The Smart Pet Feeder

The Design and Building of an Automated Pet Feeder Capable of Preventing One Pet From Eating Another Pet's Food

Submitted to Professor Salah Badjou

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by

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Abstract:

This paper details the process of the design and manufacturing of a prototype of The Smart Pet Feeder, an automated feeder which is capable of preventing one pet from eating another pet's food. The goals of this design project were to create a feeder which would hold 6 meals to be revealed at user-programmable times and would allow only authorized pets to eat from the feeder. If an unauthorized (or "forbidden") pet were to approach the feeder, then the food would be hidden until the forbidden pet had left. The ability to keep a forbidden pet from eating another pet's food is unique to The Smart Pet Feeder since there is no product on the market at this time which even attempts to do this. Ultimately, the prototype did successfully prevent a forbidden pet from eating the food it held. Unfortunately, the timing mechanism did not work, but with more time, functionality would have been attained and the prototype would have fulfilled all of the goals laid out for it.

Table of Contents:

I. Introduction:

Pet care is a multi-billion dollar industry is the US and is the second fastest growing retail area. According to the American Pet Products Manufacturing Association (known as the APPMA), 63% of US households included a pet as of 2007 (that is over 162 million cats and dogs) [1]. Moreover, as Americans increasingly view their pets more as family members than possessions, the amount of money they are willing to spend on their care is steadily increasing. According to the APPMA, Americans spent $41 billion on their pets in the year 2007 [1]. This trend is relatively new (for example, in 1996 Americans spent only $21 billion on their pets [2]), but it shows no sign of slowing down. After consumer electronics, pet care is the fastest growing industry in the US [3] and yearly spending is expected to reach $52 billion by 2009 [3].

In spite of the plethora of pet care products on the market, there is no product that keeps one pet from eating another animal's food, even though this is a very common problem among pet owners, and therefore there is an obvious need. We have designed and built a prototype of The Smart Pet Feeder, which is suitable for use by cats and small dogs. This feeder holds enough food for six meals. In addition to the features typically found on such feeders, The Smart Pet Feeder allows the pet owner to prevent one pet from eating food that belongs to another pet.

Most pet owners cannot stay home to feed their pet several times a day, yet they want their pet to be able to eat as needed throughout the day. One of the most common ways that pet owners try to solve this problem is by so-called free feeding, where a pet has food available all day and eats at will [4]. The problem is that the pet owner has no control over how much the pet eats or which pet eats the food. Many households have

more than one pet that is fed from a bowl on the floor. Among those households, it is a common occurrence that those pets cannot eat the same food for either medical or financial reasons. These reasons include:

- One pet is on a special diet, such as for diabetes or kitten food, but the other pets eat normal food
- One pet needs to eat less than the others for weight control reason
- There is a dog and a cat, and the cat wants to eat the dog food (or vice versa), which is not healthy
- One pet has to eat a special diet and, while it is not unhealthy for the other pets to eat this food, it is more expensive than normal food and so it is cost effective to restrict the consumption of this food to only the pet which needs it

However, there is no effective way of keeping one pet from eating another's food short of physically removing the pet from the forbidden food. This creates a problem for both the pet owner and the pet. The issue for the pet owner is that they now have to supervise the pet's meals to assure that each pet eats its own food, or feed the pets at the same time in different rooms. Either way, the owner's presence at home is required during meal times. The issue for the pet is that, since the food cannot be left out to be eaten at leisure, it is forced to eat in the amount of time the pet owner allows it, regardless of its own eating preferences.

In addition, having to supervise a pet's eating leads to reduced mobility on the owner's part. As the feeding requirements become more complex it gets more expensive to hire some one to look after one's pets for long periods of time, and even day-to-day care while not traveling can become restrictive. Many pet owners are faced with

scheduled pet feedings that require them to get up at the same time every morning to give the pets breakfast and to be home at the same time every night to give them dinner. If a pet takes medication, it becomes even more important that a schedule is kept and the pet owner is even more restricted. Add to that the requirement that the different pets not eat each other's food and it can leave the pet owner with a demanding and, for some, unrealistic schedule. This type of feeding routine can also cause the pet stress since it knows that it will not be fed until the owner is home.

In short, the problems which pet owners face in feeding their pets are:

1. Making sure that each pet has access to a healthy amount of food throughout the day, regardless of the owner's schedule
2. Making sure that each pet eats only its own food

II. Objectives:

The Smart Pet Feeder gives pet owners a solution to both problems, thereby improving the lives of both pets and owners by allowing the owner to:

1. Reliably provide food to a pet at the time the owner wishes
2. Keep the pet from reaching the food stored for later feedings
3. Restrict an unauthorized pet access to the feeder

The Smart Pet Feeder looks like the model in Figure 1. It consists of a tray that holds 6 cups of food mounted to a motor. The motor and the base are inside an enclosure that will display only one bowl of food at a time. At predetermined times (which are programmable by the owner) the tray rotates and reveals a fresh cup of food.

The Smart Pet Feeder is designed to feed only one pet. To make sure that no "forbidden pet" eats the food in this feeder there is a radio-frequency identification

(RFID) reader mounted to the enclosure of the feeder in front of the revealed bowl (see Figure 1). This reader is paired with a tag on the forbidden pet's collar. When the reader receives the signal from the tag, it triggers the motor to rotate so that the spot on the tray with no bowl is exposed, thus keeping the forbidden pet from eating.

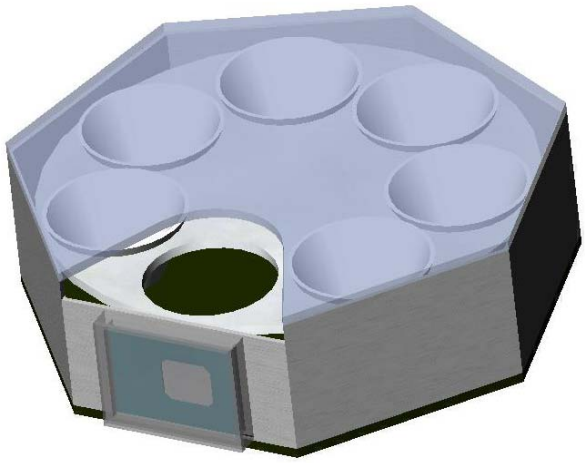

Figure 1: Model of The Smart Pet Feeder

III. Research and Design

III. A. The System and Subsystems:

The Smart Pet Feeder consists of three main systems: the Feeder Enclosure, the Motor System, and the Control System (see Figure 2). Each system has roles that it must fulfill. The Feeder Enclosure's roles are to:

1. Be heavy enough so that a pet cannot turn it over
2. To close securely enough that the pet cannot open it and access the food
3. To be opened easily so that the owner can refill the dishes
4. To protect the electronics inside of it
5. To assure that all of the parts of the feeder that touch food are washable

The Motor System's roles are:

1. To receive commands from the microcontroller
2. To be able to rotate the fully loaded tray an exact distance
3. To not allow the full weight of the tray to sit on the shaft of the motor

The Control System's roles are:

1. To rotate the tray to a new dish at a specified time
2. To rotate the tray to the blank spot if the forbidden pet approaches the feeder
3. To keep and display an accurate real-time clock
4. To allow the owner to easily set both the current time and the time the feeder will rotate to reveal fresh food

A block diagram showing all of the systems and how they interact with one another can be found in Figure 2.

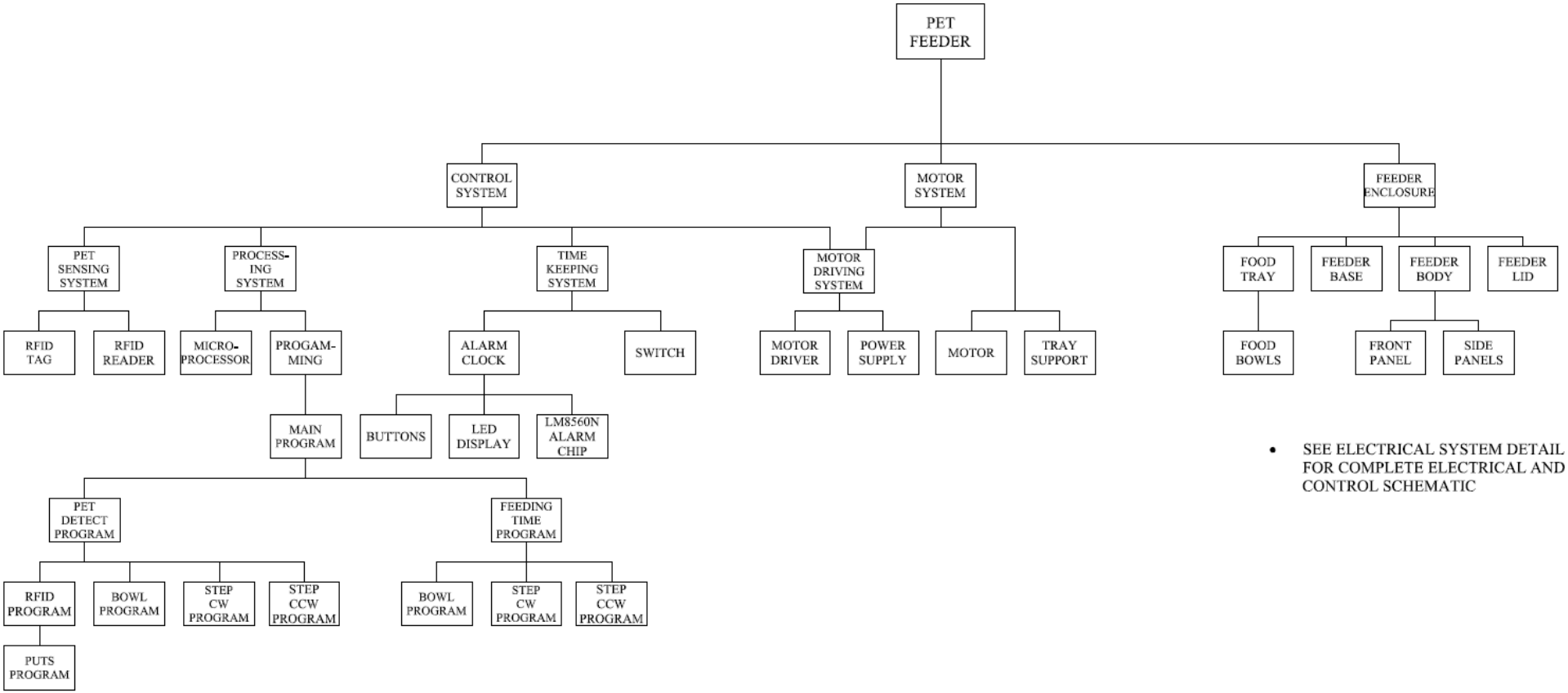

Figure 2: System Block Diagram

III.A.i. The Feeder Enclosure:

The main function of the feeder enclosure is to provide protection for the electronics inside the feeder and to prevent the pet from accessing the food stored for later feedings. In order to achieve these goals it has to:

1. Be strong enough to withstand the weight of the pet, should the pet stand on it
2. Be capable of preventing the pet from accessing food stored for later meals
3. Provide access to the food at the same location every time
4. Be heavy enough to prevent the pet from turning it over
5. Have a removable cover so the user can easily access the bowls
6. Have easily removable dish-washer safe bowls

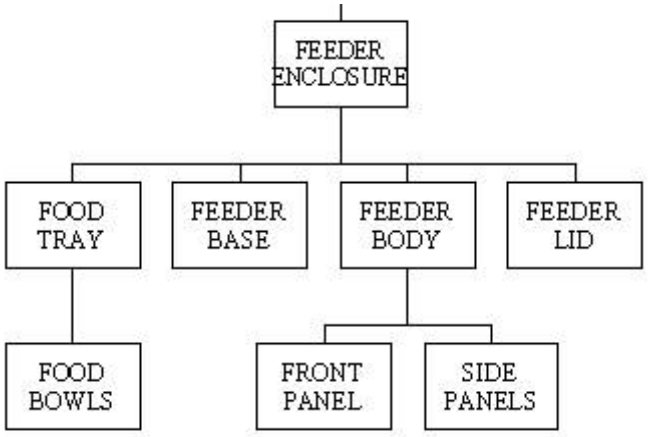

Figure 3: Block Diagram of the Feeder Enclosure Subsystem

As Figure 3 and Figure 5 show, the Feeder Enclosure consists of several parts: the base, the body, and the lid. Inside the enclosure, there is the food tray with the bowls and the motor system. The basic shape of the feeder was inspired the ERGO 8 day feeder (Figure 4). The advantage of this type of feeder over the gravity-type feeders is that there is no chute to be clogged with food, and the owner does not need to rely on the feeder

itself to measure how much food will be served, since the owner places the exact amount to be fed in each compartment. Another advantage of this type of feeder is its ability to administer medication on a schedule, since the medicine can be mixed with the food and released at a specified time. Finally, there are less moving parts and therefore fewer things to break.

The most common user complaints about this type of feeder were flimsy construction which allow the pet tear the feeder apart and to access all of the food, the use of floor space, frequent battery replacement, and the fact that, in most models, the lid rotates so that in order for the pet to eat from the back compartments it must stand on the feeder.

Figure 4: The ERGO 8 day feeder [5]

Therefore, we decided to address these issues by using stronger materials, have it powered from a wall outlet and to have the tray with the bowls rotate inside the feeder that would allow for the access to the food to be at a fixed location. The base is made of PVC, which is a material with a relatively high mass, in order to keep the feeder's center of gravity low to prevent the pet from turning it over and eating the food stored in it. Both the dish tray and the sides of the feeder are made of aluminum alloy 6061T6

because it is a strong, lightweight material that is easy to work with. The lid is made of clear polycarbonate so that the user can see how much food is left in the feeder and plan to refill it accordingly. At the same time, the lid is strong enough to prevent the pet from breaking in the feeder. It can also easily support the pet's weight if it decided to sit on the top of the feeder. The lid is secured to the rest of the enclosure with a thumb screw that make it both easy to remove and sturdy enough so that the pet will not be able to get to the food inside.

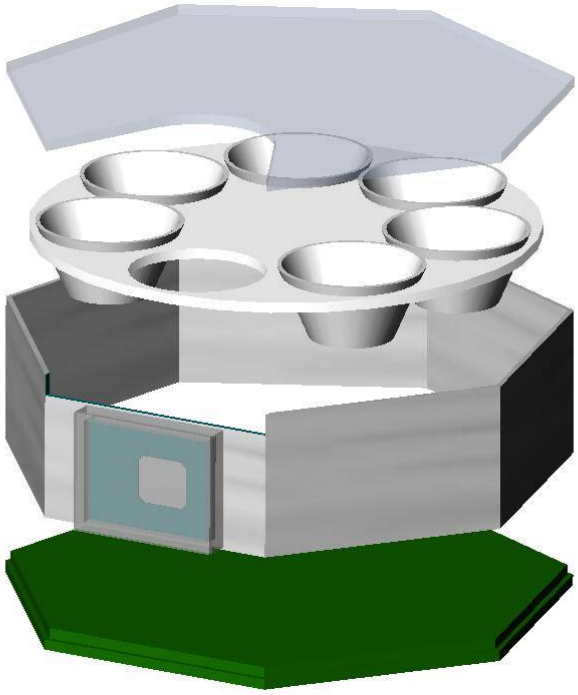

Figure 5: Exploded View of the Feeder Body

Figure 5 shows a three-dimensional model of the Smart Pet Feeder that was created using SolidWorks. This software was used not only to design the feeder but also to help to generate the file for the CNC milling machine that was used to machine most of the feeder's components. Figure 6 shows the base of the feeder after it was machined from gray PVC. Figure 7 shows the dish tray after it was machined from aluminum alloy

6061T6. Figure 8 shows the polycarbonate lid after it was machined. Figure 9 shows the base of the feeder with the sides mounted to it. While most of the feeder's components were machined, the sides were made by hand by bending a sheet of aluminum. Figure 9 shows the base with the sides mounted to it and Figure 10 shows the enclosure fully completed with the transparent lid on top.

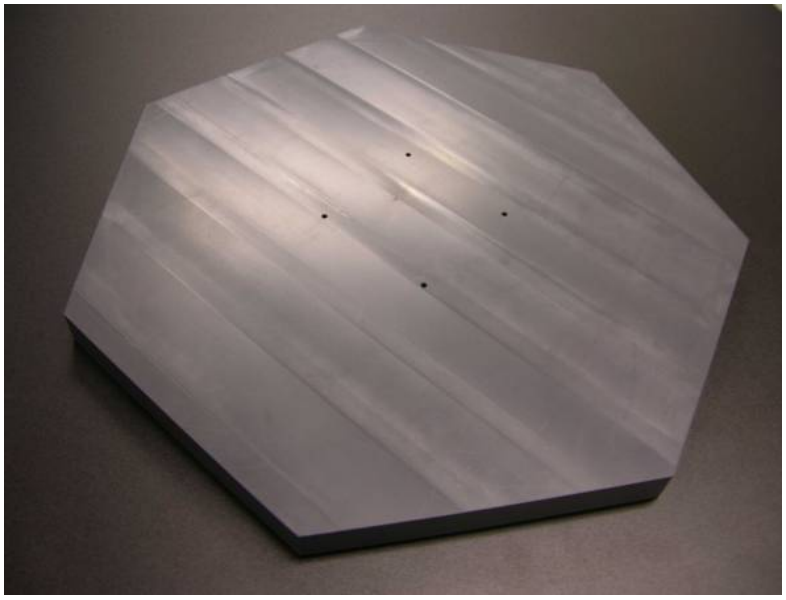

Figure 6: Feeder Base machined from gray PVC

Figure 7: Machining the Dish Tray

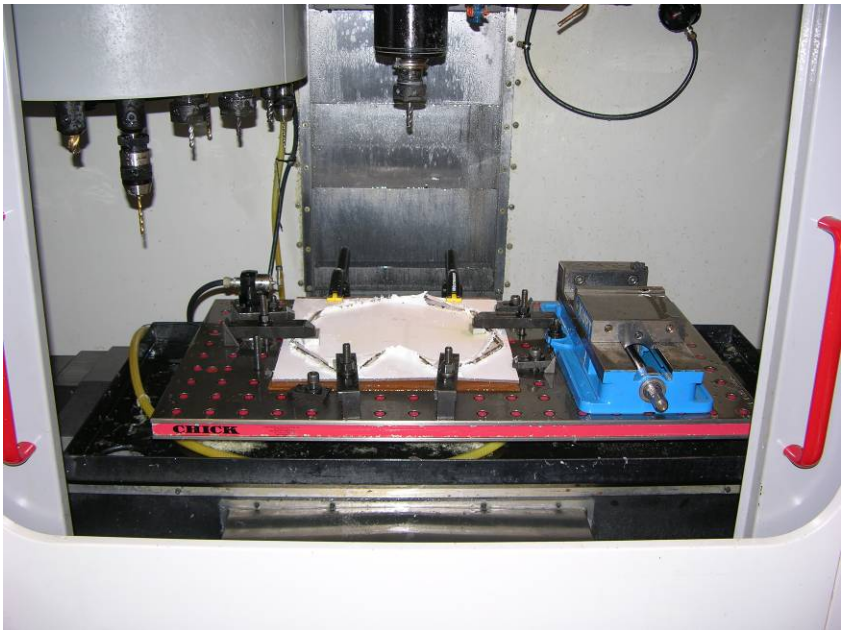

Figure 8: Machining the Lid

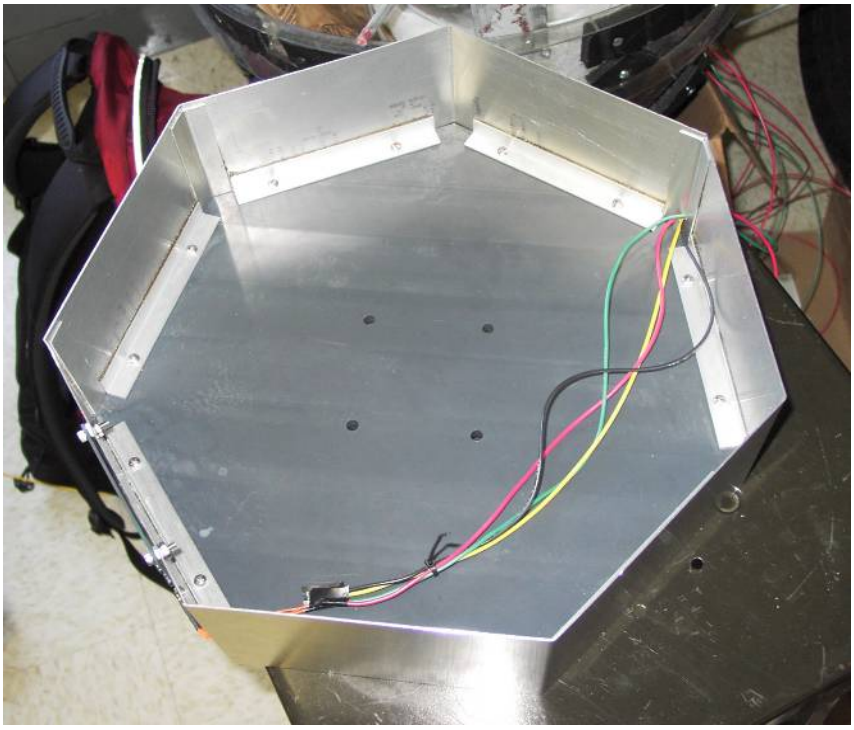

Figure 9: Base with sides mounted to it

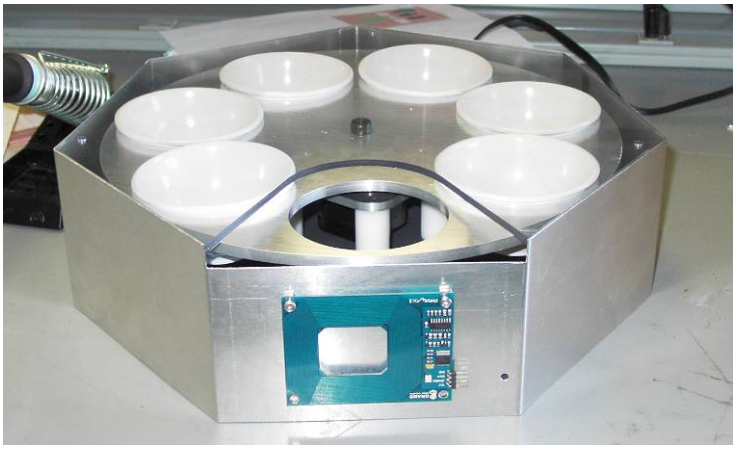

Figure 10: Assembled Enclosure

The feeder enclosure prevents the pet from accessing the food stored inside the feeder for later meals by either turning the feeder over or by pulling the lid off. This is achieved by the sturdy construction of the feeder as well as using stronger materials than our competition. At the same time, it is very easy for the pet owner to remove the lid and to access the food bowls to either refill them or clean them. The bowls are easily removable and dishwasher safe so cleaning them is easy. Additionally, the enclosure provides protection to the electronic components inside from both pets and possible falling household objects.

III.A.ii. The Motor System:

As Figure 11 shows, the motor system consists of the following components: the stepping motor, the motor driver chip, the power supply, and the tray support.

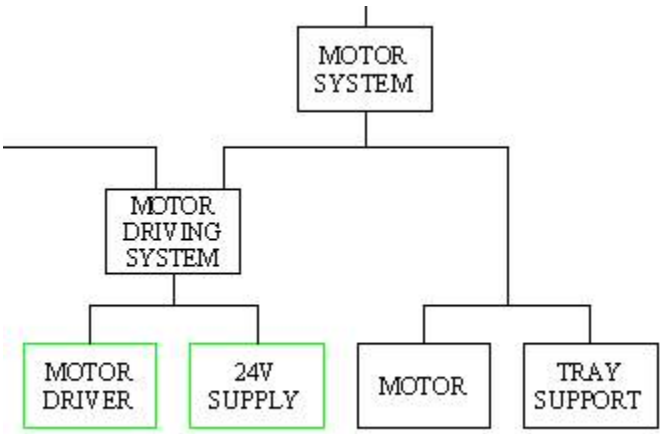

Figure 11: Block Diagram of the Motor System

The stepping motor provides rotational motion for the tray with the bowls whenever it receives a command to do so from the microcontroller. There are two scenarios when this happens. The first one is at the user programmed feeding time and the second one is the proximity of the forbidden pet.

The reason why we selected a stepping motor is its ability to rotate in precise steps as opposed to spinning continuously, like a DC motor. In addition, it does not require position feedback like a servo motor.

The motor had to meet the following criteria:

1. To be able to be controlled by the CML12S
2. To be able to rotate the fully loaded food tray (including pet food) a precise distance both clockwise and counterclockwise
3. To cost less than $50.00

After choosing to use a stepping motor, the following questions need to be answered: Should the motor be unipolar or bipolar? What does the output torque need to be so the motor can operate at the desired speed and with the right acceleration? How fine should the step size be?

The difference between a unipolar and a bipolar motor is the complexity of their internal coils winding. The bipolar motor is much simpler in terms of its internal construction, and has a higher torque-to-size ratio than a unipolar motor, but requires much more complex external circuitry to control it. A unipolar motor, on the other hand, is more complex in terms of its internal arrangements, has less torque than a bipolar motor of the same size, is more expensive, but is much easier to control. Because some members of our design team worked with unipolar stepper motors in the past, it was our first choice for the automated pet feeder.

Traditionally, a number of mathematical equations would be used to calculate the needed output torque and the motor's power consumption. However, there is an easier way. Lin Engineering, a California-based company that specializes in motor design and manufacture, offers an easy-to-use tool for a stepping motor selection on their website. Figure 12 and Figure 13 are screenshots showing the use of this tool. The shape and size of the load are entered in the appropriate fields as well as the maximum desired speed and acceleration in addition to the available power specifications. For this project, the weight of the load was determined using SolidWorks. The necessary maximum speed of the motor and the time to reach this speed were estimated at one Revolution per Second (RPS) and 0.5 second, respectively. These values resulted mainly from customer complaints about similar products that are currently on the market. These state that the speed at which the cover rotates is too slow, which allows the pet to eat while the feeder is in motion.

The next choice to be made was the size of the step. A stepping motor is designed to revolve in precise increments, or steps, in addition to continuous rotation. One step is

typically the smallest distance the motor can turn. The step size depends on the motor, but 1.8° step and 0.9° step are the most common. Generally, the smaller the step size the more precise the motor's movement.

With the help of the Lin Engineering's online motor selection tool we chose to use the 4118M-06 unipolar stepping motor. It has more than enough torque to turn the tray full of pet food at the maximum speed of 1 RPS. Its 1.8° step size guarantees good accuracy when revolving the tray.

