximated calculation of the force required from the solenoid based on some assumed input quantities.

Table 2.4: Spring design analysis

| Input Quantities           |                 | Calculated Values                   |                          |
|----------------------------|-----------------|-------------------------------------|--------------------------|
| Mass Ball and Holder       | 0.1 kg          | Total inertia about pivot           | 0.0105 kg*m <sup>2</sup> |
| Mass Bar                   | 0.05 kg         | angle of travel (bar)               | 40.3 deg                 |
| Length Bar                 | 0.3 m           | angular velocity                    | 36.7 rad/s               |
| Distance solenoid to pivot | 0.03 m          | angular acceleration                | 957 rad/s <sup>2</sup>   |
| Initial Velocity of Ball   | 11 m/s          | torque required                     | 10.0 Nm                  |
| <b>Solenoid Travel</b>     | <b>1 in</b>     | <b>Force required from solenoid</b> | <b>335 N</b>             |
|                            | <b>0.0254 m</b> |                                     | <b>75.3 lbf</b>          |

The table shows that for an initial ball velocity of 11 m/s, a solenoid that will provide 75 lbf and 1 inch of travel would be required. Solenoids with these characteristics are not

available, so the spring would have to be charged in a different way for this design to be feasible.

## **2.2.4 Ball Launch Tests**

Tests were performed on the spinning disc and spring designs to confirm the results of the analysis and verify the feasibility of the designs.

### ***2.2.4.1 Spring Design Testing***

A mouse trap and a rat trap were used to determine:

1. How much force / torque it takes to energize the springs
2. How far the tennis ball is thrown with that spring energy.

A spoon was attached to the spring loaded frame and the trap was clamped down. The trap was then set and the tennis ball placed in the spoon. The trap was tripped and the tennis ball was launched as the trap closed. In each case the clamping was not sufficient to hold the trap. This indicates that if the trap were more firmly clamped the ball would likely be launched even farther than these tests indicate. The actual distance would be expected to be larger since:

- More of the spring energy would go into launching the ball rather than into moving the trap
- The trap would be mounted to optimize the launch angle

#### **Mouse trap:**

Force to energize spring:  $\approx 2.5$  lbs at 1.75" (4.38 ft-in or 70 oz-in or 0.36 ft-lb))  
 Distance ball launched:  $\approx 4'$   
 Ball moment arm: 5.5" and 9.5" (ball thrown same distance)

#### **Rat trap:**

Force to energize spring:  $\approx 10$  lbs at 3.25" (32.5 ft-in or 520 oz-in or 2.71 ft-lb or 3.67 N-m)  
 Distance ball launched:  $\approx 20'$  (and rolled another 6-8')  
 Ball moment arm: 9.5"

The spreadsheet used for the spring design calculation was used to verify the numbers for the rat trap with some modifications due to the different geometry. The ball exit velocity was calculated based on the distance the ball was launched and was determined to be 7.8 m/s. Estimating the masses of the system and assuming the ball was in contact with the spoon for 45 degrees, a required torque of 4.0 N-m was calculated, which is reasonably close to the experimental value of 3.67 N-m. The values are shown below.

Table 2.5: Rat trap (spring test) calculation

| Rat Trap Calculation          |                        |               |
|-------------------------------|------------------------|---------------|
| Mass Ball and Holder          | 0.1 kg                 |               |
| Mass Bar                      | 0.01 kg                |               |
| Length Bar                    | 0.24 m                 |               |
| Initial Velocity of Ball      | 7.8 m/s                |               |
| accelerate through this angle | 45 deg                 |               |
| angular velocity              | 32.5 rad/s             |               |
| angular acceleration          | 672 rad/s <sup>2</sup> |               |
| torque required               | 4.0 N-m                | 35.4 lbf-inch |
| force required                | 48.5 N                 | 10.9 lbs      |

This calculation verifies that the spreadsheet used in the spring design calculations gives a good approximation of the required forces. This result also confirms that the solenoid required to charge a spring to launch the tennis ball 40 ft would require a prohibitively large force.