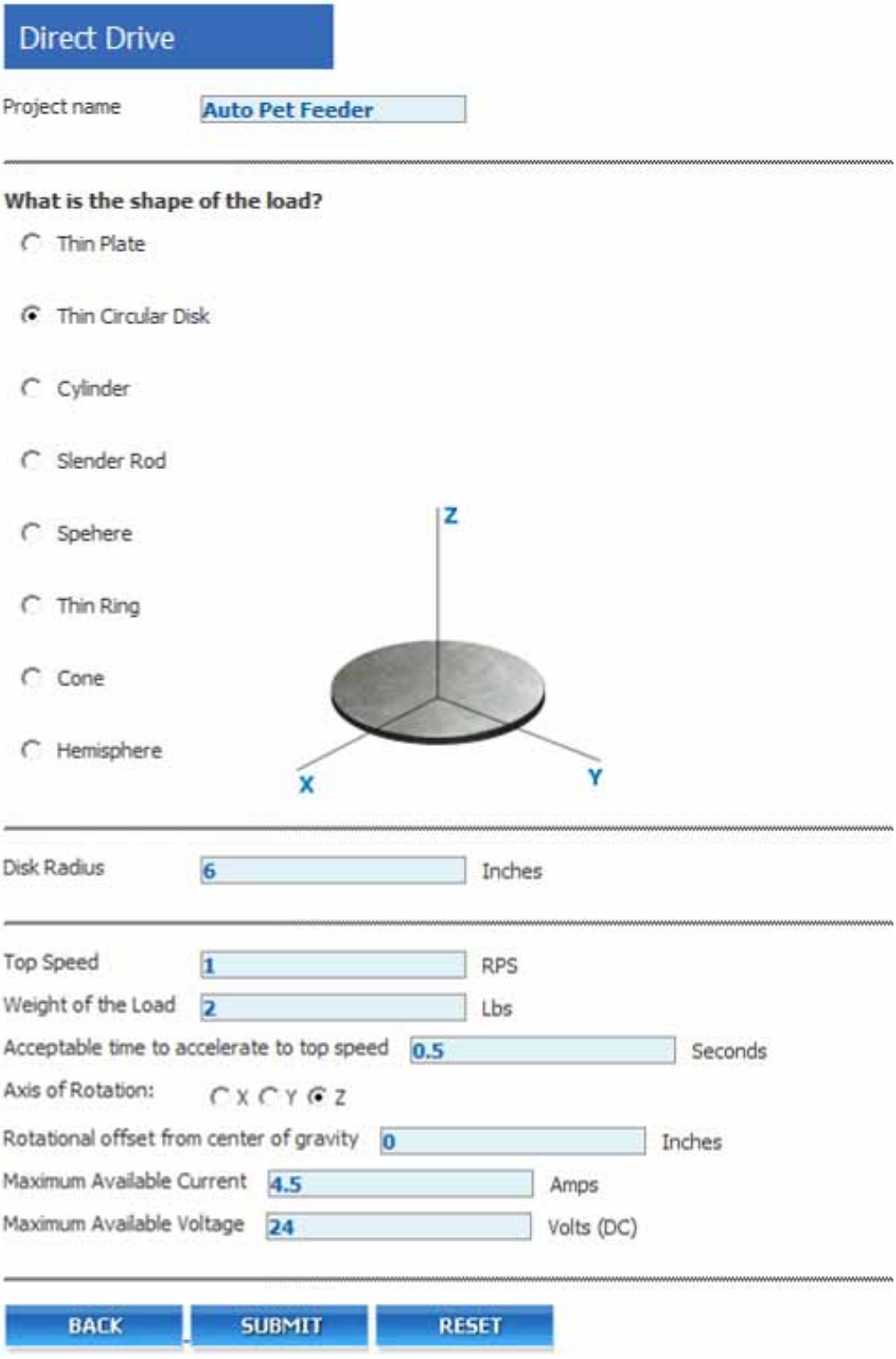

Figure 12: First Step in Motor Selection

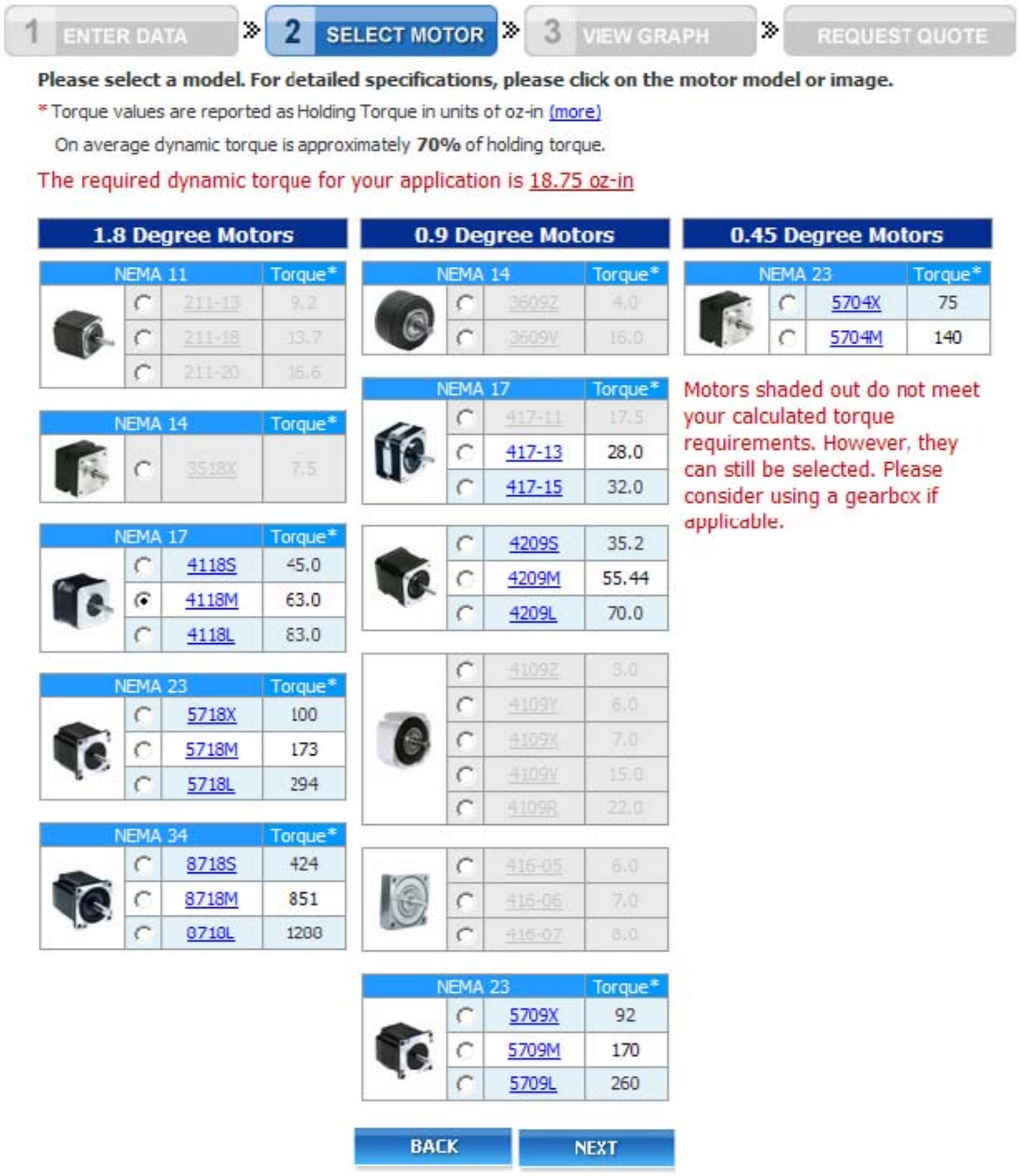

Figure 13: Second Step in Motor Selection

Frame Size 17
STEP SIZE 1.8°

Super Torque Motor - 4118

- NEMA Size 17 Mounting
- Cost Effective
- Custom Windings Available (No addtional cost)
- Inquire about RoHS versions

| BIPOLAR |

Dimension "A"	Model Number	Amp/ Phase	Holding Torque oz-in	Holding Torque N-m	Resistance Ohm/ Phase	Inductance mH/ Phase	Inertia oz-in²	Weight Lbs.	Number of Leads
1.34" 34.0 mm	4118S-02	1.30	45.0	0.32	2.8	3.6	0.18	0.40	4
	4118S-04S	0.67	45.0	0.32	9.9	12.5	0.18	0.40	4
	4118S-04P	1.34	45.0	0.32	2.5	3.1	0.18	0.40	4
	4118S-09	0.90	45.0	0.32	5.3	6.7	0.18	0.40	4
1.58" 40.1 mm	4118M-01	1.70	63.0	0.44	1.5	3.0	0.28	0.60	4
	4118M-06S	0.70	63.0	0.44	10.8	21.8	0.28	0.60	4
	4118M-06P	1.40	63.0	0.44	2.7	5.5	0.28	0.60	4
1.89" 48.0 mm	4118L-01	2.00	83.0	0.59	1.4	2.7	0.37	0.70	4
	4118L-07S	1.05	83.0	0.59	5.2	9.4	0.37	0.70	4
	4118L-07P	2.10	83.0	0.59	1.3	2.3	0.37	0.70	4
2.34" 59.9 mm	4118C-01	2.0	125	0.89	2.0	3.3	0.56	0.90	4

| UNIPOLAR |

Dimension "A"	Model Number	Amp/ Phase	Holding Torque oz-in	Holding Torque N-m	Resistance Ohm/ Phase	Inductance mH/ Phase	Inertia oz-in²	Weight Lbs.	Number of Leads
1.34" 34.0 mm	4118S-04	0.95	30.0	0.21	5.0	3.1	0.18	0.40	6
1.58" 40.1 mm	4118M-06	1.00	45.0	0.32	5.4	5.5	0.28	0.60	6
1.89" 48.0 mm	4118L-07	1.50	65.0	0.46	2.6	2.3	0.37	0.70	6
	4118L-25	0.45	65.0	0.46	25.0	17.4	0.37	0.70	6

Figure 14: Third Step in Motor Selection

The motor required more than the 5V that the microcontroller was able to supply, so an additional power source had to be purchased. Lin Engineering recommends the PS1-100-24 (Figure 15), a source with 120VAC input and 24V DC output capable of delivering up to 4.5A of current. Since the motor requires only 1.5A at 24V DC this power source is more then adequate.

Figure 15: PS1-100W-24 Power Supply

Because the HC12 can neither deliver nor receive more than 25mA, it had to be isolated from the motor by a driver chip. A driver chip is an integrated circuit that serves two purposes: 1) it controls the flow of the current through the motor and 2) it protects the microcontroller from the motor's high current. This is one of the two functions of the driver circuit, the other being energizing and de-energizing the coils in the motor in a sequence dictated by the microcontroller. The driver may be thought of as a hub to which the motor, the power supply, and the microcontroller are connected. It determines what signals may pass and where they go. Different types of drivers exist and the appropriate chip was selected for the motor. .The driver chip we chose to use had to meet the following criteria:

1. It had to be capable of handling the voltage (24V DC) and the current (1.5A) necessary for the motor's operation.
2. It had to be easily interfaced with the microcontroller
3. It should cost less then $10.00

The SanKen manufactured SLA7026M (Figure 16) driver chip is a good choice for the 4118M-06 because it is capable of handling up to 5.0A of current and up to 46VDC, which is more than enough considering that the motor draws only 1.5A at 24VDC.

Figure 16: SLA7026M Driver Chip

The main obstacle we have encountered with the driver chip was to determine the values of the resistors and the capacitors that connect the SLA7026M to the ground on one side and to the microcontroller on the other side (Figure 17 and Figure **18**). SanKen, the chip manufacturer, provides a list of recommended values in the datasheet (Figure 17) but we were not sure whether these needed to be recalculated to match our specific power requirements. Finally, with the help of Joseph Diecidue and Professor Badjou, we determined that the recommended resistors and capacitors were accurate as long as the current was less then 3.0A.

Another problem was that the pins of the SLA7026 are not compatible with the breadboard. They are not only wider than the holes in the breadboard but also spaced out

in way that does not align with the grid of the breadboard holes. We solved this problem by soldering wires to all the pins, which allowed us to connect the chip to a breadboard.

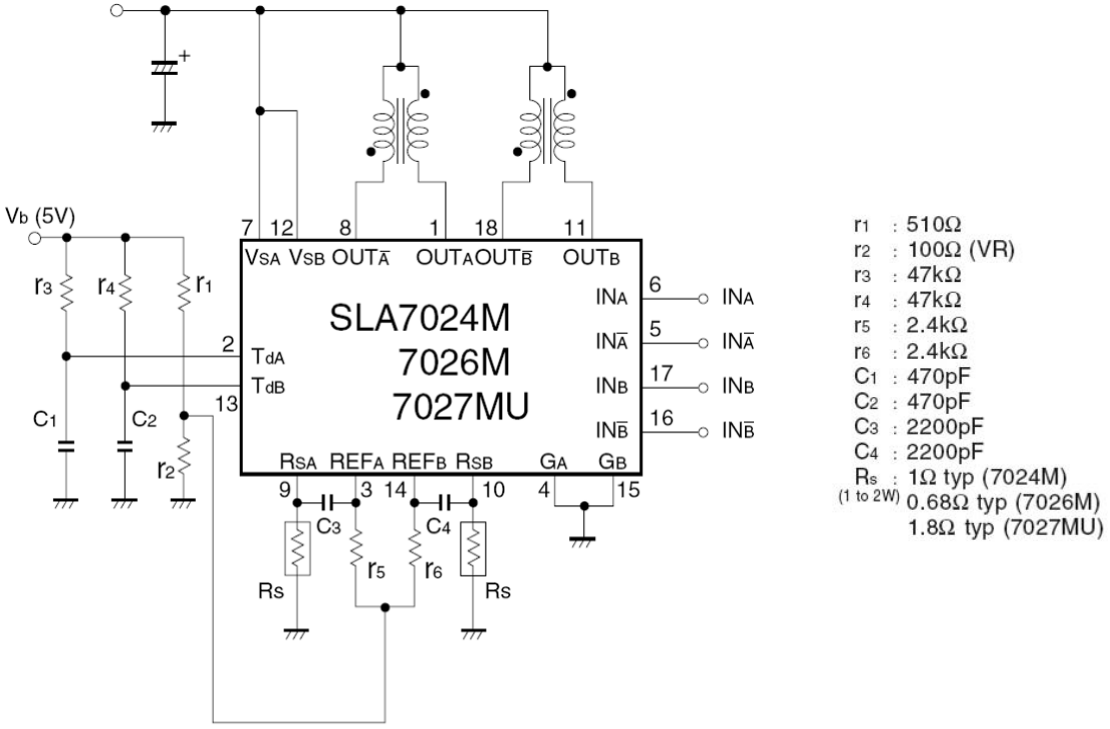

Figure 17: Motor Driver Circuit [6]

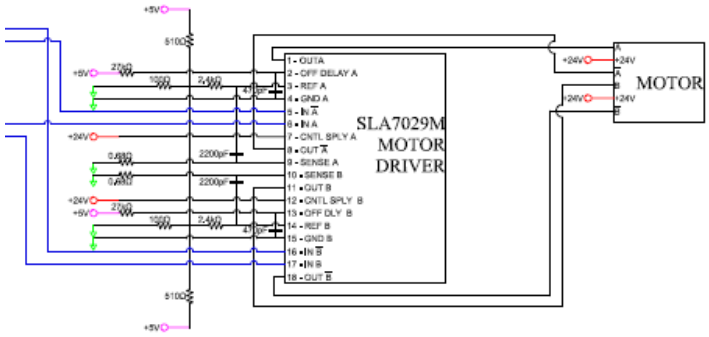

Figure 18: Motor Driver Circuit

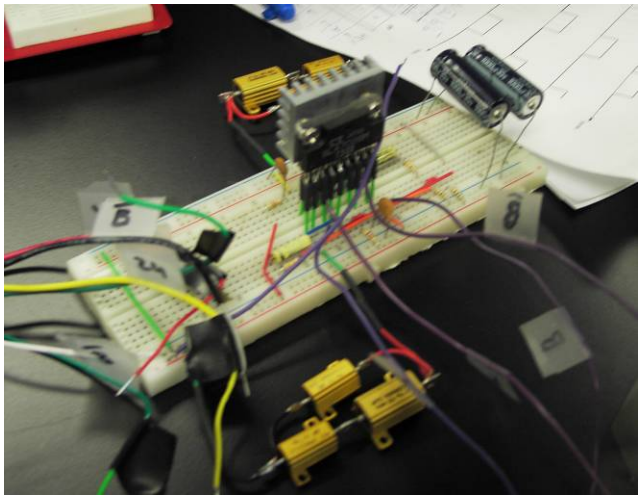

Figure 19: Motor Driving Circuit, View 1

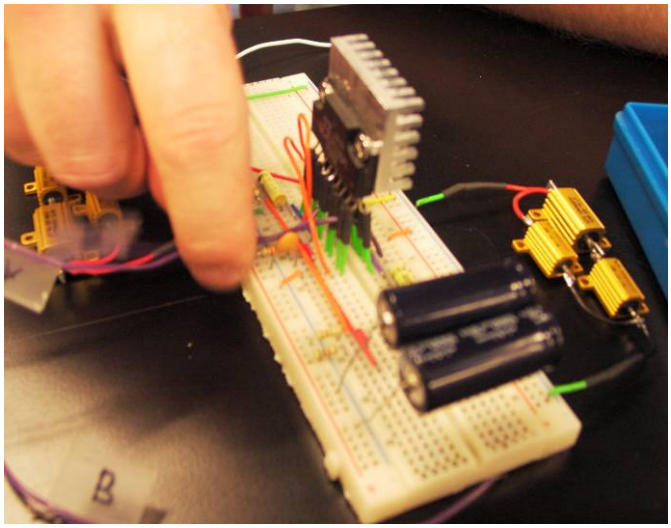

Figure 20: Motor Driving Circuit, View 2

The Tray Support System:

The function of the dish tray support system is to isolate the weight of the tray with the dishes and pet food, a maximum of two pounds, from the motor's shaft. Stepping motors are designed to carry torsional loads but not axial loads. In other words, they are not equipped to withstand loads that either pull or push on the shaft. A

SolidWorks model of the Tray Support System is shown in Figure 21. Again, a code for a CNC machine was generated using this model.

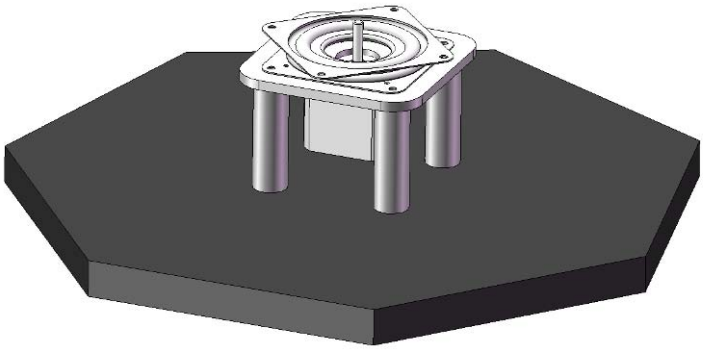

Figure 21: Model of the Tray Support System mounted to the Feeder's Base

The central piece of the load bearing system is a 3.8"x 3.8"x 0.2" plate machined from 6061 aluminum alloy (Figure 22).

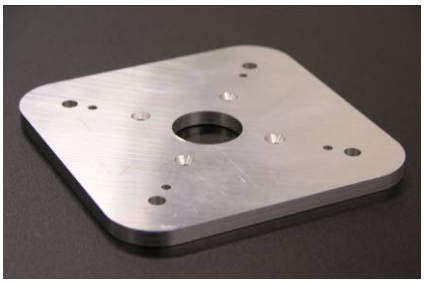

Figure 22: Transition Plate

A turntable that interfaces between the dish tray and the tray support system is mounted to top of this plate (Figure 21). As can be seen from Figure 23, the motor is attached to the bottom of the plate so that its shaft protrudes through the center of the plate and the center of the rotary table.

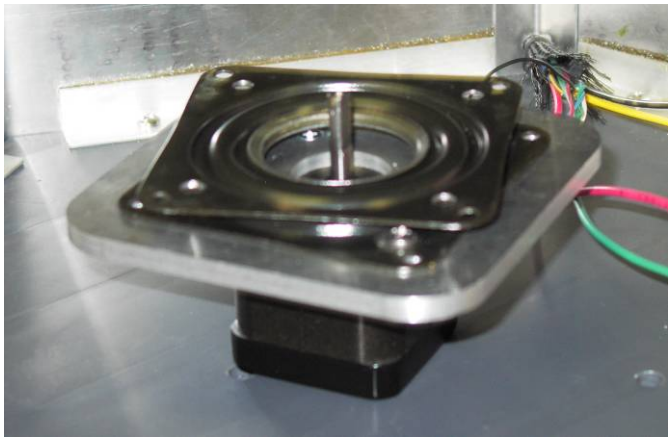

Figure 23: Tray Support System

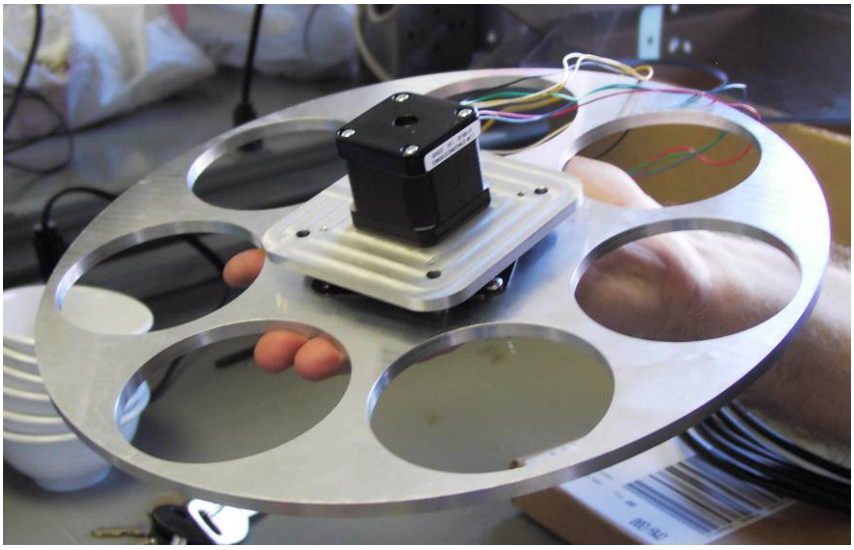

Figure 24: Tray Support System mounted to the Dish Tray

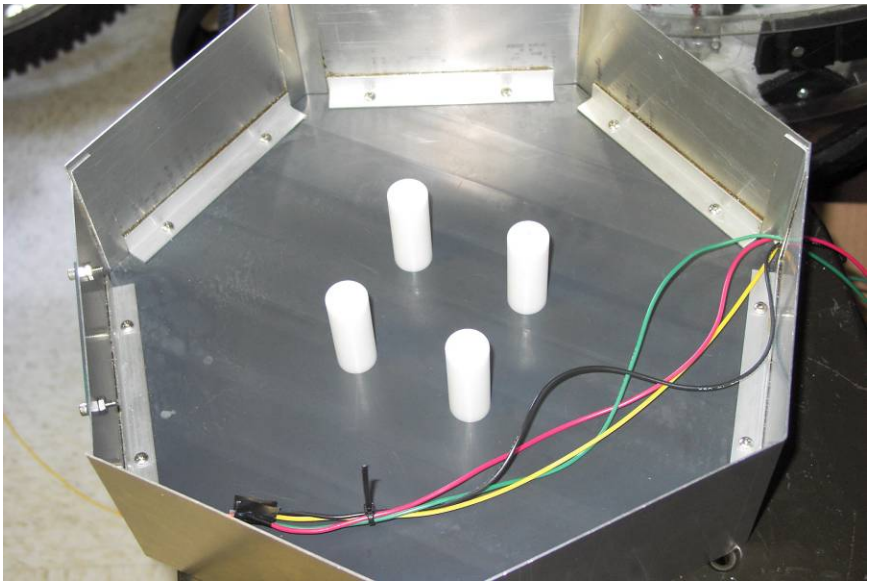

Figure 25: Tray Support System Legs

Both the shaft of the motor and the hole in the center of the dish tray are keyed to ensure a secure fit without slipping. The plate is attached to the base of the feeder with four bolts. In order to make sure that the bearing plate is parallel to the base, four glass-filled Delrin tubes of uniform length fit over the bolts to support the plate in each corner.

Two motor driving programs controlled the motor. These programs had to turn the motor clockwise and counter-clockwise by a distance that is equal to the distance between two bowls. While searching for a suitable stepper motor driving tutorial we found the *Quick Start for Beginners to Drive a Stepper Motor* [7] on the Freescale Semiconductor website. This document not only explains the basics of stepper motor operation very well but also provides a sample program in C to drive a stepper motor. The program that we have used to control our motor is a slightly modified version of this template.

There are two versions of the program. One of them, called StepCW, turns the motor clockwise. The program called StepCCW turns the motor counterclockwise. The

only difference between the two programs is the sequence in which the array states are sent to Port K. StepCW goes through the array from left to right and StepCCW goes through it the other way. Figure 26 shows the flow chart diagram for the StepCW program. If it were the StepCCW the line

```
char state_array[NUM_OF_STATES] = {0x06, 0x04, 0x05, 0x01, 0x09, 0x08, 0x0A, 0x02}
```

would be

```
char state_array[NUM_OF_STATES] = {0x02, 0x0A, 0x08, 0x09, 0x01, 0x05, 0x04, 0x06}
```

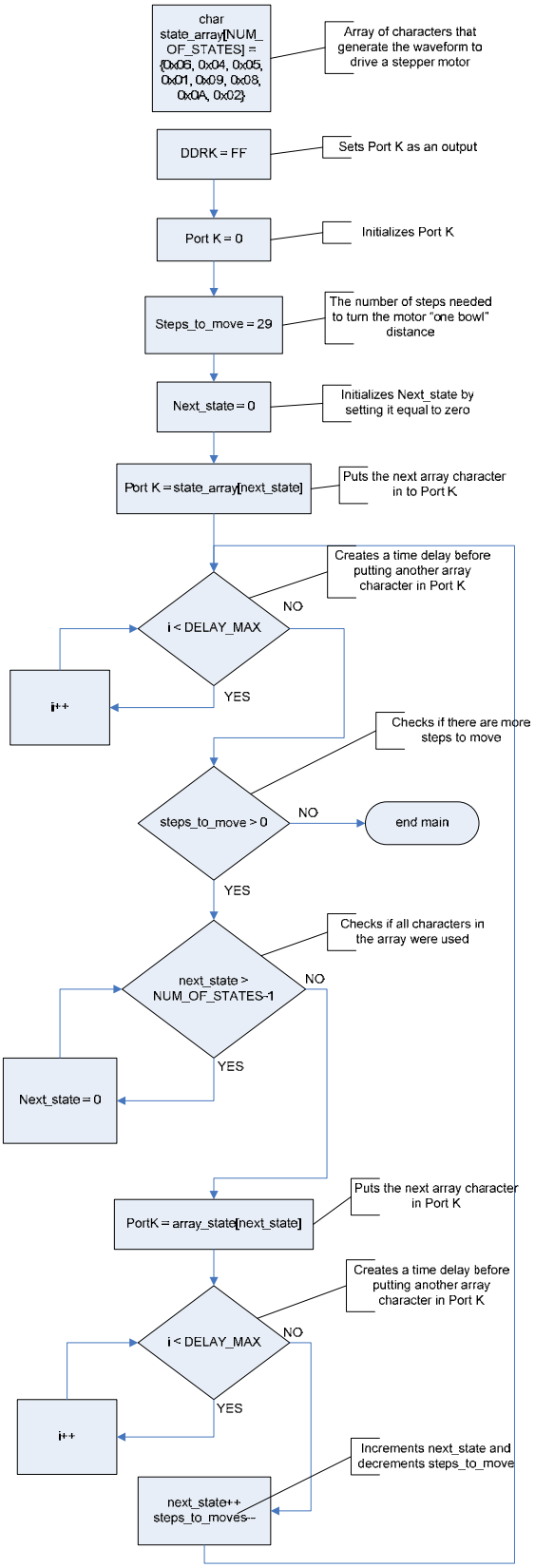

Figure 26: Motor Program Flow Chart

In summary, the 4118M-06 stepping motor will turn the tray with pet food to reveal a fresh serving at user-preset times. It will also turn the tray to the empty position (Figure 5) every time the RFID reader registers the proximity of the forbidden pet. The motor will be connected to the microcontroller as well as to the PS1-100-24 power supply through the SLA7026M driver chip. The feeder enclosure will prevent the pets from accessing the food stored inside of it either by turning the feeder over or by pulling the lid off. At the same time, it will be easy for the user to remove the lid to clean or refill the food bowls. Additionally, the enclosure will provide protection to the electronic components inside of it. The weight of the tray will be isolated from the motor's shaft by the tray support system.

III.A.iii. The Control System:

The Control System consists of several subsystems: the Pet Sensing System, the Processing System, the Time Keeping System, and the Motor Driving System (which was discussed above). This section will detail the requirements for each subsystem in Figure 27, the criteria used to select components, and discuss to what extent those components fulfill the system's requirements.

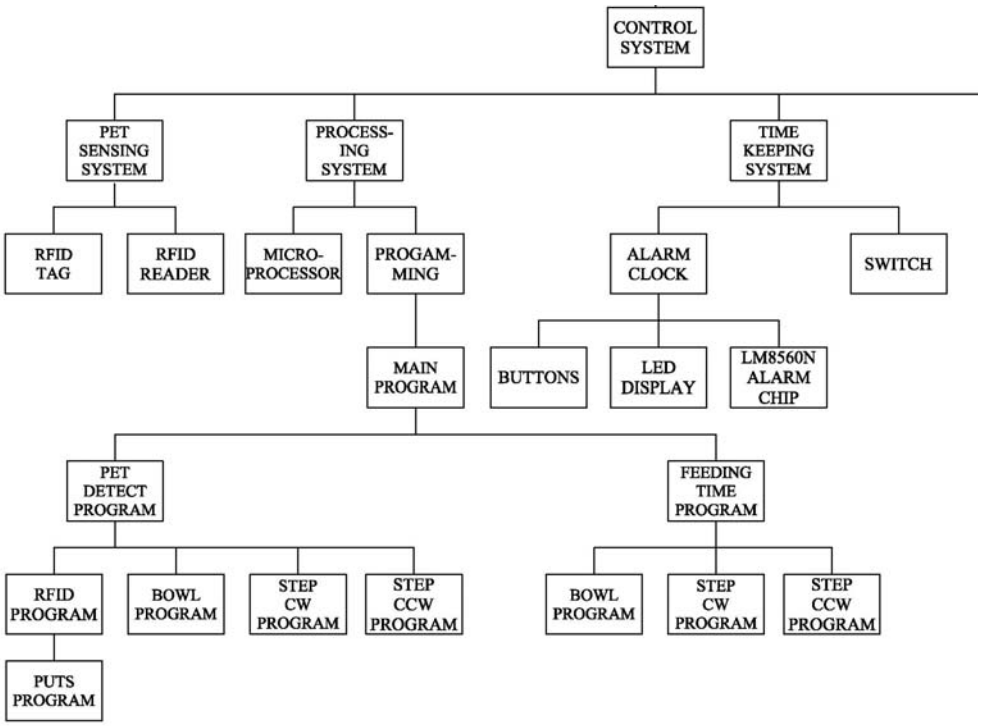

Figure 27: Control System Block Diagram

III.A.iii.a. The Pet Sensing System:

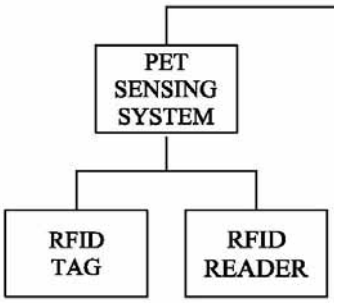

Figure 28: Pet Sensing System Block Diagram

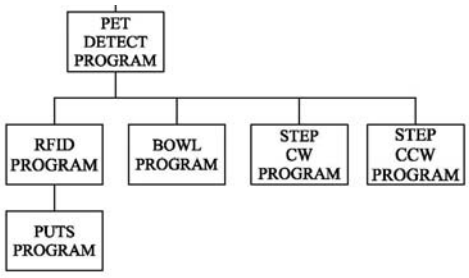

Figure 29: Pet Detect Program Block Diagram

The Pet Sensing System fulfills the design objective to create a product that can distinguish between different animals in order not to allow the forbidden pet to eat from the feeder. In order to do this it is necessary for the forbidden pet to wear an emitter on its collar that a sensor on the feeder can detect and react to.

Our requirements for the emitter/sensor pair are:

1. That the emitter be small enough to be worn comfortably on the pet's collar
2. That the emitter does not pose any health risks to the pet
3. That the sensor fit on the feeder
4. That the sensor be able to interface with the microcontroller
5. That the sensor be able to react to the emitter while the pet is several inches away from the feeder

We have chosen to use a Parallax RFID tag/reader combination in order to fulfill the main design objective of the Pet Sensing System. The transponder tags come in very small sizes so a tag can easily be placed on a pet's collar, the sensor is small enough to be mounted to the feeder (see Figure 30), can be easily interfaced with the microcontroller, and has a read range of at least 2 to 4 inches [8].

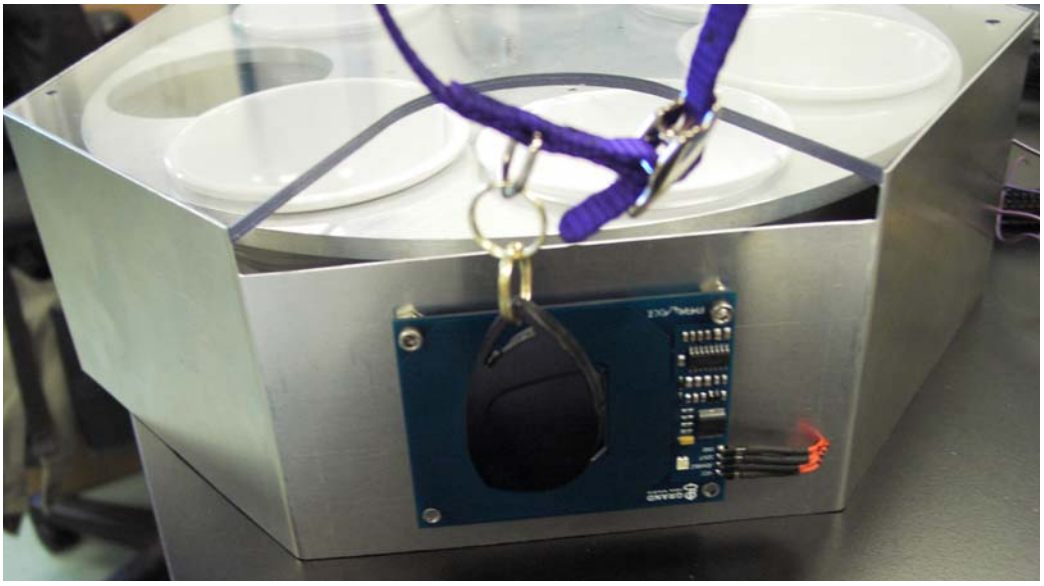

Figure 30: RFID tag on collar in front of reader, which is mounted on the side of the feeder

There are two types of RFID tags: passive and active. A passive tag is one that does not have an internal power source and is only operational when a reader is near by and trying to access it. The signal the reader sends powers the tag long enough to send a signal. This allows them to be used in situations where it is not practical to have a power source or where it is undesirable to have constant radio transmissions. These tags are only useful in applications where short reading distances will be used since they only have a read distance of about 2 to 4 inches [8][9].

Active tags have an internal battery and are constantly sending its own signal to be picked up by any reader in range. These tags are generally more reliable than passive tags, because they are able to initialize the session with the reader, generate stronger signals, and have longer read distances, some of which some are up to 1500 feet [9]. They also tend to be larger in size since they have the onboard power source [9].

We have chosen to use an active tag for our application for two reasons. The first is that the read range is considerably larger with an active tag than with a passive tag, and the second is that the response time is much quicker. The tag we are using can be seen in Figure 30 and Figure 31.

Figure 31: Active RFID Fob [8]

One aspect that had to be researched carefully before considering an active tag for The Smart Pet Feeder was the potential for health risks in the pet wearing the tag. Some studies have shown that RFID chips embedded in lab rats and mice may have caused tumors to form near the site of the chip [10]. However, after doing research on the subject, we found several factors that make us comfortable placing an active tag on the collar of a pet. For example, thousands of tags have been implanted in humans and thus far, no cases have been reported where a tumor has formed [11]. Additionally, Dr. George Demetri, director of the Center for Sarcoma and Bone Oncology at the Dana-Farber Cancer Institute in Boston, said that the incidences of tumors in the rats were reasonably small [10]. This view is further supported by Dr. Cheryl London, who is a veterinary oncologist at Ohio State University, who noted, "It's much easier to cause cancer in mice than it is in people. So it may be that what you're seeing in mice represents an exaggerated phenomenon of what may occur in people [10]." It is also

important to note that all the incidents where cancer was said to be caused by RFID tags have occurred when the tag was implanted in the animal.

Also, this technology has been approved by the FDA for implantation in humans. There are proposed plans of placing RFID chips under the skin of humans in order to store medical information. These chips would act like medical alert bracelets worn today [11][12]. There is one company, Applied Digital Solutions, which has already received the FDA approval for this procedure [12].

As we are not planning to implant the tag in the animal, and since there are already products which use RFID technology (such as the PetSafe Electronic SmartDoor Pet Door [13]) and we have found no sources which link these products to any health risks for the pet, we feel at this time that it will not pose a risk to the pet's health to use an active tag, but that we will continue to follow the research for new developments. Also, we have designed a shield to reflect the radio waves away from the pet. The shield for the active RFID tag had the following requirements:

1. The radio waves must be blocked through the shielded side of the tag
2. The shield must be affordable
3. It must be attachable to the tag
4. The shield could not affect the range on the unshielded side by more than 50% of its original range without the shield

When researching how the radio waves could be shielded we found that one of the best ways to do so was with a Faraday Cage [14]. A Faraday Cage is an enclosure formed by a conducting material or mesh which blocks out external static electrical fields, such as radio waves [15].

The shielding method we chose to use was a part of a drain strainer. The drain strainer is made by Master*Plumber* and is made of chrome (Figure 32). The strainer was cut down to the size and shape of the tag, along with a layer of aluminum foil. This acted as a Faraday Cage.

Figure 32: Master*Plumber* Drain Strainer

The layer of aluminum foil was cut and shaped to the size of one side of the tag as well as the side "walls" of the tag (Figure 33). The foil is shaped so that the shiny side of the aluminum foil is facing in towards the tag, leaving the dull side facing out. After some testing, we found this was the most effective method of using the aluminum foil. Also, we found that the shielding does not work well if the sides are not shielded. This may be due to radio waves being emitted through the sides of the tag and wrapping back around the shielding of the tag.

Figure 33: Shielded edges of the RFID tag

The piece of the drain strainer has a bar down the center that, from our testing, we found plays a large part in the shielding of the radio waves. The piece of the drain strainer is attached to the side of the tag over the aluminum foil with scotch tape (Figure 34).

Figure 34: The shielded side of the RFID tag

The combination of the aluminum foil and the drain strainer worked the best as a shield out of anything we tested. No RF signal was detected through the shield and the shield did not significantly decrease the range on unshielded side of the tag. Shields that were tested and not used were made using only aluminum foil, varying the layers of foil used. In addition, we tested the effectiveness of using only the bar

from the drain strainer. Other tested shields that failed immediately consisted of another type of drain strainer as well as duct tape, after a quick test that showed these failed, no more testing was done using them. The data from our tests is in Table 1.

	Condition	Range of shielded side			Range of non-shielded side			Notes
	no shielding/ plain tag	XXXXX			2.75"			
Aluminum Foil (only)	"shiny side" out							
	wrapped to cover edges	1 layer .5"	2 layers .25"	3 layers .25"	1 layer 2.25"	2 layers 2.25"	3 layers 2.00"	2 layers worked best in this method, but not the best results in the end
	"dull side" out							
	cut to fit to bottom of tag	2.25"			2.00"			Doesn't work correctly
	wrapped to cover edges	0" (not detected at all)			2.25"			unable to duplicate result
Drain Strainer	full size strainer (before cutting to size of tag, strainer only)	0"			2"			works, but is not cut to a practical size
	strainer cut to fit to bottom of tag (strainer only)	1"			1.75"			doesn't work ideally
	strainer cut to size and lined with foil on the bottom only	1"			1.75"			doesn't work ideally
	strainer cut to size and lined with foil on the bottom and sides	0"			2.25"			** most ideal shielding method**

Table 1: Data from active RFID tag shielding

During testing, it was found that the bar that went down the center of the shield had to be a certain direction or the shielding would not work. This bar had to be vertical, going the full length of the shield. When tested without the bar at all the shield did not shield the radio waves at all, which is how we determined that the bar has a large impact on the shielding effect. After finding this, we tested the shielding with just the bar and not the rest of the shield and that did not shield. Thus, we determined that the bar and shield together worked the best.

The shielding, however, was not tested in conjunction with the aluminum sides of the feeder until after the feeder was built. The thought that this may affect our range slipped our minds and when we went to test the RFID shielding with the reader attached to the feeder we found that our range was severely decreased with the shielding to an almost useless range. For this reason in the final prototype we were unable to continue using the shielding. Had the sides been made of a different material the shielding would have most likely been used.

Another reason we chose to use the RFID reader/tag combination is that it is very easy to interface with the microcontroller. The RFID reader has four pins: SOUT, /ENABLE, GND, and VCC. The SOUT pin sends a series of numbers to the microcontroller if there is a tag within range, or sends a steady logic HIGH if there is no tag present. As seen in Figure 35, we chose Port P2 as the input to the microcontroller. The /ENABLE pin needs to be at a logic LOW in order for the reader to be active, so we chose to ground it so that it would always be active. The VCC and GND pins went to VCC and GND, respectively. For details, see Figure 35 below.

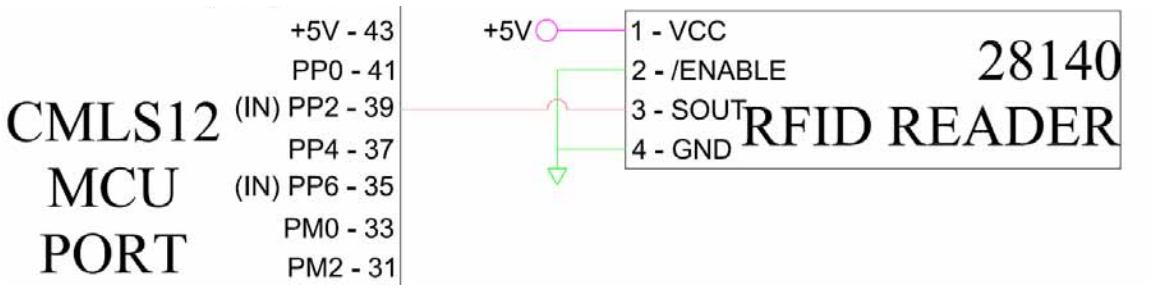

Figure 35: Control Schematic detail showing how the RFID reader interfaces with the microcontroller

In order for the microcontroller to react to the presence of the RFID tag, we had to write a program to identify when a tag was present. This program, entitled "RFID," simply determines whether a tag is present and then sends a value back to the calling program accordingly. The flowchart, seen in Figure 36, gives the exact details on how this program works. The C-language code can be seen in Appendix A 1.

The subprogram RFID worked in conjunction with another subprogram entitled "BOWL," which keeps track of which bowl is currently displayed. Its flowchart can be seen in Figure 37, and the C-language code can be seen in Appendix A 2.

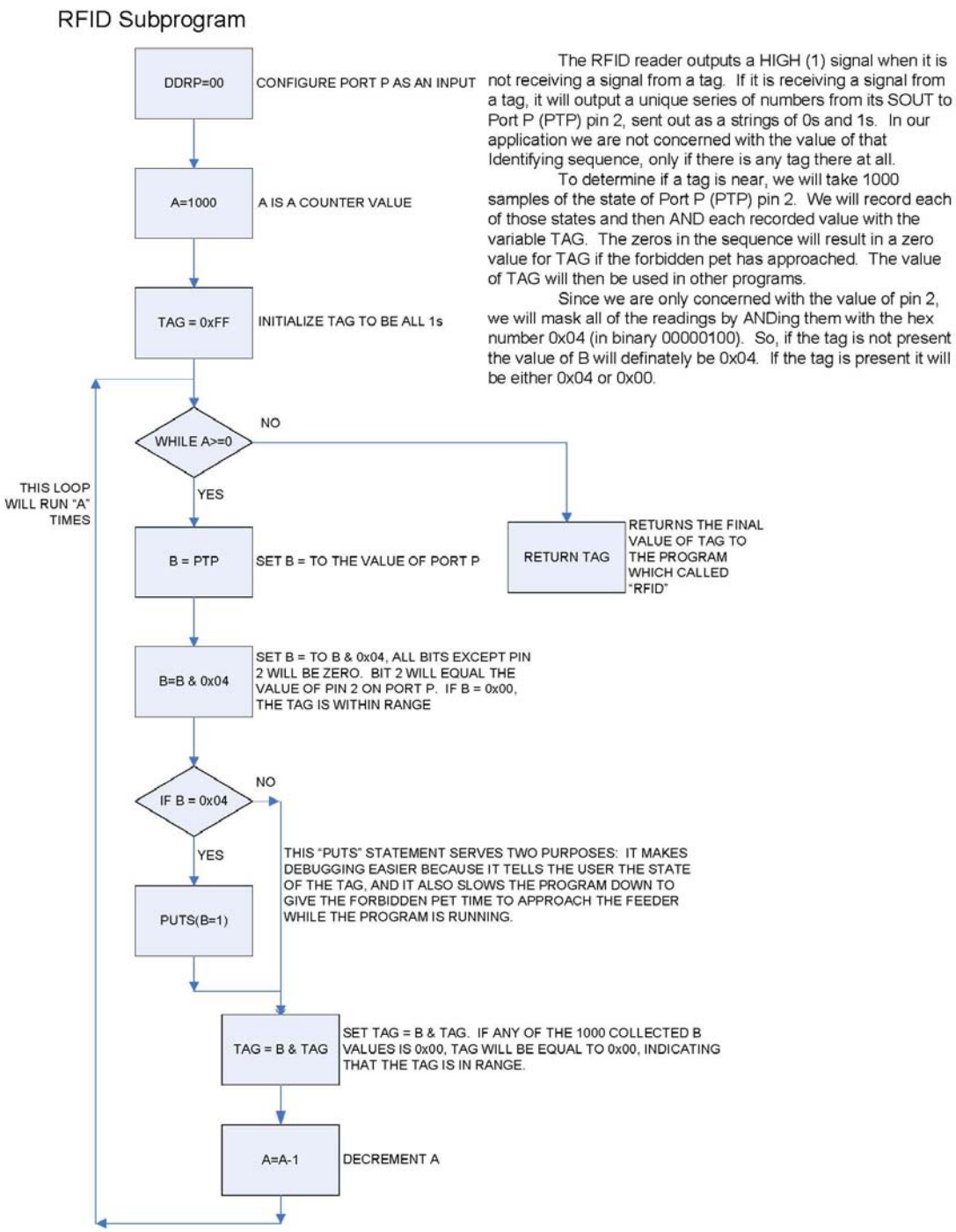

Figure 36: RFID Program Flowchart

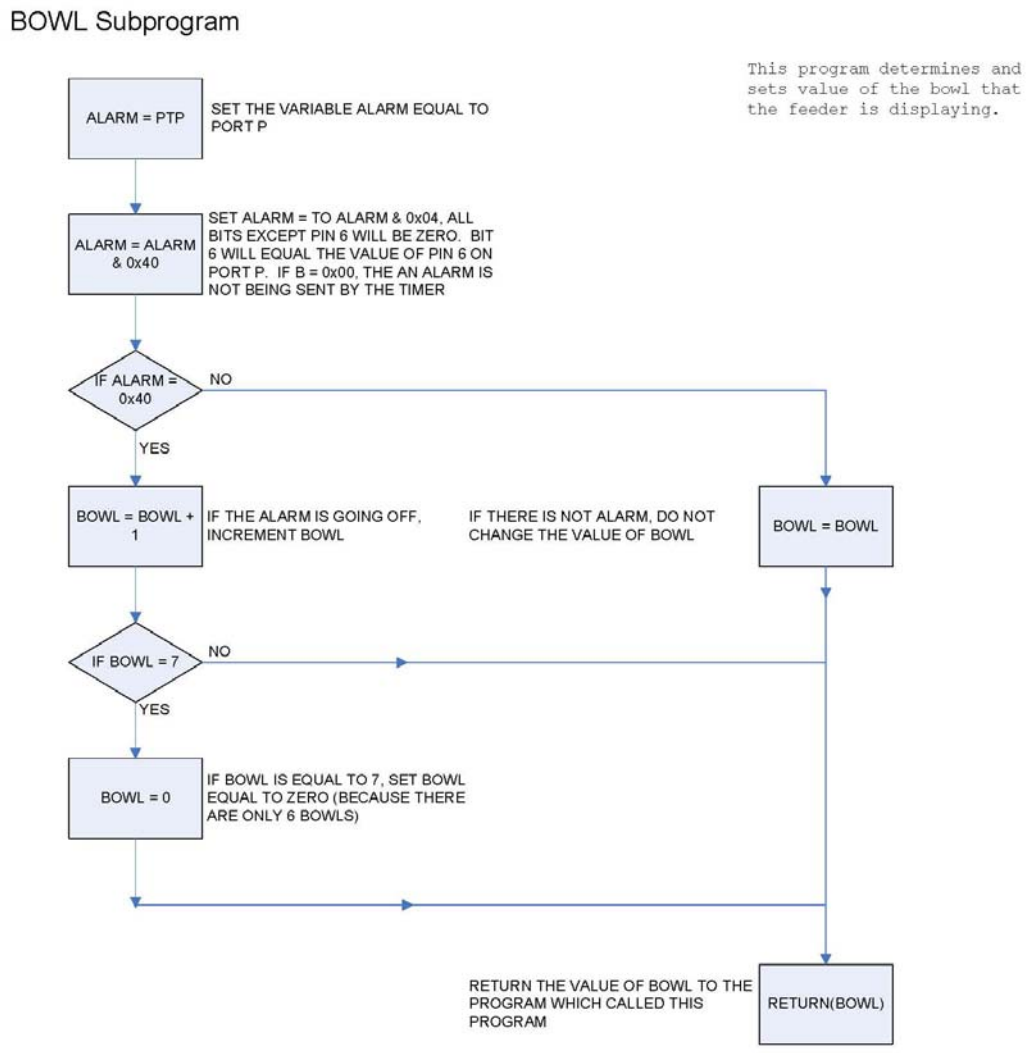

Figure 37: The flowchart for the Bowl subprogram

Both the RFID and the BOWL program are used in the Pet Detect Program. The Pet Detect program's function is to run the RFID program and react according to whether or not the forbidden pet is near (or if there is a tag present or not). If there is no tag present, then the program will simply end, but if there is a tag present, then the program will use the BOWL program to determine which bowl is currently displayed, and then will use the StepCCW program to rotate the tray to expose the empty spot so that the forbidden pet cannot eat. Once the rotation is complete, the program will repeatedly call

the RFID subprogram to determine if the forbidden pet is still near. Once RFID reports that the forbidden pet is gone, then the program will rotate the tray back to the bowl that was displayed to begin with. The flowchart for the Pet Detect program can be seen in Figure 38. This program, along with the Feeding Time subprogram discussed below, make up the core of The Smart Pet Feeder's programming.

The combination of the RFID reader and tag along with the programs discussed above completely satisfy all of the requirements of the pet sensing system. The active RFID tag no bigger than any of the other tags typically worn on a pet's collar and we feel confident that the tag will not have an adverse affect on the pet's health. The reader mounted easily to the feeder enclosure and, using the RFID program, was easily interfaced with the microcontroller. Together, all of these elements provide easy detection of the reaction to the forbidden pet, which satisfies all of the requirements for this system.

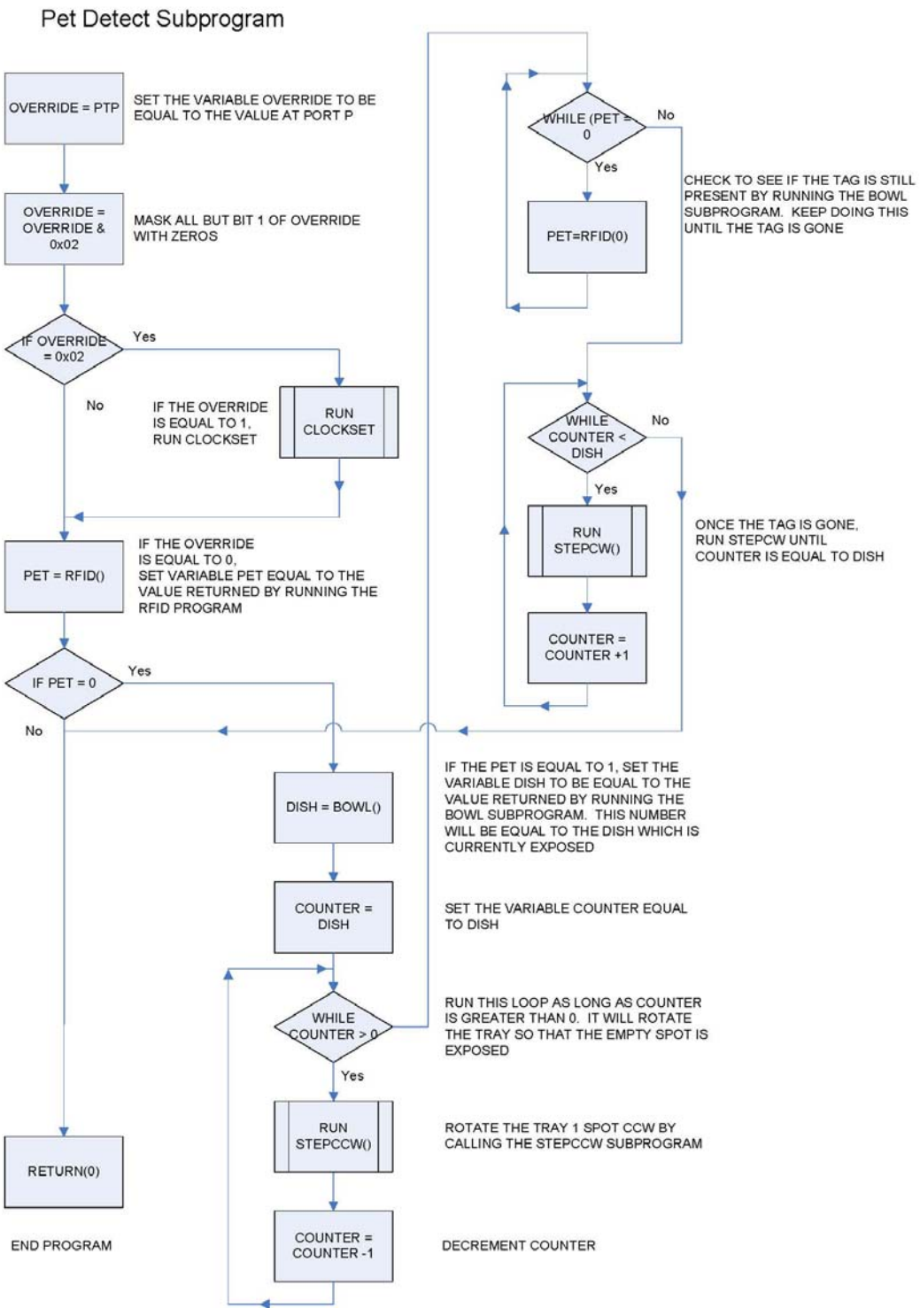

Figure 38: Pet Detect subprogram flowchart

III.A.iii.b. The Time Keeping System:

One of the subsystems of the Control System is the Time Keeping system. This is the portion of the design that keeps time and allows the user to program when the feeder should rotate in order to reveal a fresh bowl of food. The criteria that this system must meet are:

1. To allow the user to set the time on the clock
2. To tell the feeder to rotate at specific times during the day to reveal fresh food
3. Be able to output the time to a display screen
4. Use a toggle switch as a manual override to prevent the bowls from rotating
5. When the toggle switch is turned off, allow the system to rotate the bowl to the proper location and also power the RFID module back on to begin searching for the tag

The original design included the Dallas Semiconductor DS1286 Watchdog real time clock (RTC) chip as pictured in Figure 39. This was to be used with three buttons and a toggle switch in order to perform time setting functions. We have since chosen to go in an alternate direction and have integrated a different chip into our prototype.

Figure 39: The DS1286 RTC chip

An RTC is a chip that stores data for projects that utilize real time applications. It allows the programmer to store time of day data as well as alarm data to be used at a

specific time. The DS1286 is an RTC chip that is capable of keeping track of time to the hundredth of a second and is accurate to ± 1 minute per month. It comes in a 28 pin encapsulated package and has an embedded lithium power source that maintains the data on the chip in the event of power loss as well as a quartz crystal for timing. The chip is so intelligent that after being set, it knows the date, year, month, knows if the month has less than 31 days, and compensates for leap years.

We had chosen this chip for a number of reasons; we believed that it would allow us to output a time on an LCD panel and also allow the user to program what time the "alarms" would go off. In this case, the alarms would be a signal sent from the chip at the user-programmed time in order to tell the microcontroller that it is time to turn the stepper motor to reveal a fresh meal. It would also have been useful in that it would allow the user the freedom of moving the unit without having to reset the time and alarms. Since the chip has a battery backup, all of the data, times, and programming will be stored in the chip if the system loses power even though the LCD panel would not display it.

The chip has two different types of alarms that seemed to make it ideal for our design. There are the Watchdog Alarm and the Time of Day alarm. The Time of Day alarm is just like a regular alarm clock alarm and the RTC outputs a signal when the preprogrammed time is reached. This function would have be used to tell the microcontroller that it is time to turn the stepper motor to reveal a new dish. The Watchdog Alarm functions as a counter. A time is set into the correct register on the chip and that amount of time is counted down to zero [16].

The main reason we chose this chip was to make programming easier. This has proven not to be the case for a few reasons. First, interfacing with the chip is extremely awkward and we were unsure of how to interpret the values that the chip returned. For example, instead of seeing that the minutes register had incremented from the hex value of 43 to 44, it would increment to 47. We were unsure of what this meant and called Dallas Semiconductor only to be told that there was no way that the chip would return that value. After employing the help of faculty and fellow students here at Wentworth, we could come up with no good reason as to why it would be outputting these values. This is one of the main reasons that we have chosen not to use this in our design.

Another reason we have chosen not to use this chip is that we were having difficulty figuring out how to display the time on the LCD screen. In order to access what is in the registers on the chip, they must be looked at separately. There is no way to look at them simultaneously. Our solution to this problem was to store the values into variables and then output those to the LCD screen. This then posed another problem since, by the time all of the variable have been stored that original time data recorded is no long accurate.

For the reasons listed above, we determined that we were not able to use the Watchdog for our prototype. We have chosen to use another means of timekeeping. This has come in the form of an alarm clock using the LM8560B alarm clock chip.

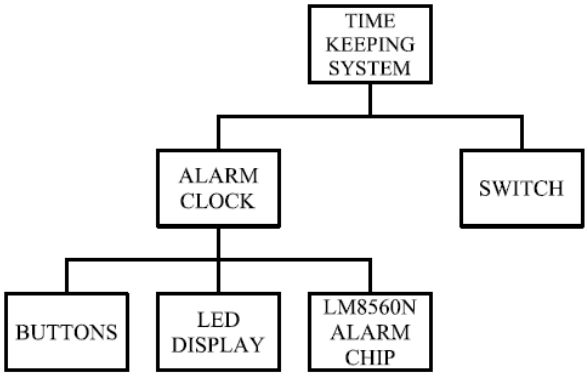

Figure 40: Block Diagram of the Time Keeping System

With the implementation of this chip, we have needed to make a few changes to our block diagram, as can be seen in Figure 40. This would be different in an actual production model since a printed circuit board would not be used, but this is the new block diagram, as it stands, for the purposes of our prototype.

By using this chip, we eliminated any code that would have been needed for this portion of the system since we are using the printed circuit board from the alarm clock as well as the display that is integrated with the circuit board. If we were to take this design further, we would eliminate the printed circuit board and simply use the alarm clock chip. This would mean that some coding would be written, but it seems very simple to interface and would be much easier to program than the RTC chip.

Another reason using the alarm clock's printed circuit board was beneficial to our prototype is that it required only three input pins on the microcontroller for the ALARM OUT, ALARM OFF, and V_{dd} (ground) pins (see Figure 41), whereas the RTC required twenty. This also eliminated possible problems with the prototype because there were fewer connections to worry about breaking.

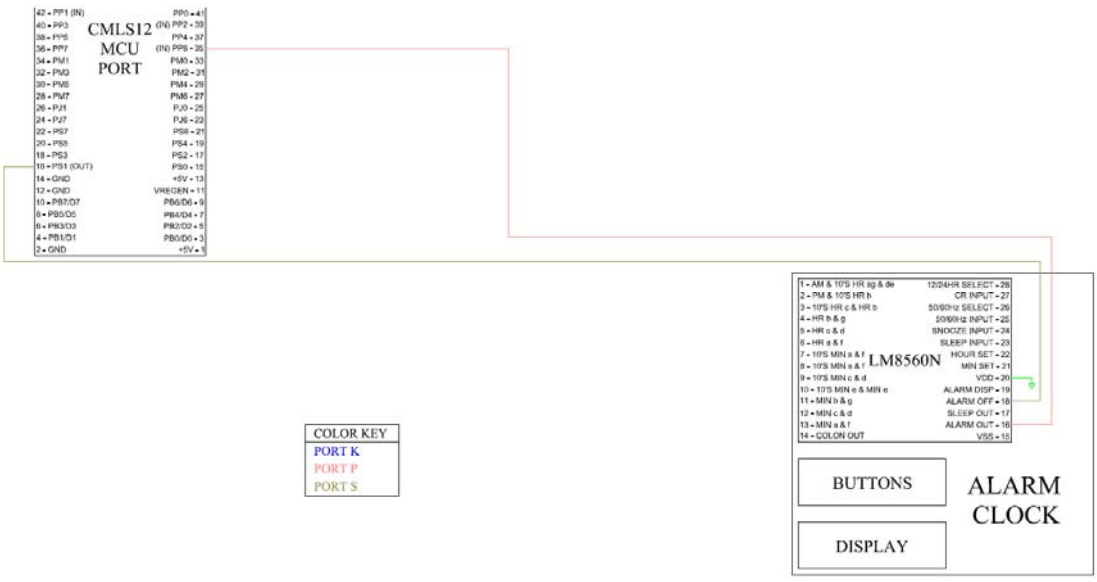

Figure 41: Control Schematic detail showing the Time Keeping System

This chip would also be much easier to program than the RTC even if we had not been using the printed circuit board. This is because there are fewer functions in the chip making it simpler. For example, there is no onboard power source, no oscillator and no watchdog functions. This means that the overall size and complexity of the chip is much smaller than the DS1286. You can see in the manufacturer's data sheet for the LM8560 that it is quite simple. There are pins for the different segments of the minutes and hours on the LED display and there is even a pin for the colon on the LED display. In general, this chip is simply much better than the one we had originally chose for our application.

Additionally, the momentary buttons that had been purchased to be used in conjunction with the RTC and toggle switch were not used in the prototype. This is because the buttons used to program the alarm clock itself are still usable. This eliminates the need to code the condition of the buttons for time.

If conditions had been optimal, we would have chosen this chip, or one similar to it, in the beginning of the semester and programmed it ourselves rather than using the

circuit board from the alarm clock itself. However, at the point in time that we chose to use it, about five days before the prototype was to be presented, there was simply no time and no point in reinventing the wheel when it performed all of the functions that we needed.

The only portion of the timekeeping system that has remained the same is the override switch. This toggle switch, pictured in Figure 42, is used to suspend the function of the alarm clock chip and pet detect programs. This will be used when setting the time, refilling the bowls of food and/or cleaning the unit. This will ensure that the unit does not rotate while performing any of these tasks.