#### 2.2.4.2 Spinning Disc Prototype 1

A 110 VAC, 3000 rpm, 1/3 hp washing machine pump motor was used in testing. An 8" die cast aluminum V-belt pulley was purchased as a disc with which to launch the ball.

The purpose of the first trial was to determine if:

1. The pulley would be stable rotating at 3000 rpm
2. The pulley could be coupled securely to the motor shaft.

The testing was carried out and it was confirmed that the coupling was secure and that the pulley was stable at 3000 rpm.

In a second test, an off the shelf light dimmer switch was used to control the motor. The purpose of this test was to determine if the dimmer switch technology could be used to control the motor speed. This test was performed and it was confirmed that the dimmer switch can control the motor speed.

In further tests, a V-belt was cut and attached to the pulley using adhesive and pinning the ends, as shown below in Figure 2.9. The V-belt and pulley combination were not balanced causing excessive vibration when rotated at 3000 rpm by the motor. Attempts were made to balance the belt and pulley but the vibration could only be decreased slightly, still resulting in excessive vibration. It is postulated that the factors in the excessive vibration were:

- The flexibility in the shaft mounting in the motor (the shaft had some axial movement).
- The relatively small size and weight of the motor.
- The cantilever type loading of the pulley on the end of the long motor shaft.

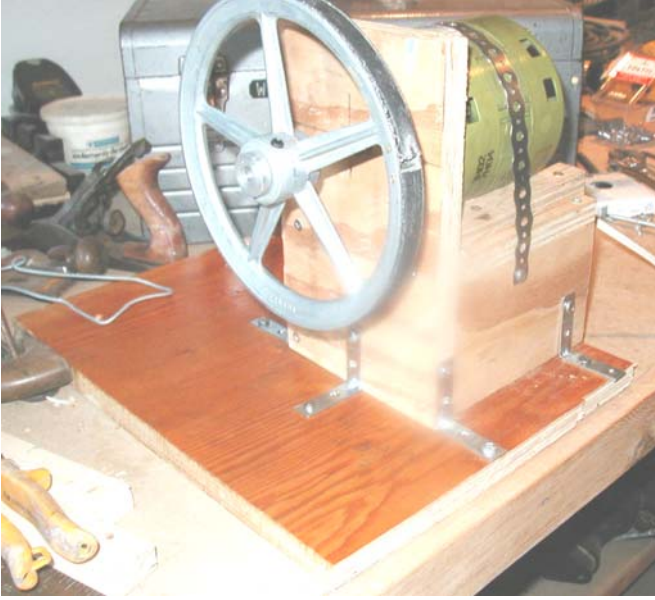


Figure 2.9: Prototype 1

#### ***2.2.4.3 Spinning Disc Prototype 2***

Once the single direct driven disc design was chosen, a second prototype was built and tested (see Figure 2.10 below). The new prototype used a radial arm saw motor, rotating at 3450 rpm and providing an estimated  $\frac{1}{2}$  -  $\frac{3}{4}$  hp. This motor is bigger and heavier than the previous motor and has a more rigidly mounted shaft. The second motor has a shorter shaft than the first motor so the pulley is mounted much closer to the motor, reducing the cantilever loading. An undersize V-belt was used on a new pulley. The bottom part of the V profile on the belt was removed allowing the undersized belt to be mounted on the pulley without cutting the belt. In testing, the larger motor and better balanced pulley and belt eliminated the excessive vibration experienced with the first prototype.



Figure 2.10: Prototype 2

PVC pipe and fittings were modified and assembled to create a path to feed the ball under the spinning disc and guide the ball as it is launched. The pipe assembly is configured to “pinch” the ball between the pulley and the tube wall at two points; where it is directly under the pulley and just before the ball exits the tube. The motor and PVC tubing assembly is shown below in Figure 2.11. The ball is fed into the inlet tube on the right and exits through the outlet tube on the left.