Figure 42: On/Off toggle switch

Through the use of the new alarm clock and the toggle switch, the user will be able to set the clock easily, program a desired time to reveal a fresh bowl of food, allow the user to decide the positioning of the tray after the time of day is set, and allow the feeder to run the main and subprograms when the override is not initiated. The chip and switch allow us to accomplish all of this easily and effectively by allowing ease of use and a wide range of possibilities as the chip can be programmed to feed the pet at any time the user desires. In addition, the new alarm clock chip allows for an even easier user interface since the way the time is set is exactly the same as the alarm clock setting that most people are accustomed to.

The integration of the LM8560 has helped to redefine the requirements for the Time Keeping System. The redefined requirements are that the system:

1. Include a chip which interfaces directly with the 7-segment LED display
2. Allows the user to set the time on the clock
3. Tells the feeder to rotate at specific times during the day to reveal fresh food
4. Is able to output the time to a display screen
5. Uses a toggle switch as a manual override to prevent the bowls from rotating
6. Allows the system to rotate the bowl to the proper location and also power the RFID module back on to begin searching for the tag when the toggle switch is turned off

The alarms sent by the timekeeping chip are used mainly in the Feeding Time subprogram. This subprogram checks to see if an alarm is being sent and, if it is, calls the Bowl subprogram and then rotates the tray forward one spot. The flowchart can be seen in Figure 43 and the C-language code in Appendix A 6.

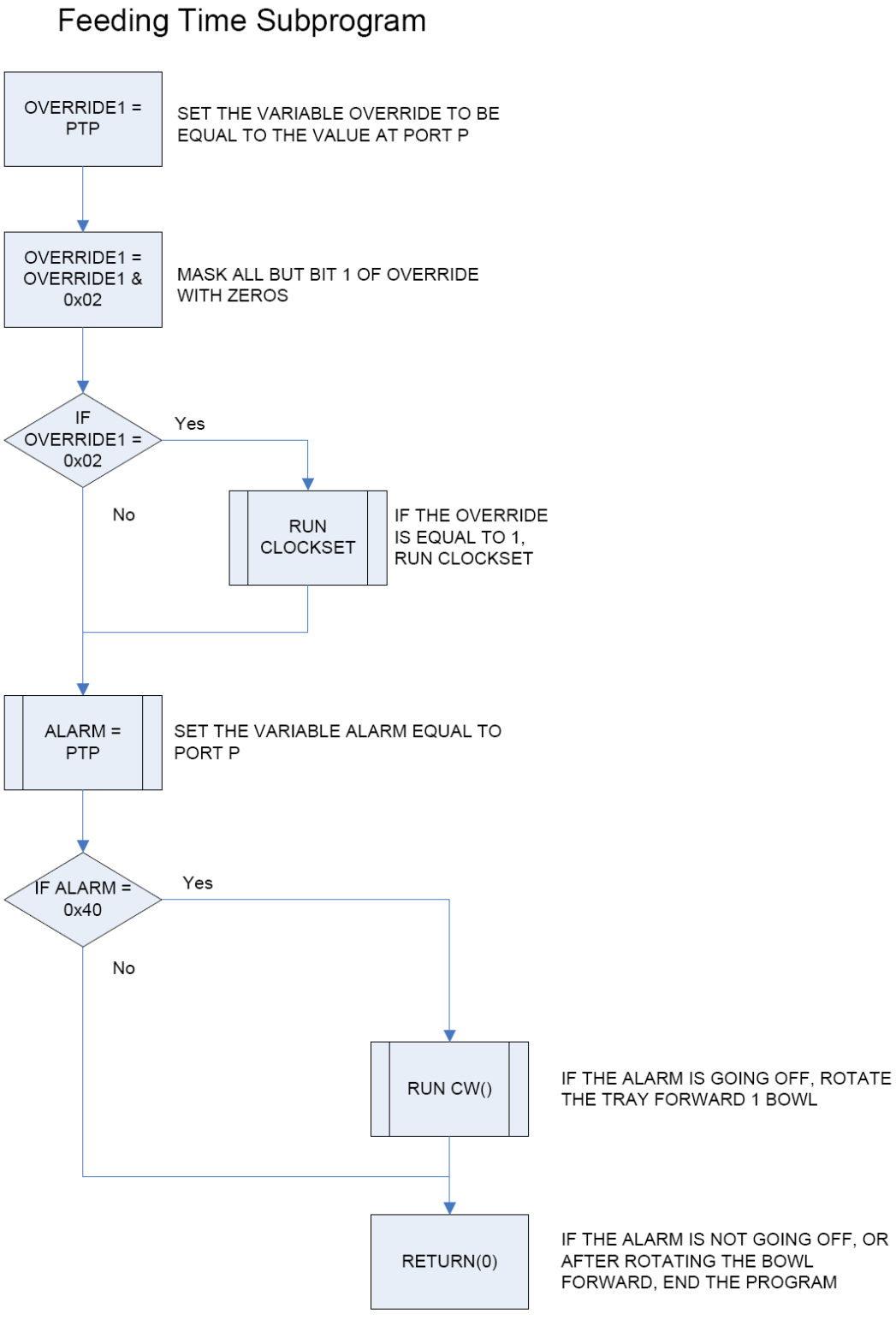

Figure 43: Flowchart for the Feeding Time Subprogram

With this combination of products and programs, we were able to create a prototype that was mostly functional, and we believe that had we more time, we would have had a fully functional prototype. Unfortunately, we damaged the LM8560 chip while working with it and were unable to use it for the presentation, but we did see it work and so know that it will fulfill our requirements.

III.A.iii.c. The Processing System:

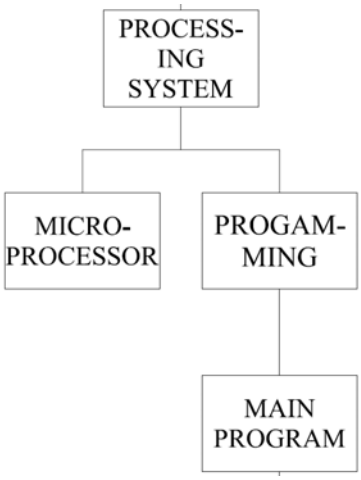

Figure 44: Block Diagram of the Processing System

The Processing System is required to integrate and control the Control System and the Motor System, as well as the different subsystems that make up the Control System. It consists of two parts: a microcontroller and the program. The requirements for a microcontroller were that:

1. It must be capable of interfacing with all of the other components that make up The Smart Pet Feeder
2. It must have enough memory to hold the programming required to control all of the components
3. It must have enough RAM to run the program

4. It must be affordable

With these requirements in mind, we chose to use the Axiom CML12S-DP512 Development Board, which uses the Motorola MC9S1DP512 microprocessor (see Figure 45).

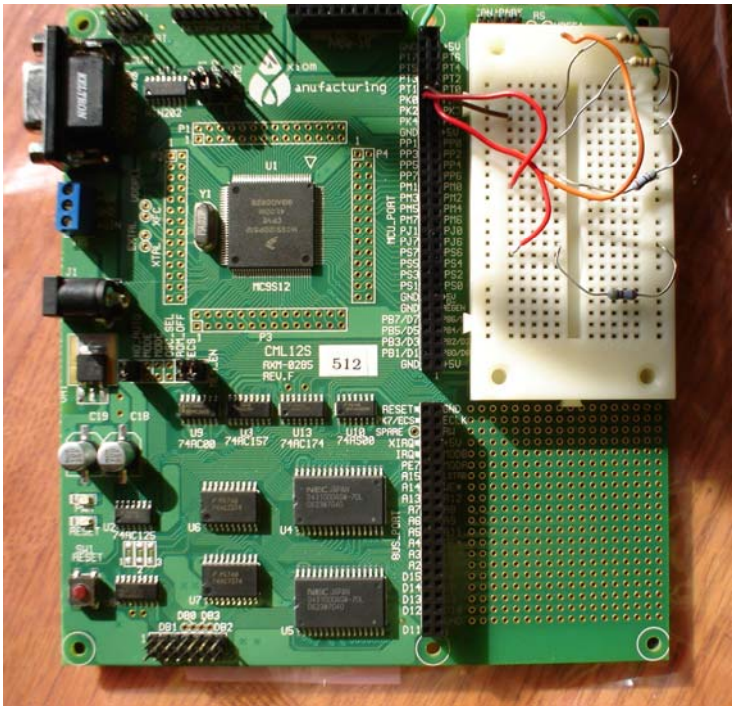

Figure 45: The Axiom CML12S-DP512 Development Board

The CML12S was chosen largely due to its affordability, since one of the team members already owned one. It exceeds all of the other requirements, as it has up to 91 in/out ports available to interface with outside equipment, 4 kB of EEPROM and 512 kB of Flash EEPROM to store the program, and 14 kB of SRAM available [17] [18]. In future versions of this product a less powerful, less expensive microcontroller would be used, but for development the CML12S will gave us ample resources for programming and interfacing without worrying about running out of ports or memory. The electrical

and control schematic, which details how all of the components were connected to the CML12S, is in Figure 46.

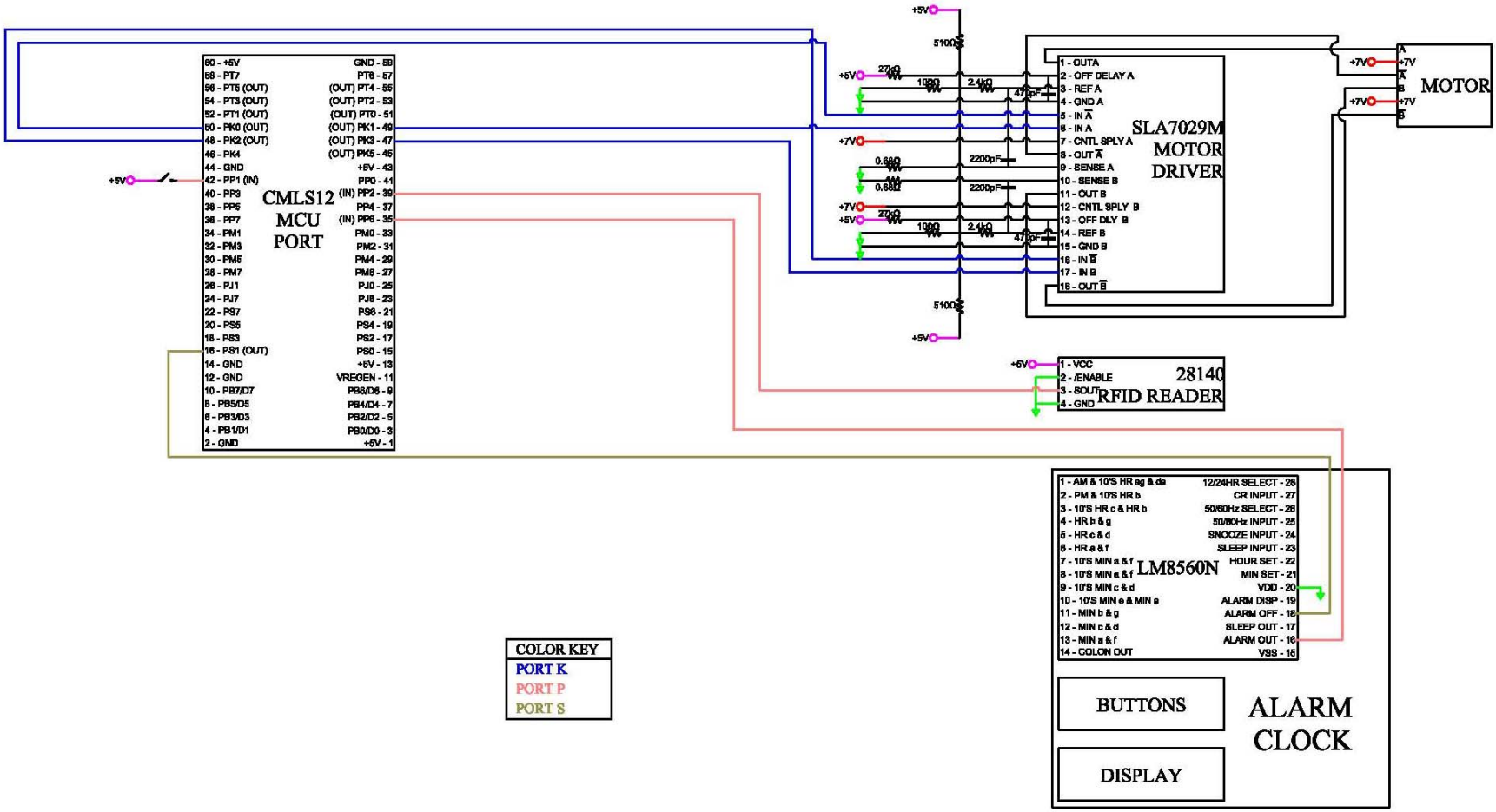

Figure 46: The complete Control Schematic

In order to download programs into the CML12S, we needed to use a cross assembler. We chose to use an Integrated Development Environment (IDE) to write and compile the code. The requirements for the IDE were as follows:

1. That it was cost effective
2. That it allowed each team member to have a copy of the software in order to program simultaneously
3. That it was compatible with the HC12 microcontroller
4. That it allowed us to program using the C language
5. That it was easy to use

We chose to use ImageCraft's ICCV7 for CPU12. It was created to operate with the HC12 family, which includes the CML12S that we are using. We were able to use the free 45-day trial version, which allowed each of us to have a copy of the software on our individual computers. This IDE allows programming in the C language, which is important since none of the team members were confident with their assembly language skills. Another advantage to using the ImageCraft software is that we had used the ICC11 version of the software previously and were familiar with the environment.

ICCV7 was used to write and compile all of the programs discussed above, as well as the Main program. The Main program consists on an infinite loop which simply runs the Pet Detect and Feeding Time Programs over and over again. The flowchart is in Figure 47 and the C-code is in Appendix A 7.

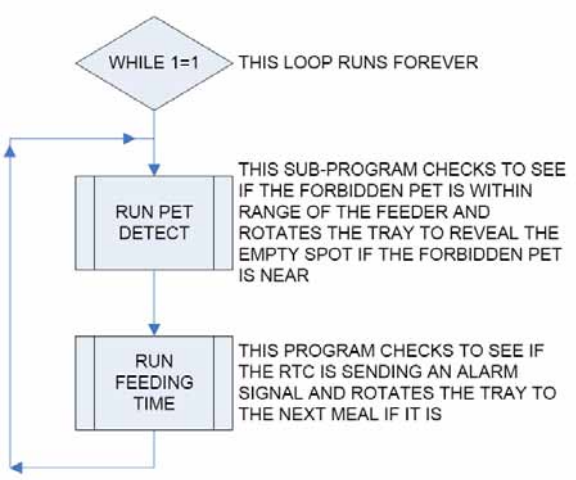

Figure 47: Flowchart for the Main program

The CML12S, in conjunction with the programs discussed above, fulfilled all of the requirements we had for the processing system, which were simply that is must integrate and control all of the other systems.

III.B. The Results:

After testing The Smart Pet Feeder, we were able to obtain results that helped us to understand what we did successfully and what needs some work in order to function the way we originally intended. For example, the range to sense the forbidden pet is far smaller than we intended. From our tests, we have found that the range of the RFID tag is about 1 inch when mounted on the front of the feeder. When not mounted on the front of the feeder the range of the tag is 2.75 inches. This is due to the interference caused by the aluminum feeder enclosure.

Unfortunately, some items could not be tested due to time constraints. The entire time keeping system was not tested due to problems with the alarm chip that we had been using. Also, we were unable to completely test the durability of the feeder with an actual pet. However, we were able to simulate and test the prototype of the feeder to determine

that the C code and programming used functions in the way that it is supposed to. This means that if all of the hardware functioned exactly as planned the results would be as intended.

IV. Discussion:

From the results of our testing, we are able to draw conclusions about a few things regarding The Smart Pet Feeder. If the RFID reader were mounted against a different material, the range would not be affected. To do this we could use a different material, other than aluminum, or any metal, as the sides of the feeder. This would bring us closer to the range that we received when testing away from the enclosure. Due to the range decrease, we were unable to use the shielding on the active RFID tag because the use of shielding also decreased the read range of the system. When mounting the reader on the aluminum side and using the shielding on the tag, the range was decreased from the original 2.75" to less than .5", which is simply unusable and impractical.

Even though there were a few parts we were unable to test, we are still able to make a few assumptions and conclusions. Since we were unable to test the feeder with a pet, we were not able to observe if the pet would be able to tip, break, or get into the feeder. However, we believe due to the weight of the feeder and the material used in manufacturing that it would be extremely difficult for a pet to break, flip, or get into the feeder, especially a small animal such as a cat or small dog, which the prototype was designed for. Despite not being able to physically set a time for an alarm to send a signal telling the feeder it is time to rotate to the next feeding, we are able to simulate an alarm signal for the feeder to rotate to the next feeding. Since we are able to send a signal simulating an alarm, we believe that given more time to work with an alarm chip, we

would be able to set an alarm for the feeder to rotate at a programmed time. We are also confident in this because we were previously able to do this; however, we encountered problems at the last minute and were not able to get this function working, and had to settle for a simulated alarm.

V. Conclusion:

Over the last semester, this design team has accomplished a massive amount of research, learning, manufacturing, and coding, and we feel that we have produced a great success. Though our prototype may not have worked exactly the way we may have wanted it to, it did work.

On the subject of what worked correctly, the majority of our design goals were met. We were able to rotate the feeder tray forward and backward a specified distance, we were able to incorporate a sensing system consisting of an RFID reader and tag that would restrict a forbidden pet from eating from the feeder, and we were able to make the tray rotate with an alarm. Though the last goal, the alarm, was not met in the way that we had hoped, we were still able to simulate its function with the use of a push button proving that our code did in fact work. Also, the pet sensing system, what set our product apart from any other on the market, worked flawlessly.

Unfortunately, the timekeeping system did not work. As stated in the timekeeping section, we were unable to make either of the chips work for us, but with more time, we believe that we would have been able to make this work correctly.

The one thing that did work, but not as well as we would have liked, was the RFID reader. Since the range was cut so drastically due to the metal walls of the enclosure, the reaction time was far greater, and the distance far smaller, than we had

hoped. This is not a problem, though, since it can be easily fixed by using a different material for the enclosure body.

This design, though not final, does in fact satisfy most of our design goals. It:

1. Keeps the pet from reaching the food stored for later feedings
2. Restricts an unauthorized pet access to the feeder

The only goals that were not fulfilled were to provide an easy user interface and to provide future meals at a predictable time. This is because at the moment, there really is no user interface or timekeeping system. This would be easily fixed by implementing the alarm clock chip since it is set exactly like an alarm clock that most people are accustomed to.

If we were to take this design further, such as in our senior design class, we would change a few things. First, we would change the material of the feeder body in order to increase the sensing range of the RFID reader. Next, we would implement the alarm clock chip rather than the RTC chip. Finally, we would make the movement of the tray smoother by implementing a better turntable into the design. All of these changes would help us to better meet the goals that we had originally laid out for out design.

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Appendix A: Program Codes:

Appendix A 1: C-code for StepCW Subprogram

```
// This program turns motor couter clockwise in half stepping mode by 52.2 degrees


#define NUM_OF_STATES 8 //There are 8 different states in this particular example.
#define DELAY_MAX 2500  //The maximum # of counts used to create a time delay.

#include <ports_d256.h>
#include <stdio.h>

void stepccw(void)
{
/*******************CREATE VARIABLES******************/
int i; //Used in a for loop
int Q;

//This array actually contains the state values that will be placed on Port K.
//State #0 corresponds to a value of 0x06, state #1 corresponds to a value of 0x02, etc.
char state_array[NUM_OF_STATES] = {0x06, 0x04, 0x05, 0x01, 0x09, 0x08, 0x0A, 0x02};
int steps_to_move; //The # of rotational steps the motor will make.
char next_state;   //Used to select the next state to put in register K.
/*******************SET UP PORT K*******************/
DDRK = 0xFF;     //Writing 0xFF to DDRK sets all bits of Port K to act as output.

PORTK = 0;       //Init Port K by writing a value of zero to Port K.
/***************************************************/
steps_to_move = 58; //Set the # of steps to move. An arbitrary positive # can be used.

next_state = 0;      //Init next_state to state 0. next_state can start from any state
                     //within the range of possible states in this example, 0-7.

PORTK = state_array[next_state];//Init Port K to the starting state. In this example,
                                //since only 4 pins are needed to control the motor, only
                                //the lower nibble of Port K is being used. This line
                                //selects state 0 and places the corresponding value
                                //(0x06) in the lower nibble of Port K.

for(i = 0; i < DELAY_MAX; i++)
{
    //Wait here for a while.
}
```

```
43  while (steps_to_move > 0)
44  {
45      if (next_state > (NUM_OF_STATES - 1))   //If next_state is greater than the highest
46                                              //available state, 7, then cycle back to 0
47      {
48      next_state = 0;
49      }
50      PORTK = state_array[next_state]; //Place new value in Port K. Rotation may be observed
51      for(i = 0; i < DELAY_MAX; i++)
52      {
53          //Wait here for a while.
54      }
55   next_state++;      //Increment next_state. Cycling though the states causes rotation
56                      //in one direction. Decrementing states causes opposite rotation.
57   steps_to_move--;   //Subtract 1 from the total # of steps remaining to be moved.
58  }
59
60  /*Q=500;
61
62  while(Q<0)
63  {
64  PORTK=0xFF;
65  Q=Q-1;
66  }
67  PORTK=0;*/
68  puts("I have rotated back 1 spot");
69  } //End of Main
70
71
72
```

Appendix A 2: C-code for StepCCW Subprogram

```
// This program turns motor clockwise in half stepping mode by 52.2 degrees


#define NUM_OF_STATES 8 //There are 8 different states in this particular example.
#define DELAY_MAX 2500  //The maximum # of counts used to create a time delay.

#include <ports_d256.h>
#include <stdio.h>

void stepcw(void)
{
/*******************CREATE VARIABLES******************/
int i; //Used in a for loop
int Q;

//This array actually contains the state values that will be placed on Port K.
//State #0 corresponds to a value of 0x06, state #1 corresponds to a value of 0x02, etc.
char state_array[NUM_OF_STATES] = {0x02, 0x0A, 0x08, 0x09, 0x01, 0x05, 0x04, 0x06};
int steps_to_move; //The # of rotational steps the motor will make.
char next_state;   //Used to select the next state to put in register K.
/*******************SET UP PORT K*******************/
DDRK = 0xFF;    //Writing 0xFF to DDRK sets all bits of Port K to act as output.

PORTK = 0;      //Init Port K by writing a value of zero to Port K.
/***************************************************/
steps_to_move = 58; //Set the # of steps to move. An arbitrary positive # can be used.

next_state = 0;     //Init next_state to state 0. next_state can start from any state
                    //within the range of possible states in this example, 0-7.

PORTK = state_array[next_state];//Init Port K to the starting state. In this example,
                                //since only 4 pins are needed to control the motor, only
                                //the lower nibble of Port K is being used. This line
                                //selects state 0 and places the corresponding value
                                //(0x06) in the lower nibble of Port K.

for(i = 0; i < DELAY_MAX; i++)
{
    //Wait here for a while.
}
while (steps_to_move > 0)
{
```

```
    if (next_state > (NUM_OF_STATES - 1))   //If next_state is greater than the highest
                                            //available state, 7, then cycle back to 0
    {
    next_state = 0;
    }
    PORTK = state_array[next_state]; //Place new value in Port K. Rotation may be observed
    for(i = 0; i < DELAY_MAX; i++)
    {
        //Wait here for a while.
    }
 next_state++;      //Increment next_state. Cycling though the states causes rotation
                    //in one direction. Decrementing states causes opposite rotation.
 steps_to_move--;   //Subtract 1 from the total # of steps remaining to be moved.
}

/*Q=500;

while(Q<0)
{
PORTK=0xFF;
Q=Q-1;
}
PORTK=0;
*/
puts("I have rotated forward 1 spot");
} //End of Main
```

Appendix A 3: C-code for RFID Subprogram

```
12      * The RFID reader outputs a HIGH (1) signal when it is not receiving a
13        signal from a tag.  If it is receiving a signal from a tag, it will output
14        a unique series of numbers from its SOUT to Port P (PTP) pin 2, sent out
15        as a strings of 0s and 1s.  In our application we are not concerned with
16        the value of that identifying sequence, only if there is any tag there at
17        all.
18        To determine if a tag is near, we will take 1000 samples of the state of
19        Port P (PTP) pin 2.  We will record each of those states and then AND each
20        recorded value with the variable TAG.  The zeros in the sequence will
21        result in a zero value for TAG if the forbidden pet has approached.  The
22        value of TAG will then be used in other programs.
23        Since we are only concerned with the value of pin 2, we will mask all of
24        the readings by ANDing them with the hex number 0x04 (in binary 00000100).
25        So, if the tag is not present the value of B will definately be 0x04.  If
26        the tag is present it will be either 0x04 or 0x00.
27  */
28
29  //header files to be included
30  #include <ports_d256.h>
31  #include <stdio.h>
32
33
34  //define variables
35  int A;                                          //Counter = to the number of
36                                                  //samples of the state of PTP1
37
38  int B;                                          //Holds Sample Values from PTP.
39                                                  //It will definately have a 1
40                                                  //in pin 2 if no tag is present
41                                                  //It may have a 0 in pin 2
42                                                  //if there is a tag present.
43
44
45  int TAG;                                        //Value equal to ANDing all
46                                                  //B's and TAG.  Will be
47                                                  //initialized to equal FF
48
49  //program begins here
50  int rfid(void)
51  {
52  puts("I am running RFID\n");
53
```

```
DDRP=00;                                          //this line configures Port P
                                                  //as an input


/*This section sets the value of each variable equal to the value in PTP ANDed
by 00000100(BIN) = 0x04(HEX).  This mask makes it possible to use only the value
at PTP2 to set the variable values.*/

TAG = 0xFF;               //set TAG = to all 1's
A = 1000;                 //set counter = to 1000.  This is equal to the number of
                          //samples taken



while (A >= 0)            //this loop will run 1000 times
{

B = PTP;                  //Set B = to the current value of PTP
B &= 0x04;                //By ANDing B with 0x04, we will set all of the bits
                          //of Port B equal to EXCEPT for pin 2, which will retain
                          //its state from B.  The resulting value will definately
                          //be 0x04 is there is no tag in range, but will
                          //occasionally be 0x00 if a tag is in range.

if (B==0x04)              //this loop will output a statement to the computer
                          //screen if B=0x04.  This makes debugging easier, and
                          //slows the the program down enough that it will
                          //definately catch the tag
{
puts("B=1");              //the statement put to the screen is B=1, indicating
                          //no tag is present
}

TAG = B&&TAG;             //variable TAG is set equal to the value of B AND the
                          //already existant value of TAG


A = A-1;                  //Decrement variable A
}
puts("I have finished RFID\n");
return(TAG);              //At the end of the program, return the value of TAG
                          //to the program calling rfid()
```

Appendix A 4: C-code for Bowl Subprogram

```
/* Program Name:  Bowl
   Written By:  Alexis Rodriguez-Carlson
   Revision Date:  April 2, 2008
   Purpose:  This program determines and sets value of the bowl that the
             feeder is displaying.*/



/**header files to be included**/
#include <ports_d256.h>
#include <stdio.h>

//define variables

int BOWL;          //this is the variable which holds the value of the revealed
                   //dish
int ALARM;         //this is the variable which holds the value of PTP to check
                   //to see if the RTC is sending an alarm

//program begins here
int bowl()
{
DDRS=0xFF;
BOWL=1;
puts("I am running the bowl program!!\n");


ALARM = PTP;      //set ALARM equal to PTP

ALARM &= 0x40;    //set ALARM equal to its current value AND 0x40.  This will set
                  //all of the bits equal to zero except bit 6

if (ALARM == 0x40)     //this statement will run if ALARM is equal to 0x40,
                       //indicating that the RTC is sending an alarm
{
puts("Alarm = 0x40.\n");
puts("I am incrementing the bowl!!\n");
BOWL=BOWL+1;           //increment BOWL
PTS=0x02;              //sending a signal to alarm off
PTS=00;                //quit sending signal to alarm off
//DDRP = 0b01000000;
PTP &= 0b10111111;
```

```
43
44
45  if(BOWL == 7)          //the statement will reset BOWL to equal 0 if it currently
46                         //equals 7 (because there are only 6 bowls)
47  {
48  puts("Bowl=7, so I'll make it 0.\n");
49  BOWL = 0;
50  }}
51
52  if(ALARM == 0x00)      //this statement will run if ALARM is equal to 0x00
53  {
54  puts("Alarm = 0, so I'll keep bowl the same.\n");
55
56
57  }
58  return(BOWL);          //this line will end the program by returning the value of
59                         //BOWL to the calling program
60  }
61
62
```

Appendix A 5: C-code for Pet Detect Subprogram

```
/* Program Name:  Pet Detect
   Written By:  Alexis Rodriguez-Carlson
   Revision Date:  April 8, 2008
   Purpose:  This program determines if the MCU is receiving a signal from the
             RFID reader.  If it is, it rotates the food tray to the blank spot,
             if it is not, it calls the Feeding Time program.*/



/**header files to be included**/
#include <ports_d256.h>
#include <stdio.h>


/*define variables*/


int DISH;                    /*variable which indicates which dish is to be
                             revealed*/
int COUNTER;                 /*variable used to count how many times the motor
                             rotation program will run*/

int PET;                     /*variable which equals 0 if forbidden pet is
                             */
int OVERRIDE;                /*variable which equals 1 if override is on*/


detect()
{
 puts("I am now running the Pet Detect Program\n");

 OVERRIDE = PTP;            //set OVERRIDE = to Port P
 OVERRIDE &= 0x02;          //ANDS all pins with zero except for pin 1,
                            //which is ANDed with 1, and sets OVERRIDE equal to
                            //the   resulting value
 //if (OVERRIDE == 0x02)      //check to see if the manual override switch
                            //is on.
// {
 //   clockset();              //run the clockset program
// }

 PET=rfid();                //set PET equal to the value returned by the rfid()
```

```
                              //program
 if (PET==0)                  //check to see if the RFID reader is
                              //receiving a signal
 {
    DISH=bowl();              //set the variable DISH to equal to the the value
                              //returned from the BOWL program
    COUNTER=DISH;             //set the variable COUNTER to be equal to DISH
                              //which is exposed


    while (COUNTER > 0)       //this loop rotates the tray to reveal the blank spo
          {
          stepccw();          //calls the counter clockwise rotation program
                              //program
          COUNTER = COUNTER-1;  //decrements COUNTER*/
          }



 while (PET==0)           //this loop repeatedly checks to see if the RFID
                          //reader is receiving a signal.  It will run until
                          //the reader is not receiving a signal
  {
  PET=rfid();             //set PET equal to the value returned by the rfid()
  }

 while (COUNTER < DISH) //this loop rotates the tray to reveal the current meal
  {
  stepcw();                   //calls the clockwise rotation program
  COUNTER = COUNTER +1;  //increments the counter
  }}
puts("this is the end of the detect program\n");
return(0);
}
```

Appendix A 6: C-code for Feeding Time Subprogram

```
/* Program Name:  Feeding Time
   Written By:  Alexis Rodriguez-Carlson
   Revision Date:  April 8, 2008
   Purpose:  This program determines if the MCU is receiving an alarm signal
             from the RTC.  If it is, it rotates the food tray to reveal the
             next meal, if it is not, it calls the Pet Detect program.*/

/**header files to be included**/
#include <ports_d256.h>
#include <stdio.h>

int OVERRIDEF;                      //variable which holds the value of PTP to
                                    //determine if the override switch (in PTP1)
                                    //is on
int ALARMF;                         //variable which holds the value of PTP to
                                    //determine if the RTC is sending an ALARMF
                                    //signal on (PTP6)


/*program code is below*/
feeding()
{
 puts("I am running the feeding time program!!\n");

 OVERRIDEF = PTP;                   //set OVERRIDEF = to Port P
 OVERRIDEF &= 0x02;                 //ANDS all pins with zero except for pin 1,
                                    //which is ANDed with 1, and sets P1 equal to
                                    //the resulting value
 if (OVERRIDEF == 0x02)             //check to see if the manual override switch
                                    //is on.  If P1 is equal to 1, then the
                                    //override switch is on and the program
                                    //clockset() will run
  {
  clockset();                       //running the program clockset()
  puts("The clockset program finished running.\n");
  }


  ALARMF = PTP;                     //Sets ALARMF to be equal to Port P
  ALARMF &= 0x40;                   //ANDS all pins with zero except for pin 6,
                                    //which is ANDed with 1, and sets ALARMF equa
                                    //to the resulting value
```

```
43
44    if (ALARMF==0x40)                 //if ALARMF = 0x04, then RTC is sending a
45                                      //signal and this statement will run
46
47    {
48     bowl();                          //run the bowl program to increment the value
49                                      //of BOWL
50     stepcw();                            //run the cw() program, which will rotate
51                                      //motor forward 1 spot
52
53
54     }
55
56    puts("Feeding time is over\n");
57
58   return(0);                       //end the program
59  }
60
61
```

Appendix A 7: C-code for Main Program

```
1
2   /**header files to be included**/
3   #include <ports_d256.h>
4   #include <stdio.h>
5
6   int Z;
7   int Y;
8
9   void main(void)
10  {
11  asm ("LDS #$3F80");
12  Z=1;
13
14  while (Z==1)
15  {
16   detect();
17   feeding();
18  }
19  }
20
21
22
23
24
```

Appendix B: Data Sheets:

Appendix B 1: Motor Data Sheets

1.8° SIZE 17 — SUPER TORQUE MOTOR

LIN ENGINEERING Step Motor Specialists

4118

- NEMA Size 17 Mounting
- Cost Effective
- Custom Windings Available (No Additional Cost)

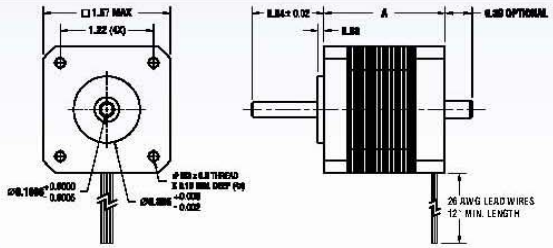
■ SPECIFICATIONS

	Dimension "A" Max	Model #	Amps/ Phase	Torque oz-in	Torque N-m	Resistance Ohm/Phase	Inductance mH/Phase	Inertia oz-in²	Weight Lbs.	Number of Leads
BIPOLAR	1.35" 34.3 mm	4118S-02	1.30	45.0	0.32	2.8	3.6	0.18	0.40	4
		4118S-04S	0.67	45.0	0.32	9.9	12.5	0.18	0.40	4
		4118S-04P	1.33	45.0	0.32	2.5	3.1	0.18	0.40	4
		4118S-09	0.90	45.0	0.28	5.3	6.7	0.18	0.40	4
	1.57" 39.9 mm	4118M-01	1.70	63.0	0.44	1.5	3.0	0.28	0.60	4
		4118M-06S	0.70	63.0	0.44	10.8	21.8	0.28	0.60	4
		4118M-06P	1.40	63.0	0.44	2.7	5.5	0.28	0.60	4
	1.9" 48.3 mm	4118L-01	2.00	83.0	0.59	1.4	2.7	0.37	0.70	4
		4118L-07S	1.05	83.0	0.59	5.2	9.4	0.37	0.70	4
		4118L-07P	2.10	83.0	0.59	1.3	2.3	0.37	0.70	4

	Dimension "A" Max	Model #	Amps/ Phase	Torque oz-in	Torque N-m	Resistance Ohm/Phase	Inductance mH/Phase	Inertia oz-in²	Weight Lbs.	Number of Leads
UNIPOLAR	1.35" 34.3 mm	4118S-04	0.95	30.0	0.17	5.0	3.1	0.18	0.40	6
	1.57" 39.9 mm	4118M-06	1.00	45.0	0.35	5.4	5.5	0.28	0.60	6
	1.9" 48.3 mm	4118L-07	1.50	65.0	0.43	2.6	2.3	0.37	0.70	6
		4118L-25	0.45	65.0	0.35	25.0	17.4	0.37	0.70	6

- Please complete our application data sheet for different windings.
- Power supply voltage can be any value as long as the driver output current is controlled at the rated current.
- Call Lin Engineering for additional bipolar torque curves.
- Performance, size, and appearance specifications of the products listed here are subject to change without notice.
- For operating temperatures, see page 94.

■ DIMENSIONS (inches)

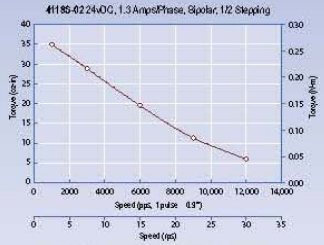


DID YOU KNOW...

The average lead time for prototypes is 3-7 business days. This includes custom windings and most shaft modifications.

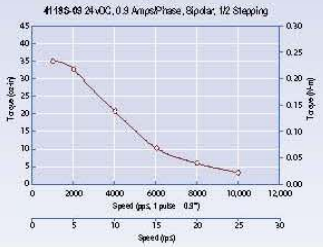
TORQUE CURVES

4118S-02 24vDC, 1.3 Amps/Phase, Bipolar, 1/2 Stepping

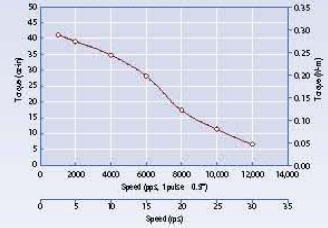


4118S-04S 24vDC, 0.67 Amps/Phase, Bipolar Series, 1/2 Stepping
4118S-04P 24vDC, 1.33 Amps/Phase, Bipolar Parallel, 1/2 Stepping

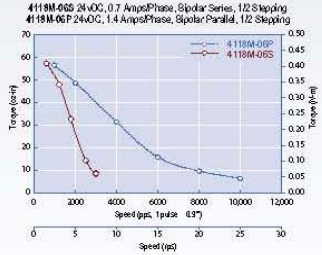
4118S-09 24vDC, 0.9 Amps/Phase, Bipolar, 1/2 Stepping



4118M-01 24vDC, 1.7 Amps/Phase, Bipolar, 1/2 Stepping

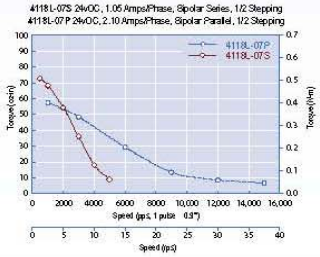


4118M-06S 24vDC, 0.7 Amps/Phase, Bipolar Series, 1/2 Stepping
4118M-06P 24vDC, 1.4 Amps/Phase, Bipolar Parallel, 1/2 Stepping



4118L-01 24vDC, 2 Amps/Phase, Bipolar, 1/2 Stepping

4118L-07S 24vDC, 1.05 Amps/Phase, Bipolar Series, 1/2 Stepping
4118L-07P 24vDC, 2.10 Amps/Phase, Bipolar Parallel, 1/2 Stepping



4118L-25 24vDC, 0.45 Amps/Phase, Unipolar, 1/2 Stepping

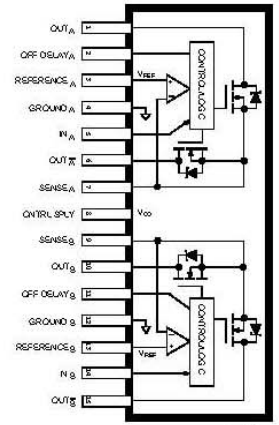
Appendix B 2: Motor Driver Data Sheet

SLA7024M, SLA7026M, AND SMA7029M

Data Sheet 29201

HIGH-CURRENT PWM, UNIPOLAR STEPPER MOTOR CONTROLLER/DRIVERS

SMA7029M



Dwg. PK-007

ABSOLUTE MAXIMUM RATINGS at T_A = +25°C

Load Supply Voltage, V_{BB}	46 V
FET Output Voltage, V_{DS}	100 V
Control Supply Voltage, V_{CC}	46 V
Peak Output Current, I_{OUTM} ($t_w \leq 100$ µs)	
SLA7024M	3.0 A
SLA7026M	5.0 A
SMA7029M	3.0 A
Continuous Output Current, I_{OUT}	
SLA7024M	1.5 A
SLA7026M	3.0 A
SMA7029M	1.5 A
Input Voltage Range, V_{IN}	-0.3 V to 7.0 V
Reference Voltage, V_{REF}	2.0 V
Package Power Dissipation, P_D	See Graph
Junction Temperature, T_J	+150°C
Operating Temperature Range, T_A	-20°C to +85°C
Storage Temperature Range, T_{stg}	-40°C to +150°C

The SLA7024M, SLA7026M, and SMA7029M are designed for high-efficiency and high-performance operation of 2-phase, unipolar stepper motors. An automated, innovative packaging technology combined with power FETs and monolithic logic/control circuitry advances power multi-chip modules (PMCMs™) toward the complete integration of motion control. Highly automated manufacturing techniques provide low-cost and exceptionally reliable PMCMs suitable for controlling and directly driving a broad range of 2-phase, unipolar stepper motors. The three stepper motor multi-chip modules differ primarily in output current ratings (1.5 A or 3.0 A) and package style.

All three PMCMs are rated for an absolute maximum limit of 46 V and utilize advanced NMOS FETs for the high-current, high-voltage driver outputs. The avalanche-rated (≥100 V) FETs provide excellent ON resistance, improved body diodes, and very-fast switching. The multi-chip ratings and performance afford significant benefits and advantages for stepper drives when compared to the higher dissipation and slower switching speeds associated with bipolar transistors. Normally, heat sinks are not required for the SLA7024M or SMA7029M. The SLA7026M, in demanding, higher-current systems designs, necessitates suitable heat transfer methods for reliable operation.

Complete applications information is given on the following pages. PWM current is regulated by appropriately choosing current-sensing resistors, a voltage reference, a voltage divider, and RC timing networks. The RC components limit the OFF interval and control current decay. Inputs are compatible with 5 V logic and microprocessors.

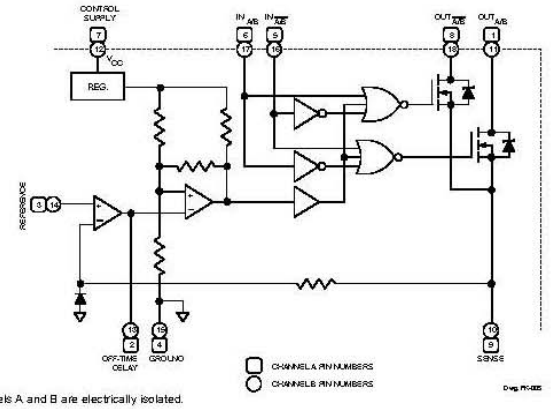
BENEFITS AND FEATURES

- Cost-Effective, Multi-Chip Solution
- 'Turn-Key' Motion-Control Module
- Motor Operation to 3 A and 46 V
- 3rd Generation High-Voltage FETs
- 100 V, Avalanche-Rated NMOS
- Low $r_{DS(on)}$ NMOS Outputs
- Advanced, Improved Body Diodes
- Single-Supply Motor/Module Operation
- Half- or Full-Step Unipolar Drive
- High-Efficiency, High-Speed PWM
- Dual PWM Current Control (2-Phase)
- Programmable PWM Current Control
- Low Component Count PWM Drive
- Low Internal Power Dissipation
- Heat Sinking (Normally) Unnecessary
- Electrically Isolated Power Tab
- Logic IC- and µP-Compatible Inputs
- Machine-Insertable Package

Always order by complete part number:

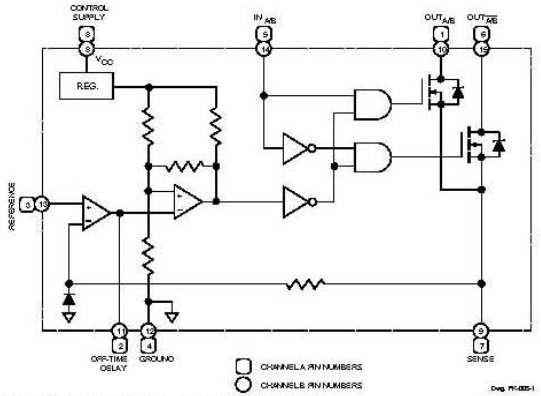
Part Number	Package	Output Current
SLA7024M	18-Lead Power-Tab SIP	1.5 A
SLA7026M	18-Lead Power-Tab SIP	3.0 A
SMA7029M	15-Lead SIP	1.5 A

SLA7024M and SLA7026M FUNCTIONAL BLOCK DIAGRAM



Note that channels A and B are electrically isolated.

SMA7029M FUNCTIONAL BLOCK DIAGRAM



Note that except for the control supply, channels A and B are electrically isolated.

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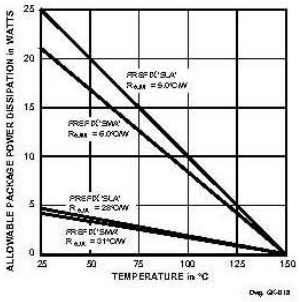
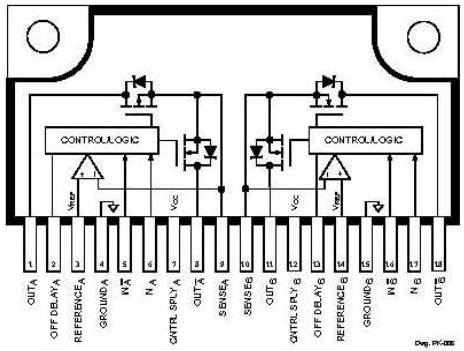
ALLOWABLE PACKAGE POWER DISSIPATION



SLA7024M and SLA7026M



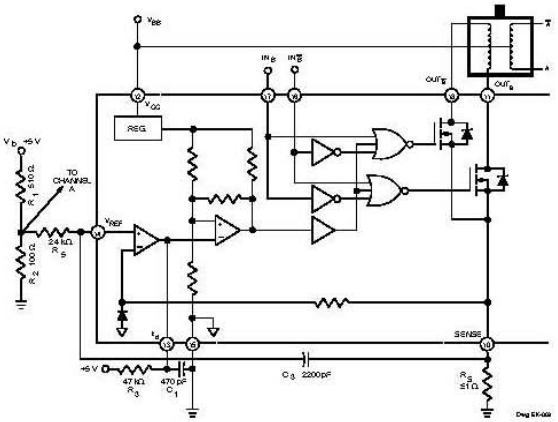
ELECTRICAL CHARACTERISTICS at T_A = +25°C

Characteristic	Symbol	Test Conditions	Limits			Units
			Min	Typ	Max	
FET Leakage Current	I_{DSS}	V_{DS} = 100 V, V_{CC} = 44 V			4.0	mA
FET ON Voltage	$V_{DS(ON)}$	(SLA7024M & SMA7029M) V_{CC} = 14 V, I_{OUT} = 1 A			600	mV
		(SLA7026M) V_{CC} = 14 V, I_{OUT} = 3 A			850	mV
FET ON Resistance	$r_{DS(on)}$	(SLA7024M & SMA7029M) V_{CC} = 14 V, I_{OUT} = 1 A			600	mΩ
		(SLA7026M) V_{CC} = 14 V, I_{OUT} = 3 A			285	mΩ
Body Diode Forward Voltage	V_{SD}	(SLA7024M & SMA7029M) I_{OUT} = 1 A		0.9	1.5	V
		(SLA7026M) I_{OUT} = 3 A		0.9	1.6	V
Control Supply Voltage	V_{CC}	Operating	10	24	44	V
Control Supply Current	I_{CC}	V_{CC} = 44 V		10	15	mA
Input Current	$I_{IN(H)}$	V_{CC} = 44 V, V_{IN} = 2.4 V			40	µA
	$I_{IN(L)}$	V_{IN} = 0.4 V			-800	µA
Input Voltage	$V_{IN(H)}$		2.0			V
	$V_{IN(L)}$				0.8	V

NOTE: Negative current is defined as coming out of (sourcing) the specified device pin.

SLA7024M, SLA7026M, AND SMA7029M
HIGH-CURRENT PWM,
UNIPOLAR STEPPER MOTOR
CONTROLLER/DRIVERS

TYPICAL STEPPER MOTOR APPLICATIONS
(Half of Each Device Shown)
SLA7024M and SLA7026M



TRUTH TABLES
(Device Types as Designated)

WAVE DRIVE (FULL STEP) for SLA7024M and SLA7026M

Sequence	0	1	2	3	0
Input A	H	L	L	L	H
Input $\overline{A}$	L	L	H	L	L
Input B	L	H	L	L	L
Input $\overline{B}$	L	L	L	H	L
Output ON	A	B	$\overline{A}$	$\overline{B}$	A

2-PHASE (FULL STEP) OPERATION for SLA7024M and SLA7026M

Sequence	0	1	2	3	0
Input A	H	L	L	L	H
Input $\overline{A}$	L	H	H	L	L
Input B	H	H	L	L	H
Input $\overline{B}$	L	L	H	H	L
Outputs ON	AB	$\overline{A}$B	$\overline{AB}$	A$\overline{B}$	AB

HALF-STEP OPERATION (2-1-2 SEQUENCE) for SLA7024M, SLA7026M, and SMA7029M

Sequence	0	1	2	3	4	5	6	7	0
Input A	H	H	L	L	L	L	L	H	H
Input $\overline{A}$ or t_{dA}*	L	L	L	H	H	H	L	L	L
Input B	L	H	H	H	L	L	L	L	L
Input $\overline{B}$ or t_{dB}*	L	L	L	L	L	H	H	H	L
Output(s) ON	A	AB	B	$\overline{A}$B	$\overline{A}$	$\overline{AB}$	$\overline{B}$	A$\overline{B}$	A

*Logic signals to external open-collector inverter connected to t_{dA} and t_{dB}.

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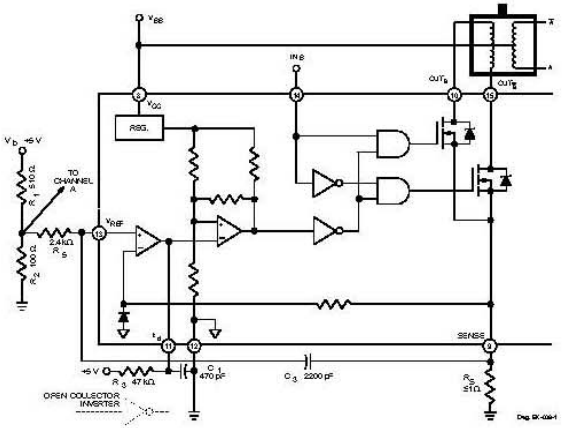
TYPICAL STEPPER MOTOR APPLICATIONS

(Half of Device Shown)

SMA7029M



TRUTH TABLES

(SMA7029M Only)

WAVE DRIVE (FULL STEP) for SMA7029M

Sequence	0	1	2	3	0
Input A	H	L	L	L	H
Input tdA*	L	L	H	L	L
Input B	L	H	L	L	L
Input tdB*	L	L	L	H	L
Output ON	A	B	$\overline{A}$	$\overline{B}$	A

*Logic signals to external open-collector inverter connected to t_{dA} and t_{dB}.

2-PHASE (FULL STEP) OPERATION for SMA7029M

Sequence	0	1	2	3	0
Input A	H	H	L	L	H
Input B	L	H	H	L	L
Outputs ON	A $\overline{B}$	AB	$\overline{A}$ B	$\overline{AB}$	A $\overline{B}$

SLA7024M, SLA7026M, AND SMA7029M
HIGH-CURRENT PWM,
UNIPOLAR STEPPER MOTOR
CONTROLLER/DRIVERS

APPLICATIONS INFORMATION

REGULATING THE PWM OUTPUT CURRENT

The output current (and motor coil current) waveform is illustrated in Figure 1. Setting the PWM current trip point requires various external components:

V_b = Reference supply (typically 5 V)

R_1, R_2 = Voltage-divider resistors in the reference supply circuit

R_S = Current sensing resistor(s)

NOTE: The maximum allowable V_{REF} input voltage is 2.0 V. The voltage-divider must be selected accordingly.

Normal PWM (Full-Current/Running) Mode

I_{OUT} is set to meet the specified running current for the motor (Figure 2) and is determined by:

$$I_{OUT} = \frac{V_{REF}}{R_S} \quad (1)$$

or, if V_{REF} is not known

$$I_{OUT} = \frac{R_2}{R_1 + R_2} \cdot \frac{V_b}{R_S} \quad (2)$$

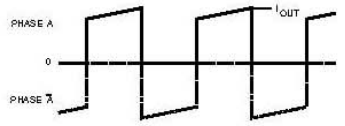


FIGURE 1. PHASE A COIL CURRENT WAVEFORM

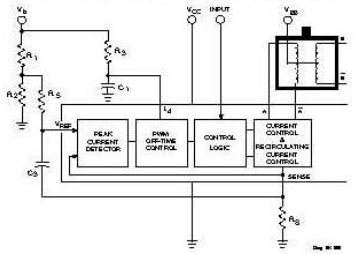


FIGURE 2. PWM CONTROL (RUN MODE)

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For given values of R_1, R_2, and V_b (V_{REF} = 0.82 V), Figure 3 illustrates output current as a function of current-sensing resistance (R_S).

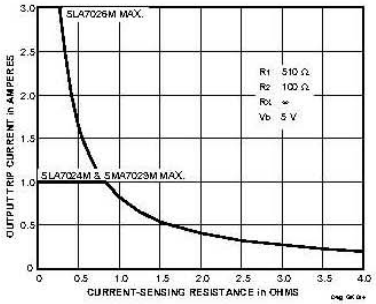

FIGURE 3. CURRENT-SENSING RESISTANCE

Reduced/Holding Current Mode

Additional circuitry (Figure 4) enables reducing motor current. The external transistor changes the voltage-divider ratio, V_{REF}, and reduces the output current. I_{HOLD} is determined by resistors R_2 and R_X in parallel:

$$I_{HOLD} = \frac{R_2 R_X}{R_1 R_2 + R_1 R_X + R_2 R_X} \cdot \frac{V_b}{R_S} \quad (3)$$

or

$$I_{HOLD} = \frac{R_2 \tilde{O}}{R_1 + R_2 \tilde{O}} \cdot \frac{V_b}{R_S} \quad (4)$$

where $R_2 \tilde{O}$ = the equivalent value of R_2 and R_X in parallel.

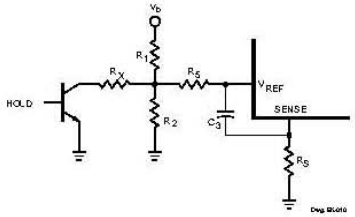

FIGURE 4. HOLD CURRENT MODE

SLA7024M, SLA7026M, AND SMA7029M
HIGH-CURRENT PWM,
UNIPOLAR STEPPER MOTOR
CONTROLLER/DRIVERS

For given values of R_1, R_2, and V_b (V_{REF} = 0.82 V), Figures 5A and 5B illustrate output holding current as a function of R_X for two values of current-sensing resistance (R_S).

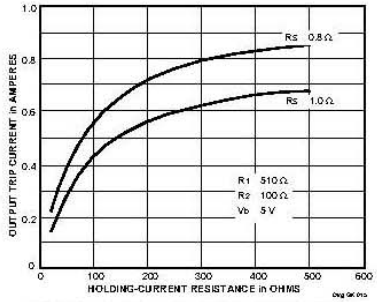

FIGURE 5A. HOLD-CURRENT RESISTANCE (SLA7024M and SMA7029M)

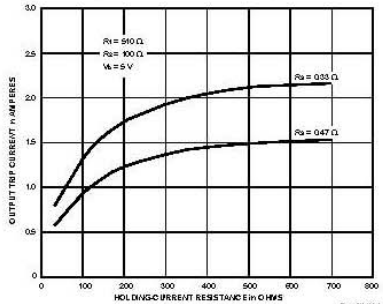

FIGURE 5B. HOLD-CURRENT RESISTANCE (SLA7026M)

NOTE: Holding current determines holding torque, which is normally greater than running torque. Consult motor manufacturer for recommended safe holding current and motor winding temperature limits in "standstill" or "detent" mode.

The MOSFET outputs create ringing noise with PWM, but the RC filter precludes malfunctions. The comparator operation is affected by R_S and C_3 and, thus, current overshoot is influenced by component values. Empirical adjustment to "fine-tune" the current limit is likely.

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DETERMINING THE MOTOR PWM FREQUENCY

The modules function asynchronously, with PWM OFF time fixed by R_d and C_1 at input t_d. The OFF time can be calculated as:

$$t_{OFF} = -R_d \cdot C_1 \cdot \log_n \left(1 - \frac{2}{V_b}\right) \quad (5)$$

Recommended circuit constants and t_{OFF} are:

V_b = 5 V
R_d = 47 kΩ
C_1 = 470 pF
t_{OFF} = 12 µs

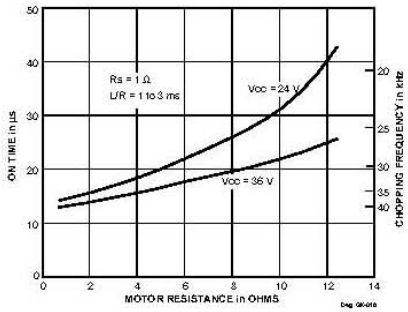

FIGURE 7.
PWM FREQUENCY vs MOTOR RESISTANCE

POWER DISSIPATION CALCULATIONS

Excepting high-current applications utilizing the SLA7026M above approximately 2.0 A at +65°C (with 2-phase operation), the need for heat sinks is rare. The basic constituents of conduction losses (internal power dissipation) include:

(a) FET output power dissipation ($I_{OUT}^2 \cdot r_{DS(on)}$ or $I_{OUT} \cdot V_{DS(ON)}$),
(b) FET body diode power dissipation ($V_{SD} \cdot I_{OUT}$), and
(c) control circuit power dissipation ($V_{CC} \cdot I_{CC}$).

Device conduction losses are calculated based on the operating mode (wave drive, half-step, or 2-phase). Assuming a 50% output duty cycle:

Wave Drive = $0.5\ (I_{OUT}^2 \cdot r_{DS(on)}) + 0.5\ (V_{SD} \cdot I_{OUT}) + (V_{CC} \cdot 15\ mA)$
Half-Step = $0.75\ (I_{OUT}^2 \cdot r_{DS(on)}) + 0.75\ (V_{SD} \cdot I_{OUT}) + (V_{CC} \cdot 15\ mA)$
2-Phase = $(I_{OUT}^2 \cdot r_{DS(on)}) + (V_{SD} \cdot I_{OUT}) + (V_{CC} \cdot 15\ mA)$

SLA7024M, SLA7026M, AND SMA7029M
HIGH-CURRENT PWM,
UNIPOLAR STEPPER MOTOR
CONTROLLER/DRIVERS

PACKAGE RATINGS/DERATING FACTORS

Thermal ratings/deratings for the multi-chip module packages vary slightly. Normally, the SLA7024M and SMA7029M do not need heat sinking when operated within maximum specified output current (≤1.0 A with 2-phase drive) unless the design ambient temperature also exceeds +60°C. Thermal calculations must also consider the temperature effects on the output FET ON resistance. The applicable thermal ratings for the PMCM packages are:

SLA7024M and SLA7026M 18-Lead Power-Tab SIP

$R_{\theta JA}$ = 28°C/W (no heat sink) or 4.5 W at +25°C and a derating factor of -36 mW/°C for operation above +25°C. $R_{\theta JC}$ = 5°C/W.

SMA7029M 15-Lead SIP

$R_{\theta JA}$ = 31°C/W (no heat sink) or 4.0 W at +25°C and a derating factor of -32 mW/°C for operation above +25°C. $R_{\theta JC}$ = 6°C/W.

TEMPERATURE EFFECTS ON FET $r_{DS(on)}$

Analyzing safe, reliable operation includes a concern for the relationship of NMOS ON resistance to junction temperature. Device package power calculations must include the increase in ON resistance (producing higher output ON voltages) caused by higher operating junction temperatures. Figure 8 provides a normalized ON resistance curve, and all thermal calculations should consider increases from the given +25°C limits, which may be caused by internal heating during normal operation.