Figure 2.11: Motor and PVC tubing assembly

This prototype was tested using different tennis balls. A new (hard to compress), regulation size ball could be launched almost 60 ft while a slightly undersize, “dead” ball (which could be easily compressed to half its diameter) could be launched almost 30 ft. These distances are significantly less than those predicted by the spinning disc spreadsheet because the spreadsheet doesn’t take into account deformation and resulting variation in the contact pressure of the ball. The testing of prototype 2 proved that ball deformation obviously plays a major role determining the ball range. The prototype was capable of launching balls with a wide variety of compressibilities a reasonable distance (30-60 ft). Differences in ball range due to varying ball compressibility are acceptable (even desirable) since variations in ball launch distance are desirable. The ball also has a high rate of top spin as it leaves the launcher which tends to reduce the height of its flight path, and thereby reducing the distance it travels through the air. Due to this top spin though, the ball will roll a considerable distance on the ground.

### **2.2.5 Ball Launcher Design Selection**

A pneumatic design was avoided because:

1. Controlling ball range is problematic, as you have to control the flow, and an electronically controlled flow control valve is likely expensive
2. Compressors are expensive and draw a lot of current (though a \$10 compressor was purchased – it had a very low flow rate)
3. To launch the ball far, the ball would need to be somewhat sealed in the tube. It could be difficult to load the ball and then seal it to build pressure.
4. An accumulator tank is required and they are expensive (about \$45).

The solenoid energized spring design was ruled out by the analysis. The spring tests also verified that a large spring force would be required to launch the ball. Analysis indicated that a typical solenoid with 3/8" travel would have to exert a very large force to energize a spring sufficiently to launch the ball with an initial velocity of 11 m/s. Such large force solenoids are uncommon and would most likely be expensive and draw large amounts of current.

The rotating disc design was chosen as it appears to be the easiest to make and the least expensive since many of the components can be scavenged. This is the design that will be focused on, pending success in certain upcoming tests. A design using a single large pulley direct driven by an AC motor will be the preliminary design. The ball will be dropped onto (or under) the rotating pulley, pinched between the pulley and a solid surface, and launched through a short guide tube.

## 2.3 Problems

This project has not been without its problems. Designing an electromechanical system has been a learning process for both the mechanical and electrical students. Both factions of the team have to advise each other before any actions can be taken. This slows down the production time. Meetings are frequent and often do not solve anything. Progress is being made; it is just slower than originally expected.

Near the beginning of the project there was a large problem with delivery times. A TINI microcontroller and breadboard adapter was ordered the Vinculum Technology Group in Texas. When the controller had not arrived in one week phone calls were made to the company, however, they were never answered. After three weeks, a replay was made at 11:00pm on a Sunday night. Universal Vinculum was out of stock on the 1MB TINI boards so they couriered the adapter board to Victoria and a TINI was purchased off another company. It was learned that Dallas Semiconductor is very slow in production and has difficulty meeting their lead times. This is a large consideration for the next project involving embedded TCP/IP applications.

The camera system chosen for the TINI microcontroller is very slow, compiling the PNG image takes up to 4 minutes to complete. The camera will create a very basic feedback system; however, it will never get to the point where it can be called a web cam. During the next month the system will be redone and streamlined. If the system is still too slow, a standard web cam or a TCP/IP camera will be implemented. The downside of using the TCP/IP camera is the cost. The Nick Click camera costs \$12, the web cam costs at least \$100, and a TCP/IP camera costs around \$250. A web cam also needs a computer within 10 feet of it.

Mechanical part development is difficult because the University has restricted use of the machine shop. To make components a private machine shop in Metchosen is used on the weekends. This slows down the prototyping process and wastes valuable time on transportation.

## 2.4 Work in Progress

There is still a lot of work required to bring this project together. At the moment the dog feeder is a large concern. There are a few mechanisms that are being looked at for delivering food to the dog. Once a technology is decided upon, the circuitry will be designed and built. On the circuitry side, a parts list, and all encompassing schematic is being worked on. The electrical components should be purchased in the next week. This should leave adequate time for any problems in the assembly. In the software area, stepper motor driver software is being built for the testing of a stepper motor.

## 2.5 Work remaining

There is quite a bit of work that still needs to be done in this project. Most of the work is construction. Most of the components have been decided on and it is now a task of assembling and testing all of the components.