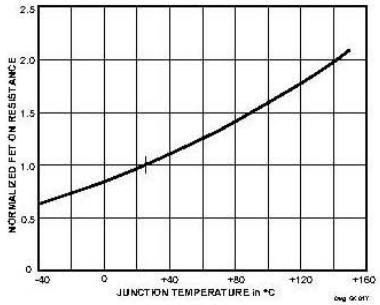

FIGURE 8. NORMALIZED ON RESISTANCE vs TEMPERATURE

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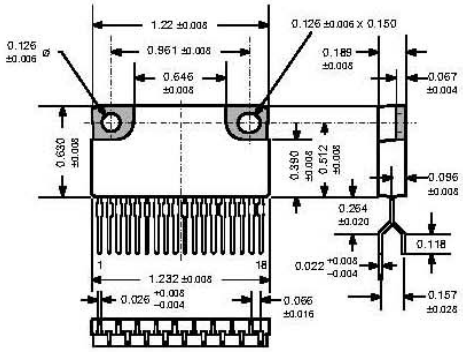
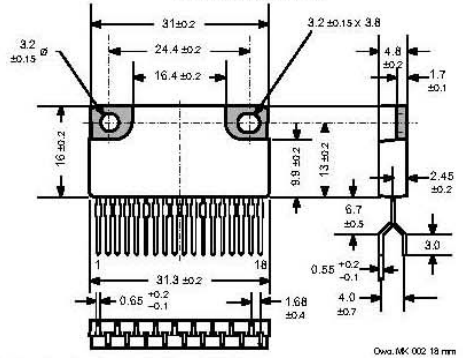
SLA7024M and SLA7026M
Dimensions in Inches
(for reference only)



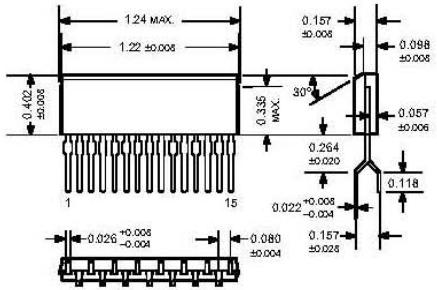
Dimensions in Millimeters
(controlling dimensions)



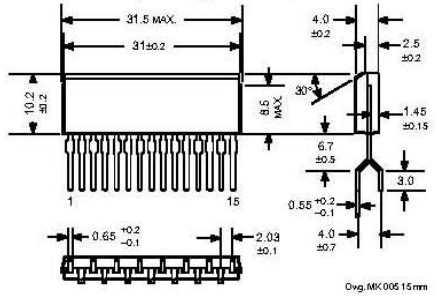
NOTES: 1. Exact body and lead configuration at vendor's option within limits shown.
2. Recommended mounting hardware torque: 4.34 – 5.79 lbf•ft (6 – 8 kgf•cm or 0.588 – 0.784 Nm).
3. The hatched area is exposed (electrically isolated) heat spreader.
4. Recommend use of metal-oxide-filled, alkyl-degenerated oil base, silicone grease (Dow Corning 340 or equivalent).

SLA7024M, SLA7026M, AND SMA7029M
HIGH-CURRENT PWM,
UNIPOLAR STEPPER MOTOR
CONTROLLER/DRIVERS

SMA7029M
Dimensions in Inches
(for reference only)



Dimensions in Millimeters
(controlling dimensions)



NOTE: Exact body and lead configuration at vendor's option within limits shown.

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Appendix B 3: RTC Data Sheet

DALLAS SEMICONDUCTOR

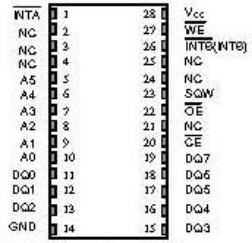
DS1286
Watchdog Timekeeper

www.dalsemi.com

FEATURES

- Keeps track of hundredths of seconds, seconds, minutes, hours, days, date of the month, months, and years; valid leap year compensation up to 2100
- Watchdog timer restarts an out-of-control processor
- Alarm function schedules real time-related activities
- Embedded lithium energy cell maintains time, watchdog, user RAM, and alarm information
- Programmable interrupts and square wave outputs maintain 28-pin JEDEC footprint
- All registers are individually addressable via the address and data bus
- Accuracy is better than ±1 minute/month at 25°C
- Greater than 10 years of timekeeping in the absence of V_{CC}
- 50 bytes of user NV RAM

PIN ASSIGNMENT



28-Pin Encapsulated Package
(720-Mil Flush)

PIN DESCRIPTION

$\overline{INTA}$	- Interrupt Output A (open drain)
$\overline{INTB}$ (INTB)	- Interrupt Output B (open drain)
A0-A5	- Address Inputs
DQ0-DQ7	- Data Input/Output
$\overline{CE}$	- Chip Enable
$\overline{OE}$	- Output Enable
$\overline{WE}$	- Write Enable
V_{CC}	- +5 Volts
GND	- Ground
NC	- No Connection
SQW	- Square Wave Output

DESCRIPTION

The DS1286 Watchdog Timekeeper is a self-contained real time clock, alarm, watchdog timer, and interval timer in a 28-pin JEDEC DIP package. The DS1286 contains an embedded lithium energy source and a quartz crystal which eliminates the need for any external circuitry. Data contained within 64 eight-bit registers can be read or written in the same manner as bytewide static RAM. Data is maintained in the Watchdog Timekeeper by intelligent control circuitry which detects the status of V_{CC} and write protects memory when V_{CC} is out of tolerance. The lithium energy source can maintain data and real time for over 10 years in the absence of V_{CC}. Watchdog Timekeeper information includes hundredths of seconds, seconds, minutes, hours, day, date, month, and year. The date at the end of the month is automatically

adjusted for months with less than 31 days, including correction for leap year. The Watchdog Timekeeper operates in either 24-hour or 12-hour format with an AM/PM indicator. The watchdog timer provides alarm windows and interval timing between 0.01 seconds and 99.99 seconds. The real time alarm provides for preset times of up to one week.

OPERATION - READ REGISTERS

The DS1286 executes a read cycle whenever $\overline{WE}$ (Write Enable) is inactive (High) and $\overline{CE}$ (Chip Enable) and $\overline{OE}$ (Output Enable) are active (Low). The unique address specified by the six address inputs (A0-A5) defines which of the 64 registers is to be accessed. Valid data will be available to the eight data output drivers within t_{ACC} (Access Time) after the last address input signal is stable, providing that $\overline{CE}$ and $\overline{OE}$ access times are also satisfied. If $\overline{OE}$ and $\overline{CE}$ access times are not satisfied, then data access must be measured from the latter occurring signal ($\overline{CE}$ or $\overline{OE}$) and the limiting parameter is either t_{CO} for $\overline{CE}$ or t_{OE} for $\overline{OE}$ rather than address access.

OPERATION - WRITE REGISTERS

The DS1286 is in the write mode whenever the $\overline{WE}$ (Write Enable) and $\overline{CE}$ (Chip Enable) signals are in the active (Low) state after the address inputs are stable. The latter occurring falling edge of $\overline{CE}$ or $\overline{WE}$ will determine the start of the write cycle. The write cycle is terminated by the earlier rising edge of $\overline{CE}$ or $\overline{WE}$. All address inputs must be kept valid throughout the write cycle. $\overline{WE}$ must return to the high state for a minimum recovery state (t_{WR}) before another cycle can be initiated. Data must be valid on the data bus with sufficient Data Set Up (t_{DS}) and Data Hold Time (t_{DH}) with respect to the earlier rising edge of $\overline{CE}$ or $\overline{WE}$. The $\overline{OE}$ control signal should be kept inactive (High) during write cycles to avoid bus contention. However, if the output bus has been enabled ($\overline{CE}$ and $\overline{OE}$ active), then $\overline{WE}$ will disable the outputs in t_{ODW} from its falling edge.

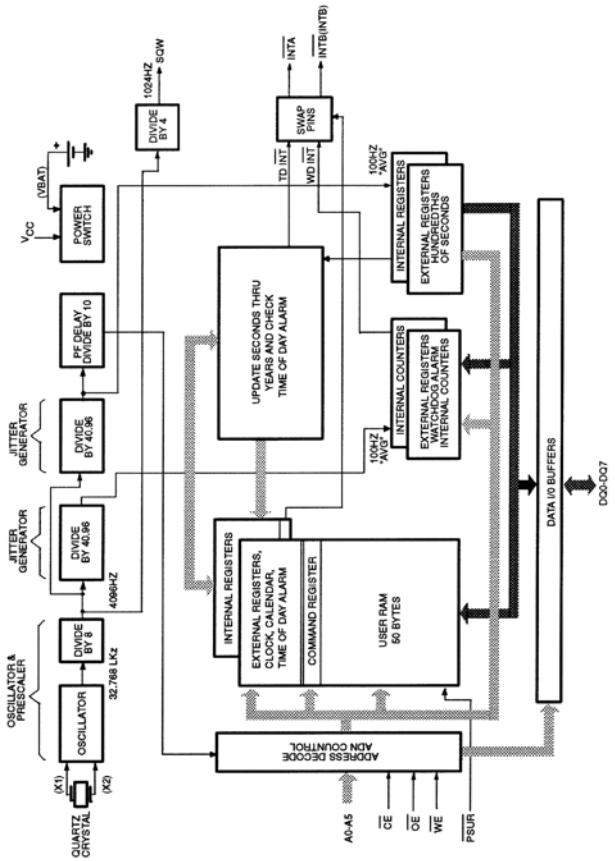
DATA RETENTION

The Watchdog Timekeeper provides full functional capability when V_{CC} is greater than 4.5 volts and write protects the register contents at 4.25 volts typical. Data is maintained in the absence of V_{CC} without any additional support circuitry. The DS1286 constantly monitors V_{CC}. Should the supply voltage decay, the Watchdog Timekeeper will automatically write protect itself and all inputs to the registers become "Don't Care." Both $\overline{INTA}$ and $\overline{INTB}$ (INTB) are open drain outputs. The two interrupts and the internal clock continue to run regardless of the level of V_{CC}. However, it is important to insure that the pull-up resistors used with the interrupt pins are never pulled up to a value which is greater than V_{CC} + 0.3V. As V_{CC} falls below approximately 3.0 volts, a power switching circuit turns on the lithium energy source to maintain the clock, and timer data functionality. It is also required to insure that during this time (battery backup mode), the voltage present at $\overline{INTA}$ and $\overline{INTB}$ (INTB) never exceeds 3.0V. At all times the current on each should not exceed +2.1 mA or -1.0 mA. However, if the active high mode is selected for $\overline{INTB}$ (INTB), this pin will only go high in the presence of V_{CC}. During power-up, when V_{CC} rises above approximately 3.0 volts, the power switching circuit connects external V_{CC} and disconnects the internal lithium energy source. Normal operation can resume after V_{CC} exceeds 4.5 volts for a period of 150 ms.

WATCHDOG TIMEKEEPER REGISTERS

The Watchdog Timekeeper has 64 registers which are 8 bits wide that contain all of the Timekeeping, Alarm, Watchdog, Control, and Data information. The Clock, Calendar, Alarm, and Watchdog registers are memory locations which contain external (user-accessible) and internal copies of the data. The external copies are independent of internal functions except that they are updated periodically by the simultaneous transfer of the incremented internal copy (see Figure 1). The Command Register bits are affected by both internal and external functions. This register will be discussed later. The 50 bytes of RAM registers can only be accessed from the external address and data bus. Registers 0, 1, 2, 4, 6, 8, 9, and A contain time of day and date information (see Figure 2). Time of Day information is stored in BCD. Registers 3, 5, and 7 contain the Time of Day Alarm information. Time of Day Alarm information is stored in BCD. Register B is the Command Register and information in this register is binary. Registers C and D are the Watchdog Alarm registers and information which is stored in these two registers is in BCD. Registers E through 3F are user bytes and can be used to contain data at the user's discretion.

BLOCK DIAGRAM Figure 1



DS1286 WATCHDOG TIMEKEEPER REGISTERS Figure 2

	ADDRESS	BIT 7						BIT 0	RANGE
CLOCK, CALENDAR, TIME OF DAY ALARM REGISTERS	0	0.1 SECONDS						0.01 SECONDS	00–99
	1	0	10 SECONDS					SECONDS	00–59
	2	0	10 MINUTES					MINUTES	00–59
	3	M	10 MIN ALARM					MIN ALARM	00–59
	4	0	12/24	10 A/P		10 HR		HOURS	01–12+A/P 00–23
	5	M	12/24	10 A/P		10 HR		HR ALARM	01–12+A/P 00–23
	6	0	0	0	0	0		DAYS	01–07
	7	M	0	0	0	0		DAY ALARM	01–07
	8	0	0	10 DATE				DATE	01–31
	9	EOSC	ESQW	0		10 MO		MONTHS	01–12
	A	10 YEARS						YEARS	00–99
COMMAND REGISTERS	B	TE	IPSW	IBH LO		PU LVL	WAM	TDM	WAF	TDF
WATCHDOG ALARM REGISTERS	C	0.1 SECONDS						0.01 SECONDS	00–99
(RETRIGGERABLE/ REPETITIVE COUNTDOWN ALARM)	D	10 SECONDS						SECONDS	00–99
USER REGISTERS	E								
	3F								

TIME OF DAY REGISTERS

Registers 0, 1, 2, 4, 6, 8, 9, and A contain Time of Day data in BCD. Ten bits within these eight registers are not used and will always read 0 regardless of how they are written. Bits 6 and 7 in the Months Register (9) are binary bits. When set to logic 0, $\overline{EOSC}$ (bit 7) enables the Real Time Clock oscillator. This bit is set to logic 1 as shipped from Dallas Semiconductor to prevent lithium energy consumption during storage and shipment. This bit will normally be turned on by the user during device initialization. However, the oscillator can be turned on and off as necessary by setting this bit to the appropriate level. Bit 6 of this same byte controls the Square Wave Output (Pin 23). When set to logic 0, the Square Wave Output pin will output a 1024 Hz Square Wave Signal. When set to logic 1 the Square Wave Output pin is in a high impedance state. Bit 6 of the Hours Register is defined as the 12- or 24- hour Select Bit. When set to logic 1, the 12-hour format is selected. In the 12-hour format, bit 5 is the AM/PM bit with logic 1 being PM. In the 24-hour mode, bit 5 is the second 10-hour bit (20-23 hours). The Time of Day registers are updated every .01 seconds from the real time clock, except when the TE bit (bit 7 of Register B) is set low or the clock oscillator is not running. The preferred method of synchronizing data access to and from the Watchdog Timekeeper is to access the Command Register by doing a write cycle to address location 0B and setting the TE bit (Transfer Enable) to a logic 0. This will freeze the External Time of Day registers at the present recorded time, allowing access to occur without danger of simultaneous update. When the watch registers have been read or written, a second write cycle to location 0B, setting the TE bit to a logic 1, will put the Time of Day registers back to being updated every 0.01 second. No time is lost in the real time clock because the internal copy of the Time of Day register buffers is continually incremented while the external memory registers are frozen.

An alternate method of reading and writing the Time of Day registers is to ignore synchronization. However, any single read may give erroneous data as the real time clock may be in the process of updating the external memory registers as data is being read. The internal copies of seconds through years are incremented and Time of Day Alarm is checked during the period that hundreds of seconds read 99 and are transferred to the external register when hundredths of seconds roll from 99 to 00. A way of making sure data is valid is to do multiple reads and compare. Writing the registers can also produce erroneous results for the same reasons. A way of making sure that the write cycle has caused proper update is to do read verifies and re-execute the write cycle if data is not correct. While the possibility of erroneous results from reads and write cycles has been stated, it is worth noting that the probability of an incorrect result is kept to a minimum due to the redundant structure of the Watchdog Timekeeper.

TIME OF DAY ALARM REGISTERS

Registers 3, 5, and 7 contain the Time of Day Alarm registers. Bits 3, 4, 5, and 6 of Register 7 will always read 0 regardless of how they are written. Bit 7 of Registers 3, 5, and 7 are mask bits (Figure 3). When all of the mask bits are logic 0, a Time of Day Alarm will only occur when Registers 2, 4, and 6 match the values stored in Registers 3, 5, and 7. An alarm will be generated every day when bit 7 of Register 7 is set to a logic 1. Similarly, an alarm is generated every hour when bit 7 of Registers 7 and 5 is set to a logic 1. When bit 7 of Registers 7, 5, and 3 is set to a logic 1, an alarm will occur every minute when Register 1 (seconds) rolls from 59 to 00.

Time of Day Alarm registers are written and read in the same format as the Time of Day registers. The Time of Day Alarm Flag and Interrupt is always cleared when Alarm registers are read or written.

WATCHDOG ALARM REGISTERS

Registers C and D contain the time for the Watchdog Alarm. The two registers contain a time count from to 99.99 seconds in BCD. The value written into the Watchdog Alarm Registers can be written or read in any order. Any access to Registers C or D will cause the Watchdog Alarm to reinitialize and clears the Watchdog Flag bit and the Watchdog Interrupt Output. When a new value is entered or the Watchdog Registers are read, the Watchdog Timer will start counting down from the entered value to 0. When 0 is reached, the Watchdog Interrupt Output will go to the active state. The Watchdog Timer countdown is interrupted and reinitialized back to the entered value every time either of the registers is accessed. In this manner, controlled periodic accesses to the Watchdog Timer can prevent the Watchdog Alarm from ever going to an active level. If access does not occur, countdown alarm will be repetitive. The Watchdog Alarm registers always read the entered value. The actual countdown register is internal and is not readable. Writing Registers C and D to 0 will disable the Watchdog Alarm feature.

COMMAND REGISTER

Address location 0B is the Command Register where mask bits, control bits, and flag bits reside. Bit 0 is the Time of Day Alarm Flag (TDF). When this bit is set internally to a logic 1, an alarm has occurred. The time of the alarm can be determined by reading the Time of Day Alarm registers. However, if the transfer enable bit is set to logic 0 the Time of Day registers may not reflect the exact time that the alarm occurred. This bit is read only and writing this register has no effect on the bit. The bit is reset when any of the Time of Day Alarm registers are read. Bit 1 is the Watchdog Alarm Flag (WAF). When this bit is set internally to a logic 1, a Watchdog Alarm has occurred. This bit is read only and writing this register has no effect on the bit. The bit is reset when any of the Watchdog Alarm registers are accessed. Bit 2 of the Command Register contains the Time of Day Alarm Mask Bit (TDM). When this bit is written to a logic 1, the Time of Day Alarm Interrupt Output is deactivated regardless of the value of the Time of Day Alarm Flag. When TDM is set to logic 0, the Time of Day Interrupt Output will go to the active state, which is determined by bits 0, 4, 5, and 6 of the Command Register. Bit 3 of the Command Register contains the Watchdog Alarm Mask bit (WAM). When this bit is written to a logic 1, the Watchdog Interrupt Output is deactivated regardless of the value in the Watchdog Alarm registers. When WAM is set to logic 0, the Watchdog Interrupt Output will go to the active state which is determined by bits 1, 4, 5, and 6 of the Command Register. These 4 bits define how Interrupt Output Pins $\overline{INTA}$ and $\overline{INTB}$ (INTB) will be operated. Bit 4 of the Command Register determines whether both interrupts will output a pulse or level when activated. If bit 4 is set to logic 1, the pulse mode is selected and $\overline{INTA}$ will sink current for a minimum of 3 ms and then release. Output $\overline{INTB}$ (INTB) will either sink or source current for a minimum of 3 ms depending on the level of bit 5. When bit 5 is set to logic 1, the B interrupt will source current. When bit 5 is set to logic 0, the B interrupt will sink current. Bit 6 of the Command Register directs which type of interrupt will be present on interrupt pins $\overline{INTA}$ or $\overline{INTB}$ (INTB). When set to logic 1, $\overline{INTA}$ becomes the Time of Day Alarm Interrupt pin and $\overline{INTB}$ (INTB) becomes the Watchdog Interrupt pin. When bit 6 is set to logic 0, the interrupt functions are reversed such that the Time of Day Alarm will be output on $\overline{INTB}$ (INTB) and the Watchdog Interrupt will be output on $\overline{INTA}$. Caution should be exercised when dynamically setting this bit as the interrupts will be reversed even if in an active state. Bit 7 of the Command Register is for Transfer Enable (TE). The function of this bit is described in the Time of Day registers.

TIME OF DAY ALARM MASK BITS Figure 3

REGISTER			
(3)MINUTES	(5)HOURS	(7)DAYS	
1	1	1	ALARM ONCE PER MINUTE
0	1	1	ALARM WHEN MINUTES MATCH
0	0	1	ALARM WHEN HOURS AND MINUTES MATCH
0	0	0	ALARM WHEN HOURS, MINUTES, AND DAYS MATCH

ABSOLUTE MAXIMUM RATINGS*

Voltage on Any Pin Relative to Ground	-0.3V to +7.0V
Operating Temperature	0°C to 70°C
Storage Temperature	-40°C to +70°C
Soldering Temperature	260°C for 10 seconds (See Note 14)

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

RECOMMENDED DC OPERATING CONDITIONS (0°C to 70°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Power Supply Voltage	V_{CC}	4.5	5.0	5.5	V	10
Input Logic 1	V_{IH}	2.2		V_{CC}+0.3	V	10
Input Logic 0	V_{IL}	-0.3		0.8	V	10

DC ELECTRICAL CHARACTERISTICS (0°C to 70°C; V_{CC} = 5V ± 10%)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Input Leakage Current	I_{IL}	-1.0		+1.0	µA	
Output Leakage Current	I_{LO}	-1.0		+1.0	µA	
I/O Leakage Current $\overline{CE} \geq V_{IH} \leq V_{CC}$	I_{LIO}	-1.0		+1.0	µA	
Output Current @ 2.4V	I_{OH}	-1.0			mA	
Output Current @ 0.4V	I_{OL}	2.0			mA	13
Standby Current $\overline{CE}$ = 2.2V	I_{CCS1}		3.0	7.0	mA	
Standby Current $\overline{CE}$ > V_{CC} -0.5	I_{CCS2}			4.0	mA	
Active Current	I_{CC}			15	mA	
Write Protection Voltage	V_{TP}		4.25		V	

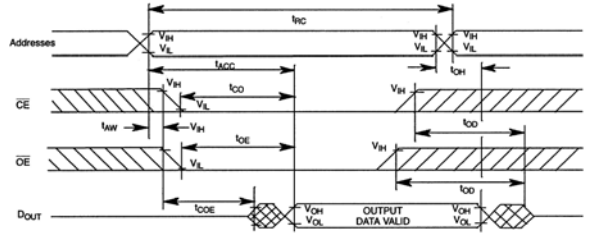
CAPACITANCE (t_A = 25°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Input Capacitance	C_{IN}		7	10	pF	
Output Capacitance	C_{OUT}		7	10	pF	
Input/Output Capacitance	$C_{I/O}$		7	10	pF	

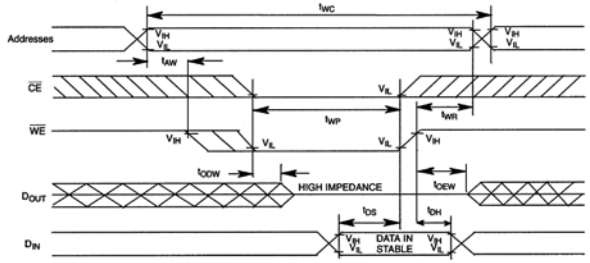
AC ELECTRICAL CHARACTERISTICS (0°C to 70°C; V_{CC} = 4.5V to 5.5V)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Read Cycle Time	t_{RC}	150			ns	1
Address Access Time	t_{ACC}			150	ns	
$\overline{CE}$ Access Time	t_{CO}			150	ns	
$\overline{OE}$ Access Time	t_{OE}			60	ns	
$\overline{OE}$ or $\overline{CE}$ to Output Active	t_{COE}	10			ns	
Output High Z from Deselect	t_{OD}			60	ns	
Output Hold from Address Change	t_{OH}	10			ns	
Write Cycle Time	t_{WC}	150			ns	
Write Pulse Width	t_{WP}	140			ns	3
Address Setup Time	t_{AW}	0			ns	
Write Recovery Time	t_{WR}	10			ns	
Output High Z from $\overline{WE}$	t_{ODW}			50	ns	
Output Active from $\overline{WE}$	t_{OEW}	10			ns	
Data Setup Time	t_{DS}	45			ns	4
Data Hold Time	t_{DH}	0			ns	4,5
$\overline{INTA}$, $\overline{INTB}$ Pulse Width	t_{IPW}	3			ns	11,12

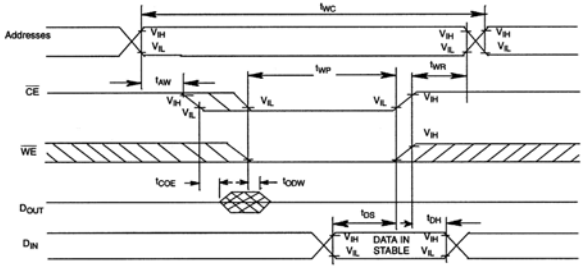
READ CYCLE (NOTE 1)



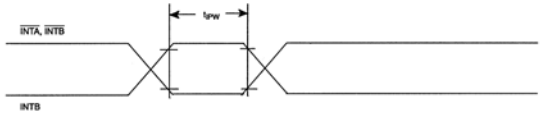
WRITE CYCLE 1 (Notes 2, 6, 7)



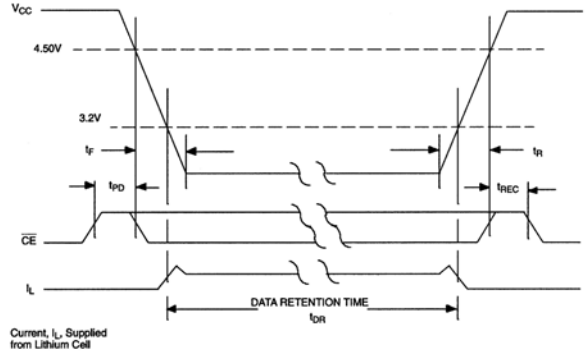
WRITE CYCLE 2 (Notes 2, 8)



TIMING DIAGRAM: INTERRUPT OUTPUTS PULSE MODE (SEE NOTES 11, 12)



POWER-DOWN/POWER-UP CONDITION



POWER-UP/POWER-DOWN CONDITION

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
$\overline{CE}$ at V_{IH} before Power-Down	t_{PD}	0			µs	
V_{CC} slew from 4.5V to 0V ($\overline{CE}$ at V_{IH})	t_F	350			µs	
V_{CC} slew from 0V to 4.5V ($\overline{CE}$ at V_{IH})	t_R	100			µs	
$\overline{CE}$ at V_{IH} after Power Up	t_{REC}			150	ns	

(t_A=25°C)

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Expected Data Retention Time	t_{DR}	10			years	9

WARNING:

Under no circumstances are negative undershoots, of any amplitude, allowed when device is in battery backup mode.

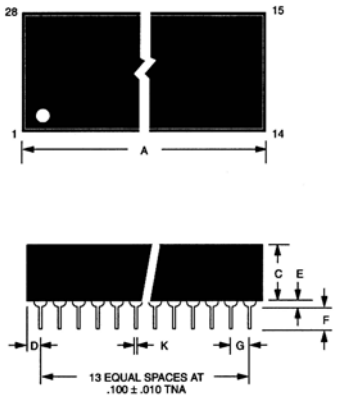
NOTES:

1. $\overline{WE}$ is high for a read cycle.
2. $\overline{OE}$ = V_{IH} or V_{IL}. If $\overline{OE}$ = V IH during write cycle, the output buffers remain in a high impedance state.
3. t_{WP} is specified as the logical AND of the $\overline{CE}$ and $\overline{WE}$. t_{WP} is measured from the latter of $\overline{CE}$ or $\overline{WE}$ going low to the earlier of $\overline{CE}$ or $\overline{WE}$ going high.
4. t_{DS} or t_{DH} are measured from the earlier of $\overline{CE}$ or $\overline{WE}$ going high.
5. t_{DH} is measured from $\overline{WE}$ going high. If $\overline{CE}$ is used to terminate the write cycle, then t_{DH} = 20 ns.
6. If the $\overline{CE}$ low transition occurs simultaneously with or later than the $\overline{WE}$ low transition in Write Cycle 1, the output buffers remain in a high impedance state during this period.
7. If the $\overline{CE}$ high transition occurs prior to or simultaneously with the $\overline{WE}$ high transition, the output buffers remain in a high impedance state during this period.
8. If $\overline{WE}$ is low or the $\overline{WE}$ low transition occurs prior to or simultaneously with the $\overline{CE}$ low transition, the output buffers remain in a high impedance state during this period.
9. Each DS1286 is marked with a four-digit date code AABB. AA designates the year of manufacture. BB designates the week of manufacture. The expected t_{DR} is defined as starting at the date of manufacture.
10. All voltages are referenced to ground.
11. Applies to both interrupt pins when the alarms are set to pulse.
12. Interrupt output occurs within 100 ns on the alarm condition existing.
13. Both $\overline{INTA}$ and $\overline{INTB}$ (INTB) are open drain outputs.
14. Real-Time Clock Modules can be successfully processed through conventional wave-soldering techniques as long as temperature exposure to the lithium energy source contained within does not exceed +85°C. Post-solder cleaning with water washing techniques is acceptable, provided that ultrasonic vibration is not used.

AC TEST CONDITIONS

Output Load: 100 pF + 1TTL Gate
Input Pulse Levels: 0-3.0V
Timing Measurement Reference Levels
Input: 1.5V
Output: 1.5V
Input Pulse Rise and Fall Times: 5 ns.

DS1286 WATCHDOG TIMEKEEPER



PKG	28-PIN	
DIM	MIN	MAX
A IN.	1.520	1.540
MM	38.61	39.12
B IN.	0.695	0.720
MM	17.65	18.29
C IN.	0.350	0.375
MM	8.89	9.52'
D IN.	0.100	0.130
MM	2.54	3.30
E IN.	0.015	0.030
MM	0.38	0.76
F IN.	0.110	0.140
MM	2.79	3.56
G IN.	0.090	0.110
MM	2.29	2.79
H IN.	0.590	0.630
MM	14.99	16.00
J IN.	0.008	0.012
MM	0.20	0.30
K IN.	0.015	0.021
MM	0.38	0.53

NOTE: PINS 2,3,21,24 AND 25 ARE MISSING BY DESIGN

Appendix B 4: Alarm Clock Chip Data Sheet

Ordering number: EN 3490B

PMOS LSI

SANYO No.3490B

LM8560N, 8560B

Digital Alarm Clock

Overview

Both the LM8560N and LM8560B are alarm equipped digital clock ICs with built-in drivers capable of directly driving LED display equipment. As ICs themselves, the V_{DD} pin for the LM8560N is graded to withstand a voltage of 15V while the LM8560B V_{DD} is graded for up to 17 V.

Applications

- Alarm clocks
- Clock-radios

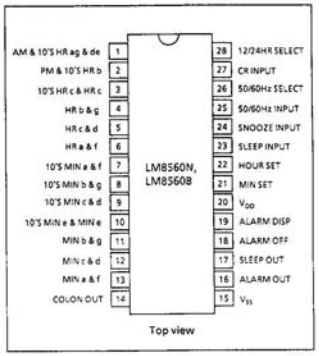
Functions

- Current time display
- Snooze alarm function
- Sleep timer function (maximum intervals of 59 minutes or 1 hour and 59 minutes)

Features

- Single chip P-channel ED MOS LSI
- LED direct drive using time division (duplex configuration)
- Wide operating power supply voltage range
- Built-in alarm function with 24-hour control
- Supports changeover between 12-hour AM/PM and 24-hour displays
- Built-in battery backup CR oscillator
- Uses 50Hz or 60Hz as standard frequency
- Built-in automatic fast forward function for hour and minute settings
- Built-in sleep timer function (maximum intervals for 59 minutes or 1 hour and 59 minutes)
- Built-in snooze function supporting repeat use
- Equipped with power failure display function
- 900Hz output for alarm tone

Pin Assignment

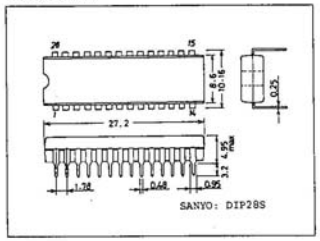


Top view

Package Dimensions

unit : mm

3029A-DIP28S



Description of Operations

- 50/60 Hz Input : Built-in Shumidt circuit enables noise elimination at 50/60Hz commercial frequencies with use of a simple CR filter. Built-in pull-up resistor.
- CR Input : When the AC power supply is interrupted, the time counter switches to a holding state and a built-in oscillator promptly begins operation. If 50/60Hz input continues for 3 clocks without arriving, this oscillator's output is activated and functions as the time counter clock in place of 50/60Hz input. The frequency level of this clock oscillator is determined according to the CR value. While the above mentioned oscillator is operating using backup mode, all segment output is switched to OFF.

  (Note) When the backup oscillator is in use due to an AC power supply interruption, the 50/60Hz input pin must be maintained open or at a V_{SS} level.
- 50/60 Selective Input : When 50/60 selective input is connected to V_{SS}, 50Hz use is enabled. When 50/60 selective input is left open, V_{DD} is activated using an internal pull-down resistor and the setting is switched to enable use at 60Hz.
- Display Mode Selective Input (Alarm Select/ Sleep Select):

  Since the pull-down resistor is built-in, selection from four display modes is possible using two SPST switches (single-pole and single-throw switches). Table 1 shows these display mode selections.

Table 1 Display Modes

Selective Input		Display Mode	Digit No. 1	Digit No. 2	Digit No. 3	Digit No.4
Alarm	Sleep					
NC	NC	Time display	10's place for hour, AM/PM	Hour	10's place for minute	Minute
V_{SS}	NC	Alarm display	10's place for hour, AM/PM	Hour	10's place for minute	Minute
NC	V_{SS}	Sleep display	Clear	Hour	10's place for minute	Minute
V_{SS}	V_{SS}	Second display	Clear	Minute	10's place for second	Second

Note: Activating V_{SS} using two inputs simultaneously (alarm select and sleep select), the display mode is switched to display seconds.

- Time Setting Input : There are two setting inputs for use with "hour" and "minute". Time content settings shown in Table 2 are possible by activating V_{SS} to these pins. A pull-down resistor is built-in.

Table 2 Setting Contents

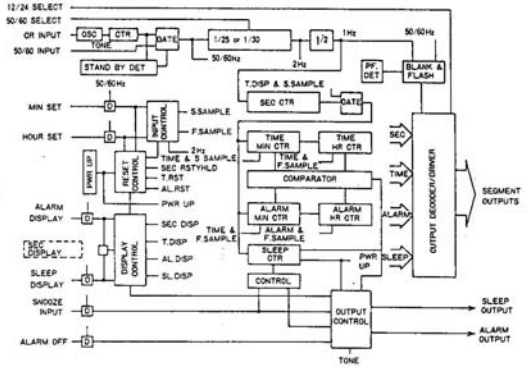
Display Mode	Set Input	Functions
Time	HOUR	Immediately adds 1 to hour digits and then assigns an additional 1, at a speed of 2 Hz, after each 1/4 to 3/4 second.
	MIN	Immediately adds 1 to minute digits and then assigns an additional 1, at a speed of 2 Hz, after each 1/4 to 3/4 second. Seconds are reset.
	BOTH	Operates both as outline above.
Second (Alarm & Sleep)	HOUR (Note)	Second digits are cleared to [00].
	MIN	Time holds.
	BOTH*	Resets hour and minute digits as [0:00] when operating in 24-H mode or [12:00] when operating in 12-H mode.
Alarm	HOUR	Immediately adds 1 to hour digits and then assigns an additional 1, at a speed of 2 Hz, after each 1/4 to 3/4 second.
	MIN	Immediately adds 1 to minute digits and then assigns an additional 1, at a speed of 2 Hz, after each 1/4 to 3/4 second.
	BOTH	Resets hour and minute digits to [0:00] when operating in 24-hour mode or [12:00] when operating in 12-hour mode.
Sleep	–	Sets sleep counter to [0:59] instantly when V_{DD} is activated to sleep select.
	HOUR	Sets sleep counter to [1:59] instantly when V_{DD} is activated to sleep select and hour at the same time.
	MIN	Sleep counter looses 1 at a speed of 2 Hz.
	BOTH	Sleep counter looses 1 at a speed of 2 Hz.

* Once conditions have been switched to reset or hold, input of other functions is locked until both HOUR and MIN input have been separated.

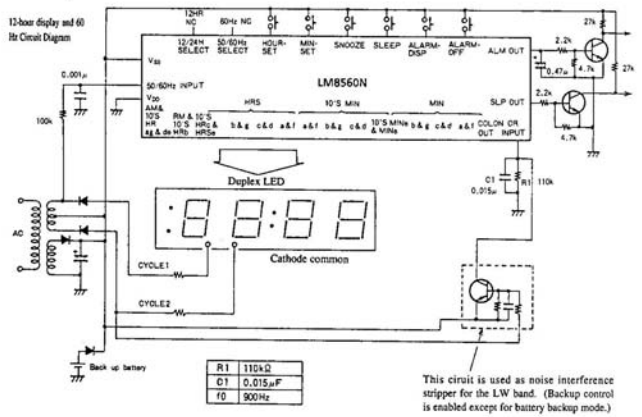
Note: When the digital reading for seconds is between 30 and 59 seconds, 1 is added to the digits for minutes as the digital reading for seconds resets to [00].

- 12/24H Select Input : When this pin is set open (V_{DD}), a 12-hour display is enabled whereas connecting this pin to V_{SS} enables the 24-hour display. A pull-down resistor is build-in.
- Power Failure Detection Display :
  When activated by drop in power supply, all segments which are lit begin to blink and the unit switches to a power failure detection display.
  The power failure detection display is canceled by activating V_{SS} to HOUR SET or MIN SET.
- Alarm Operation and Alarm Output :
  The alarm signal outputs when alarm content matches the content of current time. When not reset by either snooze input or alarm off input, output continues after 1 hour and 59 minutes. This output signal consists of 900 Hz 2 Hz intermittent (50% duty) modulation signals. When the need arises, a filter can be applied to alter the alarm signal to a DC signal.
- Snooze Input : When the alarm is sounding and instantly activating V_{SS} to this pin, alarm output is set to OFF for a period between 8 and 9 minutes after which time the alarm signal is once again output. The snooze function can be used repeatedly in 1 hour and 59 minutes intervals. A pull-down resistor is built-in. Activating V_{SS} to the snooze pin when the alarm is OFF resets the sleep timer counter to [0:00]. (This is known as the one-touch sleep timer reset function.)
- Alarm Off Input : Activating this input pin to V_{SS} instantly sets alarm output to OFF. A pull-down resistor is built-in.
- Sleep Timer and Sleep Output :
  Sleep output can turn on the radio and can be set for time intervals of 59 minutes or 1 hour and 59 minutes. Refer to Table 2 for the proper selection procedure (59 minutes or 1 hour and 59 minute selection). This sleep timer is constructed using a down counter and when the counter content arrives at [00], output is set to off and the radio turns off. Adding V_{SS} to snooze input turns sleep output off. When sleep output is on.

Block Diagram

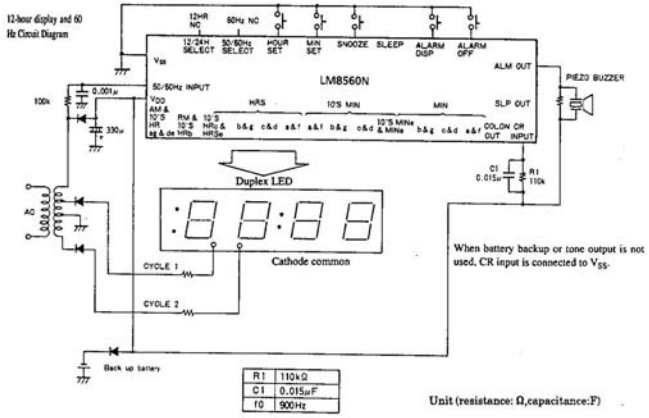


Clock-radio Applied Circuit Diagram (+ power supply)



Clock Applied Circuit Diagram (– power supply)

Unit (resistance: Ω,capacitance:F)



[LM8560N]

Specifications

Absolute Maximum Ratings at Ta = 25°C, V_{SS} = 0V

				unit
Maximum supply voltage	V_{DD} max		−15.0 to +0.3	V
Input voltage (1)	V_{IN} (1)	50/60Hz INPUT	−15.0 to +0.3	V
Input voltate (2)	V_{IN} (2)	Except 50/60Hz INPUT	−15.0 to +0.3	V
Output voltage	V_{OUT}		−15.0 to +0.3	V
Input clamp current	I_{IN}	50/60Hz INPUT	−0.4 to +0.4	mA
Allowable power dissipation	Pd max	Ta = 70°C	0.7	W
Operating temperarure	Topr		−30 to +70	°C
Storage temperature	Tstg		−55 to +125	°C

Allowable Operating Ranges at Ta = 25°C, V_{SS} = 0V

			min	typ	max	unit
Supply voltage	V_{DD}		−14.0		−7.5	V
Input "H" level voltage (1)	V_{IH} (1)	50/60Hz INPUT	−1.0			V
Input "L" level voltage (1)	V_{IL} (1)	50/60Hz INPUT			V_{DD} +2	V
Input "H" level voltage (2)	V_{IH} (2)	Except 50/60Hz INPUT	−1.5			V
Input "L" level voltage (2)	V_{IL} (2)	Except 50/60Hz INPUT			V_{DD} +2	V
50/60Hz input pin input voltage	V_{AC}-IN (Note 1)	Sets V_{SS} as reference (Note 2)	V_{LED} (Note 1)			V

Electrical Characteristics at Ta = 25°C, V_{DD} = −12V

			min	typ	max	unit
Input "H" level current (1)	I_{IH} (1)	50/60Hz INPUT, $V_{IN} = V_{SS}$			10	μA
Input "L" level current (1)	I_{IL} (1)	50/60Hz INPUT, $V_{IN} = V_{DD}$			10	μA
Input "H" level current (2)	I_{IH} (2)	Input pins other than 50/60 Hz input $V_{IN} = V_{SS}$			20	μA
Input "L" level current (2)	I_{IL} (2)	Input pins other than 50/60 Hz input $V_{IN} = V_{DD}$			10	μA
Output "H" level current (1)	I_{OH} (1)	Alarm output and sleep output $V_{OH} = V_{SS}$ −1V	5			mA
Output leakage current (1)	I_{OF} (1)	Alarm output and sleep output $V_{OUT} = V_{DD}$			10	μA
Output "H" level current (2)	I_{OH} (2)	AM & 10'S HR ag & de (24Hmode), $V_{OUT} = V_{DD}$ −1V	36			mA
Output leakage current (2)	I_{OF} (2)	AM & 10'S HR ag & de (24Hmode), $V_{OUT} = V_{DD}$			20	μA
Output "H" level current (3)	I_{OH} (3)	Segment output other than those listed above, $V_{OUT} = V_{SS}$−1V	18			mA
Output leakage current (3)	I_{OF} (3)	Segment output other than those listed above, $V_{OUT} = V_{DD}$			20	μA
Power failure detection voltage	V_{DD}		−7.5	−5.0		V
Consumption current	I_{CC}	Output set to off and pull-down attached input set open		5	7	mA
Backup oscillator stability factor	Fs	Standard value, 900Hz, V_{DD} = −9V±10%	−10		10	%
Backup oscillator accuracy	Fa	Standard value, 900Hz, V_{DD} = −9V	−10		10	%

[LM8560B]

Specifications

Absolute Maximum Ratings at Ta = 25°C, V_{SS} = 0V

				unit
Maximum supply voltage	V_{DD} max		−17.0 to +0.3	V
Input voltage (1)	V_{IN} (1)	50/60Hz INPUT	−17.0 to +0.3	V
Input voltate (2)	V_{IN} (2)	50/60Hz INPUT	−17.0 to +0.3	V
Output voltage	V_{OUT}		−17.0 to +0.3	V
Input clamp current	I_{IN}	50/60Hz INPUT	−0.4 to +0.4	mA
Allowable power dissipation	Pd max	Ta = 70°C	0.7	W
Operating temperature	Topr		−30 to +70	°C
Storage temperature	Tstg		−55 to +125	°C

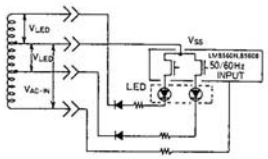
Allowable Operating Ranges at Ta = 25°C, V_{SS} = 0V

			min	typ	max	unit
Supply voltage	V_{DD}		−14.0		−6.5	V
Input "H" level voltage (1)	V_{IH} (1)	50/60Hz INPUT	−1.0			V
Input "L" level voltage (1)	V_{IL} (1)	50/60Hz INPUT, $V_{DD} \leqq -8V$			V_{DD} +2	V
		50/60Hz INPUT, $V_{DD} > -8V$			V_{DD} +1	V
Input "H" level voltage (2)	V_{IH} (2)	Except 50/60Hz INPUT, $V_{DD} \leqq -8V$	−1.5			V
		Except 50/60Hz INPUT, $V_{DD} > -8V$	−1.0			V
Input "L" level voltage (2)	V_{IL} (2)	Except 50/60Hz INPUT, $V_{DD} \leqq -8V$			V_{DD} +2	V
		Except 50/60Hz INPUT, $V_{DD} > -8V$			V_{DD} +1	V
50/60Hz input pin input voltage	V_{AC}-IN (Note 1)	Sets V_{SS} as reference (Note 2)	V_{LED} (Note 1)			V

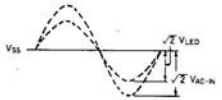
Electrical Characteristics at Ta = 25°C, V_{DD} = −12V

			min	typ	max	unit
Input "H" level current (1)	I_{IH} (1)	50/60Hz INPUT, $V_{IN} = V_{SS}$			2	μA
Input "L" level current (1)	I_{IL} (1)	50/60Hz INPUT, $V_{IN} = V_{DD}$			10	μA
Input "H" level current (2)	I_{IH} (2)	Input pins other than 50/60 Hz input $V_{IN} = V_{SS}$			20	μA
Input "L" level current (2)	I_{IL} (2)	Input pins other than 50/60 Hz input $V_{IN} = V_{DD}$			2	μA
Output "H" level current (1)	I_{OH} (1)	Alarm output and sleep output $V_{OH} = V_{SS}$−1V	5			mA
Output leakage current (1)	I_{OF} (1)	Alarm output and sleep output $V_{OUT} = V_{DD}$			10	μA
Output "H" level current (2)	I_{OH} (2)	AM & 10'S HR ag & de (24Hmode), $V_{OUT} = V_{SS}$ −1V	36			mA
Output leakage current (2)	I_{OF} (2)	AM & 10'S HR ag & de (24Hmode), $V_{OUT} = V_{DD}$			20	μA
Output "H" level current (3)	I_{OH} (3)	Segment output other than those listed above, $V_{OUT} = V_{SS}$−1V	18			mA
Output leakage current (3)	I_{OF} (3)	Segment output other than those listed above, $V_{OUT} = V_{DD}$			20	μA
Power failure detection voltage	V_{DD}		−6.5	−5.0		V
Consumption current	I_{CC}	Output set to off and pull-down attached input set open		5	7	mA
Backup oscillator stability factor	Fs	Standard value, 900Hz, V_{DD} = −9V±10%	−10		10	%
Backup oscillator accuracy	Fa	Standard value, 900Hz, V_{DD} = −9V	−10		10	%

(Note 1)



(Note 2)



[Fig. 2]

V_{AC-IN} represents the average value for input voltage of the 50/60 Hz input pin.
V_{LED} represents the average value for power supply voltage for LED usage.
The above values represent those gained under no-load conditions.

[Fig. 1]

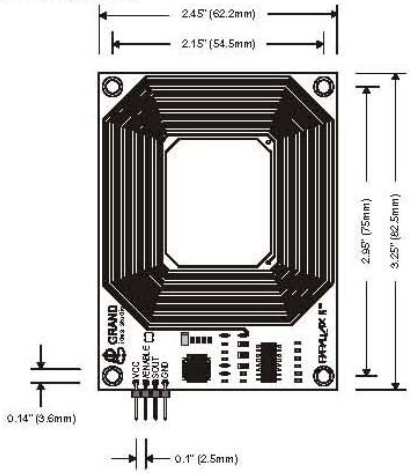
Appendix B 5: RFID Reader/Tag Data Sheet

PARALLAX
599 Menlo Drive, Suite 100
Rocklin, California 95765, USA
Office: (916) 624-8333
Fax: (916) 624-8003

General: info@parallax.com
Technical: support@parallax.com
Web Site: www.parallax.com
Educational: www.stampsinclass.com

RFID Reader Module (#28140)

RFID 54 mm x 85 mm Rectangle Tag (#28141)
RFID 50 mm Round Tag (#28142)



Introduction

Designed in cooperation with Grand Idea Studio (http://www.grandideastudio.com/), the Parallax Radio Frequency Identification (RFID) Reader Module is the first low-cost solution to read passive RFID transponder tags up to 1 ¾" - 3" inches away depending on the tag (see list below). The RFID Reader Module can be used in a wide variety of hobbyist and commercial applications, including access control, automatic identification, robotics navigation, inventory tracking, payment systems, and car immobilization.

- Fully-integrated, low-cost method of reading passive RFID transponder tags
- 1-wire, 2400 baud Serial TTL interface to PC, BASIC Stamp® and other processors
- Requires single +5VDC supply
- Bi-color LED for visual indication of activity
- 0.100" pin spacing for easy prototyping and integration

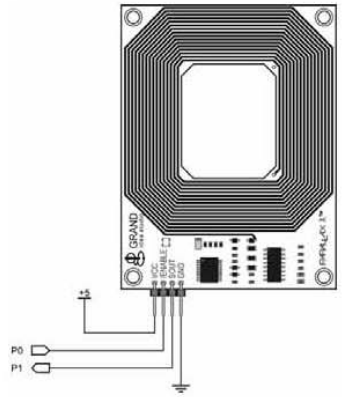
The Parallax RFID Reader Module works exclusively with the EM Microelectronics-Marin SA EM4100-family of passive read-only transponder tags. A variety of different tag types and styles exist with the most popular made available from Parallax. Each transponder tag contains a unique identifier (one of 2^{40}, or 1,099,511,627,776, possible combinations) that is read by the RFID Reader Module and transmitted to the host via a simple serial interface.

Electronic Connections

The Parallax RFID Reader Module can be integrated into any design using only four connections (VCC, /ENABLE, SOUT, GND). Use the following circuit for connecting the Parallax RFID Reader Module to the BASIC Stamp microcontroller:

Pin	Pin Name	Type	Function
1	VCC	P	System power, +5V DC input.
2	/ENABLE	I	Module enable pin. Active LOW digital input. Bring this pin LOW to enable the RFID reader and activate the antenna.
3	SOUT	O	Serial Out. TTL-level interface, 2400bps, 8 data bits, no parity, 1 stop bit.
4	GND	G	System ground. Connect to power supply's ground (GND) terminal.

Note: Type: I = Input, O = Output, P = Power, G = Ground



Communication Protocol

Implementation and usage of the RFID Reader Module is straightforward. BASIC Stamp 1, 2, and SX28AC/DP code examples (SX/B) are included at the end of this documentation.

The RFID Reader Module is controlled with a single TTL-level active-low /ENABLE pin. When the /ENABLE pin is pulled LOW, the module will enter its active state and enable the antenna to interrogate for tags. The current consumption of the module will increase dramatically when the module is active.

A visual indication of the state of the RFID Reader Module is given with the on-board LED. When the module is successfully powered-up and is in an idle state, the LED will be GREEN. When the module is in an active state and the antenna is transmitting, the LED will be RED.

The face of the RFID tag should be held parallel to the front or back face of the antenna (where the majority of RF energy is focused). If the tag is held sideways (perpendicular to the antenna) you'll either get no reading or a poor reading. Only one transponder tag should be held up to the antenna at any time. The use of multiple tags at one time will cause tag collisions and confuse the reader. The two tags available in the Parallax store have a read distance of approximately 3 inches. Actual distance may vary slightly depending on the size of the transponder tag and environmental conditions of the application.

When a valid RFID transponder tag is placed within range of the activated reader, the unique ID will be transmitted as a 12-byte ASCII string via the TTL-level SOUT (Serial Output) pin in the following format:

MSB LSB

Start Byte (0x0A)	Unique ID Digit 1	Unique ID Digit 2	Unique ID Digit 3	Unique ID Digit 4	Unique ID Digit 5	Unique ID Digit 6	Unique ID Digit 7	Unique ID Digit 8	Unique ID Digit 9	Unique ID Digit 10	Stop Byte (0x0D)

The start byte and stop byte are used to easily identify that a correct string has been received from the reader (they correspond to a line feed and carriage return characters, respectively). The middle ten bytes are the actual tag's unique ID.

All communication is 8 data bits, no parity, 1 stop bit, non-inverted, least significant bit first (8N1). The baud rate is configured for 2400bps, a standard communications speed supported by most any microprocessor or PC, and cannot be changed. The Parallax RFID Reader Module initiates all communication. The Parallax RFID Reader Module can connect directly to any TTL-compatible UART or to an RS232-compatible interface by using an external level shifter.

Absolute Maximum Ratings and Electrical Characteristics

Condition	Value
Operating Temperature	-40°C to +85°C
Storage Temperature	-55°C to +125°C
Supply Voltage (V_{CC})	+4.5V to +5.5V
Ground Voltage (V_{SS})	0V
Voltage on any pin with respect to V_{SS}	-0.3V to +7.0V

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

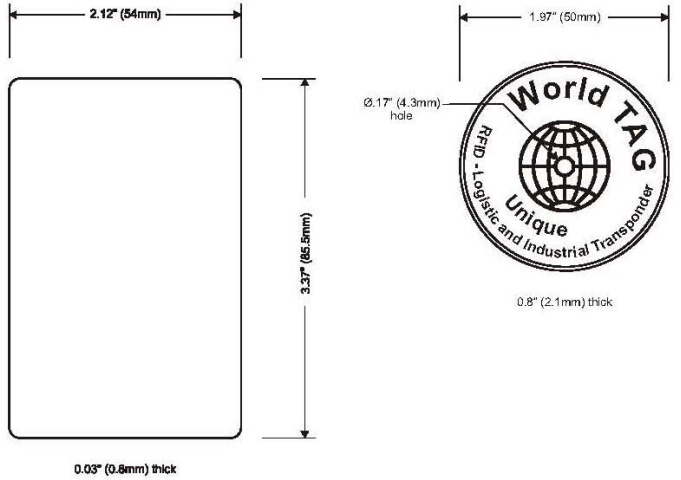
At V_{CC} = +5.0V and T_A = 25°C unless otherwise noted

Parameter	Symbol	Test Conditions	Specification Min.	Typ.	Max.	Unit
Supply Voltage	V_{CC}	—	4.5	5.0	5.5	V
Supply Current, Idle	I_{IDLE}	—	—	10	---	mA
Supply Current, Active	I_{CC}	—	—	90	---	mA
Input LOW voltage	V_{IL}	+4.5V <= V_{CC} <= +5.5V	—	—	0.8	V
Input HIGH voltage	V_{IH}	+4.5V <= V_{CC} <= +5.5V	2.0	—	---	V
Output LOW voltage	V_{OL}	V_{CC} = +4.5V	—	—	0.6	V
Output HIGH voltage	V_{OH}	V_{CC} = +4.5V	V_{CC} - 0.7	—	---	V

RFID Tags Available From Parallax

Parallax provides two passive RFID tags from our on-line store. We're stocking the tags because many suppliers have high minimums, yet many of our customers may only want a few tags for their basic experimentation.

- 54 mm x 85 mm Rectangle Tag (#28141)
- 50 mm Round Tag (#28142)



Actual tag dimensions may vary. Contact Parallax for specific information.

Optional Tag Information

Even though Parallax only carries a Round Tag and a Rectangle Tag the following values were obtained from different tags available in the market.

ISO Card:	6.3cm (2.5") +/- 10%
World Tag 50mm:	6.8cm (2.7") +/- 10%
World Tag 30mm:	5.3cm (2.1") +/- 10%
Bobsleigh Keyfob:	5.3cm (2.1") +/- 10%
Tear shape:	4.0cm (1.6") +/- 10%
Wristband:	4.0cm (1.6") +/- 10%

RFID Technology Overview

Material in this section is based on information provided by the RFID Journal (www.rfidjournal.com).

Radio Frequency Identification (RFID) is a generic term for non-contacting technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a unique serial number that identifies a person or object on a microchip that is attached to an antenna. The combined antenna and microchip are called an "RFID transponder" or "RFID tag" and work in combination with an "RFID reader" (sometimes called an "RFID interrogator").

An RFID system consists of a reader and one or more tags. The reader's antenna is used to transmit radio frequency (RF) energy. Depending on the tag type, the energy is "harvested" by the tag's antenna and used to power up the internal circuitry of the tag. The tag will then modulate the electromagnetic waves generated by the reader in order to transmit its data back to the reader. The reader receives the modulated waves and converts them into digital data. In the case of the Parallax RFID Reader Module, correctly received digital data is sent serially through the SOUT pin.

There are two major types of tag technologies. "Passive tags" are tags that do not contain their own power source or transmitter. When radio waves from the reader reach the chip's antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag (known as "parasitic power"). The tag is then able to send back any information stored on the tag by reflecting the electromagnetic waves as described above. "Active tags" have their own power source and transmitter. The power source, usually a battery, is used to run the microchip's circuitry and to broadcast a signal to a reader. Due to the fact that passive tags do not have their own transmitter and must reflect their signal to the reader, the reading distance is much shorter than with active tags. However, active tags are typically larger, more expensive, and require occasional service. The RFID Reader Module is designed specifically for low-frequency (170 kHz) passive tags.

Frequency refers to the size of the radio waves used to communicate between the RFID system components. Just as you tune your radio to different frequencies in order to hear different radio stations, RFID tags and readers have to be tuned to the same frequency in order to communicate effectively. RFID systems typically use one of the following frequency ranges: low frequency (or LF, around 170 kHz), high frequency (or HF, around 13.56 MHz), ultra-high frequency (or UHF, around 868 and 928 MHz), or microwave (around 2.45 and 5.8 GHz). It is generally safe to assume that a higher frequency equates to a faster data transfer rate and longer read ranges, but also more sensitivity to environmental factors such as liquid and metal that can interfere with radio waves.

There really is no such thing as a "typical" RFID tag. The read range of a tag ultimately depends on many factors: the frequency of RFID system operation, the power of the reader, and interference from other RF devices. Balancing a number of engineering trade-offs (antenna size v. reading distance v. power v.

manufacturing cost), the Parallax RFID Reader Module's antenna was designed with a specific inductance and "Q" factor for 170kHz RFID operation at a tag read distance of up to 1 ¾" - 3" inches.