The following tasks are still remaining:

- Final software development
- Circuit implementation
- Feeder design and implementation
- Camera software updates
- System testing
- Machine body construction

### **3. Plans and Recommendations**

Through hard work and ingenuity the project can be finished by presentation time. The next logical step in our design is to create the dog feeder system. Once this is complete, the circuitry can be finalized and built. The machine case can also be built and everything can be put into place. The final tasks will be to align the sensors and test the software. It is hoped that there will be at least three days of constant testing on the software. This should be enough time to confirm the stability of the software and circuitry systems.

The new motor will need to be tested for compatibility with a triac based speed controller. If triac based speed control is possible then an application will be built. If it is not possible then it is advised to only create an on/off style switch.

## **4. References**

- [1] Dallas Semiconductor, iButton/TINI, [www.ibutton.com](http://www.ibutton.com)
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- [3] PicoWeb, PicoWeb, [www.picoweb.net](http://www.picoweb.net)
- [4] Winbond, Chipcorder, [www.winbond.com/e-winbondhtm/partner/b\\_2\\_a\\_4.htm](http://www.winbond.com/e-winbondhtm/partner/b_2_a_4.htm)
- [5] Profcon, stiklik, [www.profcon.com/cargill/tini/stikklik/](http://www.profcon.com/cargill/tini/stikklik/)
- [6] Shawn Silverman, Tynamo, [www.ee.umanitoba.ca/~shawn/projects/tynamo/](http://www.ee.umanitoba.ca/~shawn/projects/tynamo/)

## **Appendix A**

Key

|      |      |             |
|------|------|-------------|
| Elec | Mech | Elec & mech |
|------|------|-------------|

|                                   | Jan 13-<br>Jan 19 | Jan 20-<br>Jan 26 | Jan 27-<br>Feb 2 | Feb 3-<br>Feb 9 | Feb 10-<br>Feb 16 | Feb 17-<br>Feb 23 | Feb 24-<br>Mar 2 | Mar 3-<br>Mar 9 | Mar 10-<br>Mar 16 | Mar 17-<br>Mar 23 | Mar 24-<br>Mar 30 | Mar 31<br>Apr 4 |
|-----------------------------------|-------------------|-------------------|------------------|-----------------|-------------------|-------------------|------------------|-----------------|-------------------|-------------------|-------------------|-----------------|
| Literature search                 |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec project spec (Jan 17)</b> |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Compare design alternatives       |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Test alternate designs            |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Micro Controller testing          |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Design calculations               |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Select design                     |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec report 1 (Jan 31)</b>     |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Mech Report (Feb 24)</b>       |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Circuit Design                    |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Pro/E modeling                    |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec web site (Apr 4)</b>      |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Specify components                |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Software Design                   |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Procure components                |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec review meet (Feb 21)</b>  |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec report 2 (Feb 28)</b>     |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Pro/Mechanical simulation         |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Assembly                          |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| Interface with elec/comp          |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| De-bug / refine design            |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec presentation (Mar 28)</b> |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Elec final report (Apr 4)</b>  |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |
| <b>Mech final report (Apr 4)</b>  |                   |                   |                  |                 |                   |                   |                  |                 |                   |                   |                   |                 |

**ELEC SPECIFIC DEADLINES AND DETAILS**

- Friday, Jan. 17, deadline for submission of project specification and plan to supervisor
- Friday, Jan. 31, Progress Report #1 (to supervisors)
- Friday, Feb. 21, Midterm Review Meeting, EOW-430, 2:30pm-3:20pm
- Monday, Feb. 28, Progress Report #2 (to supervisors)
- Friday, Mar. 28, Poster Presentations (from 1:30 p.m.) at ELW Lobby
- Friday, Apr. 4, Last day of Classes
  - 1) Final Report submitted to supervisors
  - 2) Web presentations finalized.

**MECH SPECIFIC DEADLINES AND DETAILS**

- Monday, Feb 24, Mid-term Report (to supervisor)
- Friday, Apr 4, Final Report and Prototype (to supervisor)

## **Appendix B**

## TRIAC + MICROCONTROLLER SAFETY PRECAUTIONS FOR DEVELOPMENT TOOL

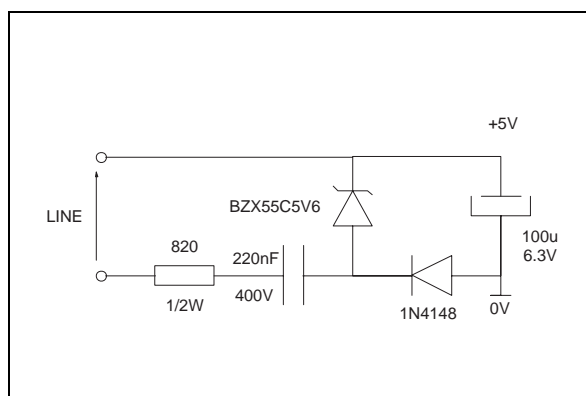
Ph. RABIER

The goal of this paper is to analyse the different ways to configure a micro-controller and a development tool during the debugging phase. The major problem is due to the direct connection of the computer I/O lines with the mains power. Some precautions have to be taken during the emulation in order to avoid destruction.

### I - LOW COST POWER SUPPLY

In most low cost applications the step down transformer is not used and the power supply delivers low current, as shown for example in figure 1.

Figure 1 : Uninsulated power supply.



In domestic appliance applications, one of the most important power switches is the triac.

The function of driving the triac becomes more and more complex. For this reason, microcontrollers are becoming more and more common. Furthermore, sensitive triacs with high commutation parameters, for example LOGIC LEVEL triacs can be triggered directly by the microcontroller without any buffer. Sensitive triacs and microcontrollers allow decrease in power consumption.

In this way the power supply can be optimized to reduce the cost. Optimisation can be achieved by removing the transformer.

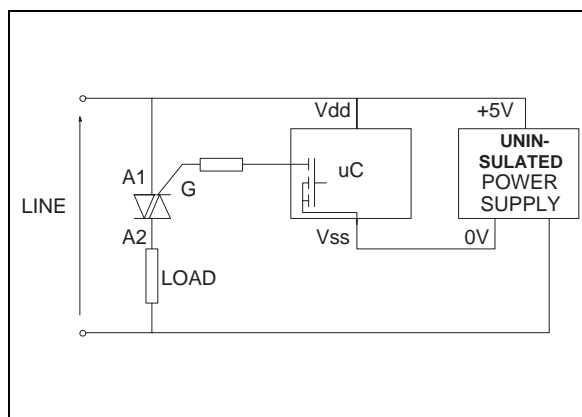
The consequence is that there is no insulation, the microcontroller is connected directly on the line !

When the software is emulated on the application board, the output port (RS232 port) of the computer is connected on the line via the emulator.

If some precaution is not taken "something" will be destroyed !

Figure 2 gives an example of an application using a triac and a microcontroller.

Figure 2 : Triac and microcontroller on the line.



In this case the micro-controller is supplied by an uninsulated +5 V power supply connected directly to the line, and a low level (0V) on the output ports of the micro-controller is needed to trigger the triac.

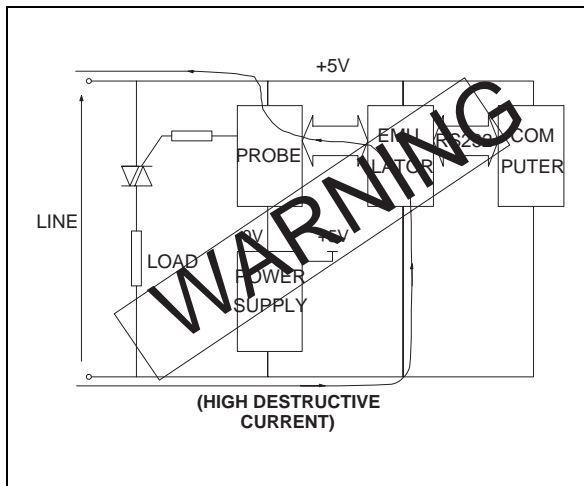
### II - USE OF A DEVELOPMENT TOOL

During the debugging phase, the micro-controller is removed and is replaced by the emulation probe. The circuit corresponding to the emulation phase of the previous example is shown in figure 3.

The line is connected directly to the +5V of the emulator and a high (destructive) current can flow through the emulator and/or the computer.

## APPLICATION NOTE

**Figure 3 : Circuit without protection**  
(Beware : this circuit is dangerous).

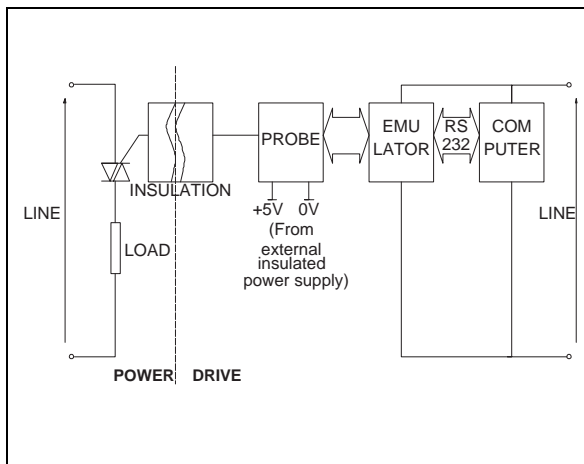


### III - INSULATED SYSTEM

To avoid destruction of the development tool it is necessary to have an insulation between line and probe. This insulation can be achieved by optocouplers, pulse transformers, or insulation transformers.

Figure 4 shows the topology of the most common insulation.

**Figure 4: Conventional insulation.**

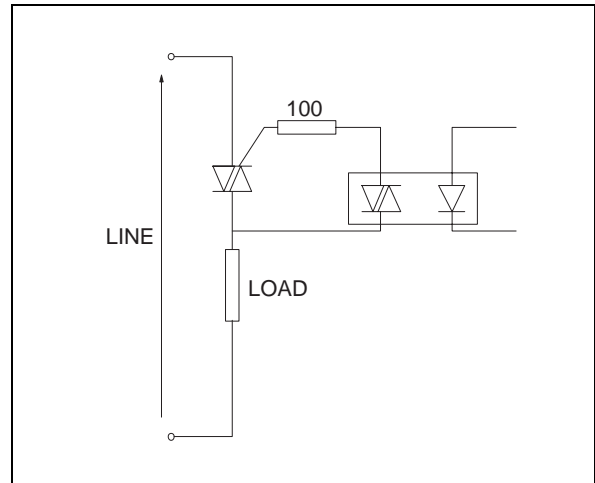


#### 1/ Optotriac

Figure 5 shows the circuit with triac and optotriac.

The triac is working in the 1st and in the 3rd quadrants.

**Figure 5 : Optotriac drive.**



The main advantage of a such system is the low cost of the optotriac, but it needs an isolated auxiliary power supply.

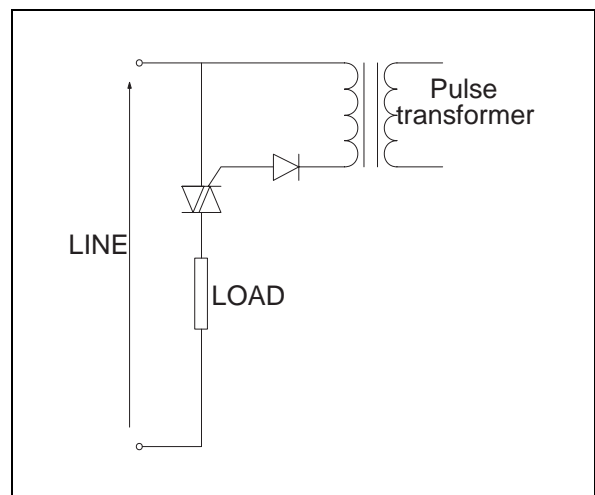
For a zero crossing optotriac, the triac is triggering with a gate current equal to the gate trigger current with a very low  $di/dt$ . This does not allow high  $di/dt$  at turn on. That is to say the control of high current resistive load is not recommended with this method.

#### 2/ The pulse transformer

Figure 6 shows the circuit with a triac and a pulse transformer.

The triac is working in the 2nd and 3rd quadrants.

**Figure 6 : Pulse transformer insulation.**



This system is simple to use when the triac was initially driven by a buffer transistor, but it needs an external power supply. The high  $dI_G/dt$  through the gate allows high current resistive loads to be driven. Due to the saturation of the magnetic material, this system cannot drive small loads because the gate current is cancelled before the latching current has been reached.

For more information refer to the application note "Triac control by pulse transformer".

Another solution is to supply each equipment connected to the board from the mains through an insulation transformer. If an oscilloscope is used, it also has to be separately insulated.

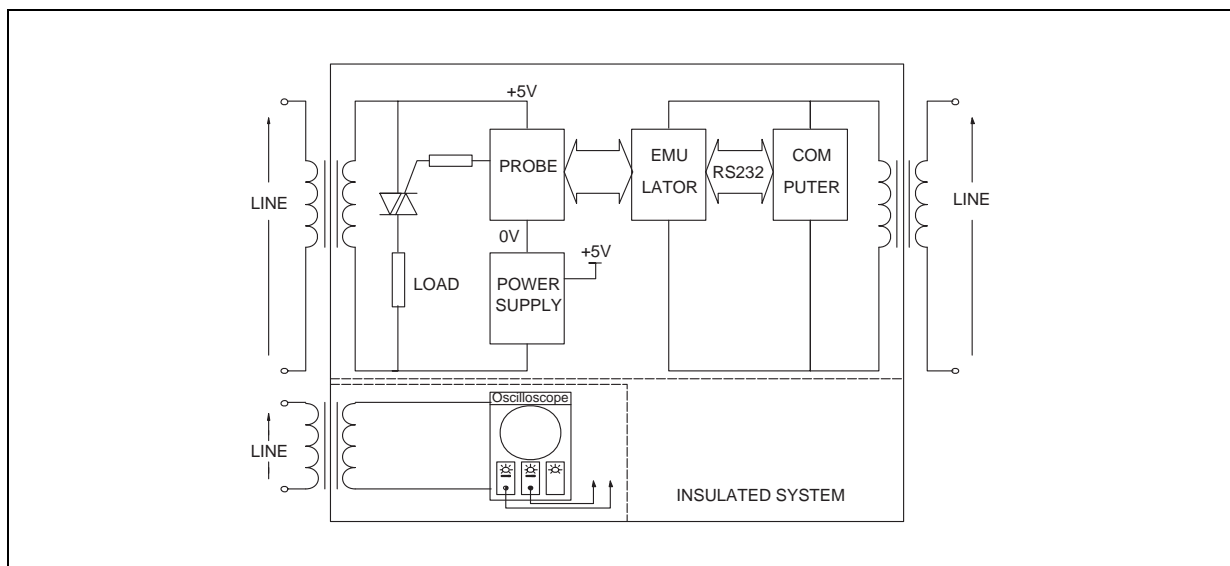
The main advantage of this system is that we do not need to modify the target system during the debugging phase and it can be used with the microcontroller.

When a transformer is used between line and triac it should be noted that the line impedance is modified and then the behaviour of the triac, load and line set can be different (waveform of current).

**3/ The line insulation transformer**

In the previous examples, the insulation was between the triac and the microcontroller.

**Figure 7:** Insulation with transformers.



**IV - SUMMARY**

New LOGIC LEVEL and SNUBBERLESS triacs can be connected directly to the microcontroller without buffers or insulation. Furthermore, low cost power supplies without a transformer are becoming more common. There is an increasing number of applications supplied directly from the mains, and the microcontroller is directly connected to it.

During the debugging phase when connecting the development tool, a galvanic insulation is absolutely necessary.

This insulation can be done in 3 ways :

- With optotriacs :
  - . Need modifications on the target system
  - . Need external power supply
- With pulse transformer :
  - . Need modifications (transistor to drive the pulse transformer)
  - . Need an external power supply
  - . Cannot drive small loads
- With insulation transformer :
  - . No modification on the application board.
  - . Modification of the line impedance due to the transformer between line and load.

Therefore a microcontroller operating on the mains with a triac may be directly connected to the line.

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