Example Code

The following code examples read tags from a RFID Reader Module and compare the values to known tags (stored in an EEPROM table).

```
' =============================================================================
'
'   File....... RFID.BS1
'   Purpose.... RFID Tag Reader / Simple Security System
'   Author..... (c) Parallax, Inc. -- All Rights Reserved
'   E-mail..... support@parallax.com
'   Started....
'   Updated.... 07 FEB 2005
'
'   {$STAMP BS1}
'   {$PBASIC 1.0}
'
' =============================================================================


' -----[ Program Description ]---------------------------------------------
'
' Reads tags from a Parallax RFID reader and compares to known tags (stored
' in EEPROM table).  If tag is found, the program will disable a lock.


' -----[ Revision History ]------------------------------------------------


' -----[ I/O Definitions ]-------------------------------------------------

SYMBOL  Enable          = 0                     ' low = reader on
SYMBOL  RX              = 1                     ' serial from reader
SYMBOL  Spkr            = 2                     ' speaker output
SYMBOL  Latch           = 3                     ' lock/latch control


' -----[ Constants ]-------------------------------------------------------

SYMBOL  LastTag         = 2                     ' 3 tags; 0 to 2


' -----[ Variables ]-------------------------------------------------------

SYMBOL  tag0            = B0                    ' RFID bytes buffer
SYMBOL  tag1            = B1
SYMBOL  tag2            = B2
SYMBOL  tag3            = B3
SYMBOL  tag4            = B4
SYMBOL  tag5            = B5
SYMBOL  tag6            = B6
SYMBOL  tag7            = B7
SYMBOL  tag8            = B8
SYMBOL  tag9            = B9

SYMBOL  tagNum          = B10                   ' from EEPROM table
SYMBOL  pntr            = B11                   ' pointer to char in table
SYMBOL  char            = B12                   ' character from table
```

```
' -----[ EEPROM Data ]---------------------------------------------------

Tags:
  EEPROM ("0F0184F20B")                         ' valid tags
  EEPROM ("0F01D9D263")
  EEPROM ("04129C1B43")
  EEPROM ("0000000000")                         ' space for other tags
  EEPROM ("0000000000")


' -----[ Initialization ]-------------------------------------------------

Reset:
  HIGH Enable                                   ' turn of RFID reader
  LOW Latch                                     ' lock the door!


' -----[ Program Code ]---------------------------------------------------

Main:
  LOW Enable                                    ' activate the reader
  SERIN RX, T2400, ($0A)                        ' wait for header
  SERIN RX, T2400, tag0, tag1, tag2, tag3, tag4 ' get tag bytes
  SERIN RX, T2400, tag5, tag6, tag7, tag8, tag9
  HIGH Enable                                   ' deactivate reader

Check_List:
  FOR tagNum = 0 TO LastTag                     ' scan through known tags
    pntr = tagNum * 10 + 0 : READ pntr, char    ' read char from DB
    IF char <> tag0 THEN Bad_Char               ' compare with tag data
    pntr = tagNum * 10 + 1 : READ pntr, char
    IF char <> tag1 THEN Bad_Char
    pntr = tagNum * 10 + 2 : READ pntr, char
    IF char <> tag2 THEN Bad_Char
    pntr = tagNum * 10 + 3 : READ pntr, char
    IF char <> tag3 THEN Bad Char
    pntr = tagNum * 10 + 4 : READ pntr, char
    IF char <> tag4 THEN Bad_Char
    pntr = tagNum * 10 + 5 : READ pntr, char
    IF char <> tag5 THEN Bad_Char
    pntr = tagNum * 10 + 6 : READ pntr, char
    IF char <> tag6 THEN Bad_Char
    pntr = tagNum * 10 + 7 : READ pntr, char
    IF char <> tag7 THEN Bad_Char
    pntr = tagNum * 10 + 8 : READ pntr, char
    IF char <> tag8 THEN Bad Char
    pntr = tagNum * 10 + 9 : READ pntr, char
    IF char <> tag9 THEN Bad_Char
    GOTO Tag_Found                              ' all match -- good tag
Bad_Char:
  NEXT

Bad_Tag:
  SOUND Spkr, (25, 80)                          ' groan
  PAUSE 1000
  GOTO Main

Tag_Found:
  DEBUG #tagNum, CR                             ' for testing
  HIGH Latch                                    ' remove latch
  SOUND Spkr, (114, 165)                        ' beep
  LOW Latch                                     ' restore latch
```



```
  GOTO Main

  END
' ============================================================================
'
'   File.....  RFID.BS2
'   Purpose...  RFID Tag Reader / Simple Security System
'   Author....  (c) Parallax, Inc. -- All Rights Reserved
'   E-mail....  support@parallax.com
'   Started...
'   Updated...  07 FEB 2005
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' ============================================================================


' -----[ Program Description ]--------------------------------------------
'
' Reads tags from a Parallax RFID reader and compares to known tags (stored
' in EEPROM table).  If tag is found, the program will disable a lock.


' -----[ Revision History ]-----------------------------------------------


' -----[ I/O Definitions ]------------------------------------------------

Enable          PIN     0                       ' low = reader on
RX              PIN     1                       ' serial from reader
Spkr            PIN     2                       ' speaker output
Latch           PIN     3                       ' lock/latch control


' -----[ Constants ]-----------------------------------------------------

#SELECT $STAMP
  #CASE BS2, BS2E, BS2PE
    T1200       CON     813
    T2400       CON     396
    T4800       CON     188
    T9600       CON     84
    T19K2       CON     32
    TMidi       CON     12
    T38K4       CON     6
  #CASE BS2SX, BS2P
    T1200       CON     2063
    T2400       CON     1021
    T4800       CON     500
    T9600       CON     240
    T19K2       CON     110
    TMidi       CON     60
    T38K4       CON     45
  #CASE BS2PX
    T1200       CON     3313
    T2400       CON     1646
    T4800       CON     813
    T9600       CON     396
    T19K2       CON     188
    TMidi       CON     108
    T38K4       CON     84
#ENDSELECT
```

```
SevenBit        CON     $2000
Inverted        CON     $4000
Open            CON     $8000
Baud            CON     T2400


#SELECT $STAMP
  #CASE BS2, BS2E
    TmAdj       CON     $100                ' x 1.0 (time adjust)
    FrAdj       CON     $100                ' x 1.0 (freq adjust)
  #CASE BS2SX
    TmAdj       CON     $280                ' x 2.5
    FrAdj       CON     $066                ' x 0.4
  #CASE BS2P
    TmAdj       CON     $3C5                ' x 3.77
    FrAdj       CON     $044                ' x 0.265
  #CASE BS2PE
    TmAdj       CON     $100                ' x 1.0
    FrAdj       CON     $0AA                ' x 0.665
  #CASE BS2Px
    TmAdj       CON     $607                ' x 6.03
    FrAdj       CON     $2A                 ' x 0.166
#ENDSELECT
```

```
LastTag         CON     3


#DEFINE   No SPRAM = ($STAMP < BS2P)            ' does module have SPRAM?


' -----[ Variables ]------------------------------------------------------

#IF   No SPRAM #THEN
  buf           VAR     Byte(10)              ' RFID bytes buffer
#ELSE
  chkChar       VAR     Byte                  ' character to test
#ENDIF

tagNum          VAR     Nib                   ' from EEPROM table
idx             VAR     Byte                  ' tag byte index
char            VAR     Byte                  ' character from table


' -----[ EEPROM Data ]----------------------------------------------------

Tag1            DATA    "0F0184F20B"          ' valid tags
Tag2            DATA    "0F01D9D263"
Tag3            DATA    "04129C1B43"

Name0           DATA    "Unauthorized", CR, 0
Name1           DATA    "George Johnston", CR, 0
Name2           DATA    "Dick Miller", CR, 0
Name3           DATA    "Mary Evans", CR, 0


' -----[ Initialization ]-------------------------------------------------

Reset:
  HIGH Enable                                   ' turn of RFID reader
  LOW Latch                                     ' lock the door!
```



```
' -----[ Program Code ]--------------------------------------------------

Main:
  LOW Enable                                    ' activate the reader
  #IF   No SPRAM #THEN
    SERIN RX, T2400, [WAIT($0A), STR buf\10]    ' wait for hdr + ID
  #ELSE
    SERIN RX, T2400, [WAIT($0A), SPSTR 10]
  #ENDIF
  HIGH Enable                                   ' deactivate reader

Check_List:
  FOR tagNum = 1 TO LastTag                     ' scan through known tags
    FOR idx = 0 TO 9                            ' scan bytes in tag
      READ (tagNum - 1 * 10 + idx), char        ' get tag data from table
      #IF __No_SPRAM #THEN
        IF (char <> buf(idx)) THEN Bad_Char     ' compare tag to table
      #ELSE
        GET idx, chkChar                        ' read char from SPRAM
        IF (char <> chkChar) THEN Bad_Char      ' compare to table
      #ENDIF
    NEXT
    GOTO Tag_Found                              ' all bytes match!

Bad_Char:                                       ' try next tag
  NEXT

Bad_Tag:
  tagNum = 0
  GOSUB Show_Name                               ' print message
  FREQOUT Spkr, 1000 */ TmAdj, 115 */ FrAdj     ' groan
  PAUSE 1000
  GOTO Main

Tag_Found:
  GOSUB Show_Name                               ' print name
  HIGH Latch                                    ' remove latch
  FREQOUT Spkr, 2000 */ TmAdj, 880 */ FrAdj     ' beep
  LOW Latch                                     ' restore latch
  GOTO Main

  END


' -----[ Subroutines ]----------------------------------------------------

' Prints name associated with RFID tag

Show_Name:
  DEBUG DEC tagNum, ": "
  LOOKUP tagNum,
         [Name0, Name1, Name2, Name3], idx      ' point to first character
  DO
    READ idx, char                              ' read character from name
    IF (char = 0) THEN EXIT                     ' if 0, we're done
    DEBUG char                                  ' otherwise print it
    idx = idx + 1                               ' point to next character
  LOOP
  RETURN
```

Appendix B 6: Microcontroller Data Sheet

CML12S-DP256

Development Board for Motorola MC9S12DP256

Axiom Manufacturing • 2813 Industrial Lane • Garland, TX 75041
Email: Sales@axman.com Web: http://www.axman.com

CONTENTS

GETTING STARTED

The Axiom CML12S-DP256 single board computer is a fully assembled, fully functional development system for the Motorola MC9S12DP256 microcontroller. Provided with wall plug power supply and serial cable. Support software for this development board is provided for Windows 95/98/NT/2000/XP operating systems.

This development board applies option selection jumpers. Terminology for application of the option jumpers is as follows:

> Jumper on, in, or installed = jumper is a plastic shunt that fits across 2 pins and the shunt is installed so that the 2 pins are connected with the shunt.
>
> Jumper off, out, or idle = jumper or shunt is installed so that only 1 pin holds the shunt, no 2 pins are connected, or jumper is removed. It is recommended that the jumpers be idled by installing on 1 pin so they will not be lost.

Development board users should also be familiar with the hardware and software operation of the target HCS12 device, refer to the Motorola User Guide for the device and the CPU12 Reference Manual for details. The development board purpose is to assist the user in quickly developing an application with a known working environment or to provide an evaluation platform for the target HCS12. Users should be familiar with memory mapping, memory types, and embedded software design for the fastest successful application development.

Application development maybe performed by applying the embedded MON12 (**default**) or NOICE firmware monitors, or by applying a BDM cable with supporting host software. The MON12 monitor provides an effective debug method for assembly level software, but has limitations in C code developments. For C/C++ code development it is recommended that source code or symbolic debug capability be provided in the debugging environment. The NOICE monitor or BDM interface with supporting software tools should be applied for C/C++ code development so the host PC can provide the symbolic support needed. User should verify the NOICE or BDM development environment supports the C compiler to be applied, not all development environments support all compilers.

The MON12 and NOICE monitors are provided in the development board HCS12 internal flash memory and apply some HCS12 resources for operation. See the respective chapter for each monitor for details on operation and resources applied. User should note both monitors apply operation of the HCS12 expanded wide mode data and address bus on HCS12 I/O ports A, B, E, and K for access to the external Ram. The external ram provides a development memory where code to be debugged can be loaded or modified quickly and software breakpoints applied. After the application is tested, the code can be relocated to the internal flash memory space of the HCS12 and programmed into the flash memory for dedicated operation.

User applications developed by applying MON12 or NOICE monitors can be modified and relocated for operation as a stand-alone application. By applying the MON12 Autostart feature, the user application will operate from Reset or Power on conditions to provide a dedicated operation of the application. See the Autostart section in this manual for more information.

Follow the steps in this section to get started quickly and verify everything is working correctly.

Installing the Software

1. Insert the Axiom 68HC12 support CD in your PC. If the setup program does not start, run the file called "SETUP.EXE" on the disk.
2. Follow the instructions on screen to install the support software onto your PC. You should at minimum install the AxIDE for Windows software.
3. The programming utility "AxIDE" requires you to specify your board. You should select "CML12SDP256" version of your development board.

Board Startup

Follow these steps to connect and power on the board for the default Monitor operation. This assumes you're using the provided AxIDE utility (installed in the previous section) or a similar communications terminal program on your PC. If you're using a different terminal program than the one provided, set it's parameters to 9600 baud, N,8,1.

1. Set the CML12Sxxx board Option jumpers to default positions:

   MEM-EN = IN, ECS = IN, JP1 = IN, NOAUTO (SPARE) = IN

   MODC = Out, JP2 = do not care, see COM Ports.

2. Connect one end of the supplied 9-pin serial cable to an available serial COM port on your PC. Connect the other end of the cable to the P-COM port on the CML12Sxxx board.
3. Apply power to the board by plugging in the power adapter that came with the system.
4. If everything is working properly, you should see a message to "**PRESS KEY TO START MONITOR…**" in your terminal window. Press the ENTER key and you should see:

```
Axiom MON12 - HC12 Monitor / Debugger V256.x
Type "Help" for commands…

> _
```

5. Your board is now ready to use! If you do not see this message prompt, or if the text is garbage, see the **TROUBLESHOOTING** section at the end of this manual.

Support Software

There are many programs and documents on the included HC12 support CD you can use with the CML12Sxxx board. You should install what you want from the main menu then browse the disk and copy what you like to your hard drive.

At minimum, you should install the AxIDE program. This provides the flash programming utility and communication with the board via the COM port and the supplied serial cable. This program includes a simple terminal for interfacing with other programs running on the CML12Sxxx and information from your own programs that send output to the serial port.

Also on the disk are free assemblers AS12 and MCU-EZ, the open source GNU C/C++ compiler tools for HC11/12, example source code, and other useful software. The introductory tutorial in this manual uses the free AS12 assembler integrated into the AxIDE program. This is a simple assembler with limited capability. For a more powerful assembly tool, install the Motorola MCUez program from the CD. This will allow you to use PAGED program memory in your application.

Software Development

Software development on the CML12Sxxx can be performed using either the MON12 monitor installed in internal FLASH of the MCU, a third party debugger (Debug12, NoICE, CodeWarrior, etc.) or a Background Debug Module (BDM) connected to the BDM PORT connector. Any of these tools can be used to assist in creating and debugging your program stored in RAM (see **Memory Map**).

After satisfactory operation running under a debugger, your program can be written to Internal Flash Memory using the included programming utilities. The Mon12 firmware in the MCU flash provides the interrupt vectors in Ram memory and an Autostart feature to launch your application. Your program may then run automatically whenever the board is powered on or RESET is applied.

TUTORIAL

This section was written to help you get started developing software with the CML12SXXX board. Be sure to read the rest of this manual as well as the documentation on the disk if you need further information.

The following sections take you through the complete development cycle of a simple "hello world" program, which sends the string "Hello World" to the serial port.

Creating Source Code

You can write source code for the CML12SXXX board using any language that compiles to Motorola 68HC12 instructions. Included on the software disk is a free Assembler, AS12.

You can write your source code using any ASCII text editor. You can use the free EDIT, WordPad, or Notepad programs that come with your computer. Note that the source file must be simple ASCII text without any document formatting added. Once your source code is written and saved to a file, you can assemble or compile it to a Motorola S-Record (hex) format. This type of output file usually has a .MOT, .HEX or .S19 file extension and is in a format that can be read by the programming utilities and programmed into the CML12SXXX board.

It is important to understand the development board's use of Memory and Addressing when writing source code so you can locate your code at valid addresses. For example, when in debug mode, you should put your program CODE in External RAM. In assembly language, you locate the code with ORG statements in your source code. Any lines following an ORG statement will begin at that ORG location, which is the first number following the word ORG, for example: `ORG $4000`. You must start your DATA (or variables) in a RAM location unused by your program, for example: `ORG $1000`.

In "debug mode" you'll be using a debugger utility (Mon12, NoICE, etc) which will handle initialization, interrupts vectors (reset, timers, etc), and the STACK. When finished debugging, you must add code to your application to handle the initialization of the CPU, STACK and possibly the Interrupt vectors. Some initialization is required to set the bus frequency, bus mode, internal EEprom and Flash memory programming clock rates, and others, see the CML-INIT.ASM file for a sample. Set the stack at the top of your available internal RAM below the Ram interrupt vector table, for example $3F80, in assembly this would be `LDS #$3F80`. Also install the RESET vector address in the Auto Start area, see the chapter in this manual.

If you are applying a software development tool that also provides a BDM cable interface to the board, the monitor installed in the flash is not required. The BDM software tools may have the capability to erase and program the flash memory. If this is the case, you may develop code in the external ram memory or internal flash without applying the monitor resources. The MON12 S record is provided on the support CD to program into the flash if desired. The BDM will allow locating programs in memory and applying resources reserved for the monitors.

A look at the example programs on the disk can make all of this clearer. If you're using a compiler instead of an assembler, consult the compiler documentation for methods used to locate (MAP) your code, data and stack.

Assembling source code

An example program called "HELLO.ASM" is provided under the `\EXAMPLES\CML12` directory of the CD and if you installed AxIDE, under that programs `\EXAMPLE` directory. You must use the example for the MCU type installed on the CML12Sxxx board. For example use the CML12S-DP256 example on the DP256 version board.

You can assemble source code by using the AxIDE "BUILD" button or command line tools under a DOS prompt by typing:

```
AS12 HELLO.ASM -L HELLO
```

Most compilers and assemblers allow many command line options so using a MAKE utility or batch file is recommended if you use this method. Run AS12 without any arguments to see all the options, or see the AS12.TXT file on the disk.

The utility software, AxIDE, provided with this board contains a simple interface to this assembler. Use it by selecting "Build" from its menu. This will prompt you for the file to be assembled. **NOTE**: You must select your board from the pull down menu first, or it may not build correctly.

DO NOT use long path or file names (> 8 characters). The free assembler is an older DOS based tool that does not recognize them.

If there are no fatal errors in your source code, 2 output files will be created:

`HELLO.S19`	a Motorola S-Record file that can be loaded or programmed into memory
`HELLO.LST`	a common listing file which provides physical address information with resulting opcode and operand information. Warnings and error messages are provided with a summary at the end of the file.

The listing file is especially helpful to look at when debugging your program. If your program has errors, they will be displayed in the listing or fatal errors will prevent output from being generated. The end of the listing file generally provides a count of errors or warnings in the file.

If you prefer a windows integrated programming environment, try the Motorola MCU-EZ tools. Refer to the MCU-EZ documentation on the disk for more information.

Also, a port for the free GNU C compiler and tools for the HC12 is available on the CD under \Shareware and also online at www.gnu-m68hc11.org. Note that this version does not support HC12 Paging operation, check the web site for updates.

Running your application

After creating a Motorola S-Record file you can "upload" it to the development board for a test run. The provided example "HELLO.ASM" was created to run from external RAM so you can use the MON12 Monitor to test it without programming it into Flash.

If you haven't done so already, verify that the CML12Sxxx board is connected and operating properly by following the steps under "GETTING STARTED" until you see the Mon12 prompt, then follow these steps to run your program:

1. Press and release the RESET button on the CML12Sxxx board. You should see the PRESS ANY KEY message. Hit the return key ↵ to get the monitor prompt.

2. Type `LOAD` ↵
   This will prepare Mon12 to receive a program.

3. Select Upload and when prompted for a file name select your assembled program file in s-record format that was created in the previous section called: `HELLO.S19`
   Your program will be sent to the board through the serial port.

4. When finished loading you will see a done message and the > prompt again. Type `GO 4000` ↵
   This tells MON12 to execute the program at address $4000 hex, which is the start of our test program.

5. If everything is working properly you should see the message "Hello World" echoed back to your terminal screen. Press RESET to return to the monitor.

6. If you do not get this message, see the **TROUBLESHOOTING** section in this manual

You can modify the hello program to display other strings or do anything you want. The procedures for assembling your code, uploading it to the board and executing it remain the same. MON12 has many features such as breakpoints, memory dump and modify and simple program trace (no redirect of the PC is followed). Type HELP at the MON12 prompt for a listing of commands or consult the Mon12 documentation on the disk for more information.

For a more powerful debugger with many advanced features such as source level debugging, you can use the NoICE debugger software. A full-featured demo version is provided on the CD, which you can use to get started. **NOTE**: To use this program instead of MON12 you must set the Autostart, see the NOICE chapter for details.

Programming HCS12 Flash EEprom

After debugging, you can program your application into Flash Memory so it executes automatically when you apply power to the board as follows:

1. Make a backup copy of HELLO.ASM then use a text editor to modify it.

2. Remove the comment '`;`' character before one of the following lines to initialize the stack pointer which is necessary when running outside of a debugger:

```
LDS     #$3F80    ; initialize stack location…
```

3. Re-Assemble HELLO.ASM as described in the "Assembling Source Code" section.

4. Select **Program** from the AxIDE menu and follow the message prompts. When prompted for a file name, enter the new HELLO.S19 file.

5. Press the RESET button on the board before clicking OK. When prompted to Erase, choose Yes.

6. When finished programming, Reset the board to get the Monitor prompt again. Use the monitor **AUTO** command to set the Autostart Reset vector:

```
>AUTO 4000 ↵

  AutoStart ON, effective address = 4000

>
```

7. Verify AUTO OFF option jumper is not installed. (Spare jumper on revision C boards)

8. RESET or re-apply Power to the board. Your new program should start automatically and the "Hello World" prompt should be displayed in the terminal window.

To return to the MON12 monitor program, install the AUTO OFF option jumper then press RESET. Execute the monitor command NOAUTO to disable the Autostart and allow removal of the Auto Off option jumper for normal operation.

MON12 OPERATION

Mon12 is an embedded monitor / debug utility that allows loading a compiled software program (S record) into Ram memory for testing and debug. The monitor may control the execution of the software by applying the SWI software interrupt service. Other features allow memory and register examination or modification.

Communication with the monitor is provided on the HCS12 SCI0 serial port or COM port on the development board. Default settings are 9600 baud with 8/n/1 bit settings. Flow control is not provided so the host PC communication software should be set to None or Hardware flow control. AxIDE utility software is recommended for use on a windows based host PC.

The monitor relies on resources from the HCS12 target to provide the monitor environment. The resources include 16K bytes of flash memory and 512 bytes of internal ram memory. The user must respect the monitor's memory map when applying the monitor to help debug code. Restricted memory areas:

Monitor Program space: **0xC000 - 0xFFFF Flash or Flash Page $3F.**

Monitor Data space: **0x3E00 - 0x3FFF, Internal Ram.**

Monitor Console: **COM Port and SCI0.**

Monitor Autostart: **0xFEC - 0xFEF, Internal EEprom.**

Monitor application provides for redirection of interrupt vectors through the ram based interrupt table, initialization of SCI0 serial port, initialization of HCS12 flash and EEprom programming clock rates, initialization of 8 MHz E clock from 4Mhz reference crystal, and detection of auto start enabled operation. The HCS12 memory map is fixed under monitor operation.

The monitor provides for interrupt vectors in the monitor data space from 0x3F8A - 0x3FFD. The vectors are in the same order as the default hardware table for the HCS12 located at address 0xFF8A - 0XFFFD (see table). The Reset vector is reserved, user should apply Auto Start for application starting from Reset.

MON12 operation notes:

1. CML12S-DP256 monitor application configures target HCS12 for 8MHz E clock, lower flash block (page $3E) disabled from memory map, and external access clock stretch set to 3 cycles. User can increase clock speed in application by modifying PLL control and setting new baud rate for serial port. Defaults will return whenever monitor is Reset.

2. Mon12 will not trace into interrupts. To trace an interrupt service set a breakpoint in the service routine and then trace.

3. Mon12 trace is limited to expecting the next linear address. Program counter modification, branches, calls, or subroutines will not trace correctly.

4. Monitor start-up procedure:

   A) Determine if Auto Start in enabled and proceed to vector if not a value of $FFFF.

   B) Set Stack, Initialize memory map and SCI0 port and send prompt.

   C) Receive first character from Console port and execute monitor if ASCII text / command, else start utility mode for programming services.

Mon12 Monitor Commands

`AUTO [<Address>]`	Enable Auto start, address is the vector
`NOAUTO`	Disable Auto start
`BF <StartAddress> <EndAddress> [<data>]`	Fill memory with data
`BR [<Address>]`	Set/Display user breakpoints
`BULK`	Erase entire on-chip EEPROM contents
`CALL [<Address>]`	Call user subroutine at <Address>
`G [<Address>]`	Begin/continue execution of user code
`HELP`	Display the Mon12 command summary
`LOAD [P]`	Load S-Records into memory, P = Paged S2
`MD <StartAddress> [<EndAddress>]`	Memory Display Bytes
`MM <Address>`	Modify Memory Bytes (8 bit values)
`MW <Address>`	Modify memory Words (16 bit values)
`MOVE <StartAddress> <EndAddress> <DestAddress>`	Move a block of memory
`RD`	Display all CPU registers
`RM`	Modify CPU Register Contents
`STOPAT <Address>`	Trace until address
`T [<count>]`	Trace <count> instructions

MON12 Interrupt Support

All interrupt services under MON12 are provided through the ram vector table, **see Table 2**. Each location in the table is initialized to a value of $0000 to cause the trap of an unscheduled interrupt. Any nonzero value will allow the interrupt to proceed to the user's service routine that should be located at the provided address value. Interrupt service delay is plus 21 cycles over standard interrupt service.

To use vectors specified in the table, the user must insert the address of the interrupt service routine during software initialization into the ram interrupt table. For an example, for the IRQ vector, the following is performed:

Example: IRQ Service routine label = IRQ_SRV
Ram Vector Table address is defined in table below, IRQ vector definition:
VIRQ EQU $3EF2 ; define ram table vector location

Place IRQ service routine address in the table:
MOVW #IRQ_SRV,VIRQ

This vector initialization should remain after debug when auto start will be applied for launching the user's application. Note that the user interrupt service routines must be located in the $4000 - $7FFF address range for correct operation. See Autostart for more details.

MON12 and NOICE Memory Map

ADDRESS	TYPE MEMORY	MEMORY APPLICATION
$C000 - $FFFF	FLASH	MON12, NOICE, and Utility firmware located in internal flash, Page $3F.
$8000 - $BFFF	External Ram	User Paged Program Memory space, pages $20 - $2E. Note: Pages $30 - $3F reside in the internal flash.
$4000 - $7FFF	External Ram	User Program Memory, emulate fixed page $3E.
$3F8C - $3FFD	Internal Ram	Ram Interrupt Vector Table
$3E00 - $3F8B	Internal Ram	Monitor reserved ram memory. Stacks and variables.
$1000 - $3DFF	Internal Ram	User Internal Ram memory
$0400 - $0FEB	Internal EEprom	User EEprom memory, Monitor reserves $FEC - $FEF for Autostart, user should avoid $FF0 - $FFF memory use.
$0000 - $03FF	HCS12 Registers	Monitor or user access to control registers.

NOICE OPERATION

NOICE is a development software provided by www.NOICEdebugger.com. NOICE provides a development environment that is supported by the NOICE host PC software. This development environment has the capability to provide symbolic debug for C source codes and compilers for a low cost. A fully functional software version is available on the support CD that will operate in demonstration mode. The user should register the software and download the latest version from the above web site to get full support. See the NOICE documentation for details.

The CML12S-DP256 provides the NOICE debug monitor kernel as a subset of the MON12 monitor in reserved flash memory. User may apply the NOICE development system by setting the MON12 Autostart for the $F800 vector, reset the board and launch the NOICE host software on the PC. The NOICE monitor kernel applies the same resources, memory map, and ram interrupt table as the MON12 monitor. NOICE operation notes:

Baud Rate = 19.2K baud 8/n/1

E clock frequency = 24MHz

BDM OPERATION

The CML12S-DP256 board will emulate supported HC12 device internal flash memory in external ram. This feature allows BDM (Background Debug Modules) such as the AX-BDM12 to load and control the execution of code being developed without the necessity of the internal flash memory being programmed many times during the development process. This feature improves updating time and allows the use of may software breakpoints instead of being limited to only 2 hardware breakpoints.

Operation Notes for BDM use:

1) CML12S-DP256 **MODC Option Jumper** should be installed if a BDM is connected to the BDM Port. Default Mode is single-chip so the MODC option installed will force Special Single-chip Mode on Reset.

2) The BDM initialization of the HC12 should set the correct operating MODE (Expanded Wide for memory access). The EME, EMK, LSTRB, RW, ROMEN and Stretch configuration bits should be set for proper external memory access operation. The Axiom support CD contains sample set-up macros for the AX-BDM12.

3) While using the BDM, the user has full control over the memory map and hardware resources of the HCS12. The no resources are required to be reserved for monitor use and the user can apply the actual HCS12 interrupt vector table located at 0xFF8C - 0xFFFF.

AUTOSTART

The MON12 Monitor allows an Autostart operation to launch user applications programmed into the HCS12 internal flash fixed page ($3E) addresses 0x4000 - 0x7FFF from Reset. The Autostart mask and vector are stored in the nonvolatile internal EEprom at addresses $FEC - $FEF. The monitor provides special commands, **AUTO** and **NOAUTO**, to enable and disable the Autostart on the next Reset sequence. After an Autostart is enabled with a valid user vector, user application code will be started after Reset instead of the monitor or utility programs. To recover monitor operation after Autostart has been enabled, the **AUTO OFF** (**Spare option on Revision C boards**) option jumper can be installed or a low level applied to the XIRQ signal and Reset applied.

User application must perform all initialization including Stack setting, hardware startup, and external memory bus enable if needed, when the Autostart is applied. MON12 Ram Interrupt Vector table must also be applied in the same manner as under MON12 supervision or application interrupts will be trapped instead of serviced. See the CML12S.asm file for sample start-up initialization code.

Developing an application under MON12 or NOICE for Autostart should follow these steps:

1) Follow the MON12/ NOICE memory map and apply startup initialization and interrupt service routines in the 0x4000 - 0x7FFF memory area.

2) After development by applying ram memory program pages $20 - $2D, user should relocate the paged program code to internal flash pages $30 - $3D for programming into the flash memory. The user code in memory area 0x4000 - 0x7FFF will translate to the lower fixed flash page $3E for programming operations. User variables and stack, as well as interrupt vectors should stay in the internal ram area 0x1000 - 0x3E80 (monitor stack and variables not needed). Then set the Autostart vector for application launching.

3) If the Autostart application fails to start after programming, user should review all initialization and memory mapping first. Make sure the AUTO OFF (Spare) Option jumper is idle or open. If the application applies the XIRQ interrupt, the interrupt must be idle (high level) during any Reset sequence. Hardware may need to be applied if XIRQ signal level cannot be guaranteed high during Reset.

4) To perform a test Autostart and apply the external ram for program space the following precaution should be observed:

   Expanded Wide Mode bus operation must be enabled from internal Ram space before access to the external ram can be performed. Use CML12S.asm file for an example and locate the PEAR/MODE Register write in internal ram space 0x1000 - 0x3F80. Program pages $20 - $2D should be applied. Code must be loaded and tested without powering down the development board (use Reset Switch).

OPTIONS and JUMPERS

MEM_EN

The MEM_EN option jumper is installed by default and enables the external ram memory on the expanded HCS12 address and data bus. Removing the MEM_CS option jumper will allow single-chip I/O port type operation of HCS12 ports A, B, E, and K (no bus enabled) without external memory interference.

ECS

The ECS option installed enables the Emulation Chip Select signal from the HCS12 to drive the upper address lines from HCS12 Port K to the external Ram on the CML12S board. With the option open or idle, only the linear 64K byte address map is available on the external address / data bus. ECS installed is required to emulate flash program pages in the external ram memory.

MODC

The MODC option jumper provides Special Mode enable during Reset. This option must be open or idle when operating with the MON12 or NOICE monitors. If a BDM cable is applied to BDM port, the MODC option must be installed to enable Special Mode. Failure to install the MODC jumper during BDM application may cause communication problems with the host.

AUTO OFF / spare

The AUTO OFF (Spare on REV C. board) option jumper installed defeats the Autostart operation so the MON12 monitor will provide a command prompt. The jumper applies a ground potential to the XIRQ* interrupt line. User should only install the jumper to restore monitor operation, perform the MON12 NOAUTO command to disable the Autostart, and remove or idle the jumper. MON12 operation will then be provided on subsequent Reset conditions.

MODE

The MODE option jumper is not installed on the CML12S-DP256 board and is hard connected by circuit copper trace for Single-chip Mode operation of the CPU. Both the MODA and MODB signals are terminated by this option. Due to the restriction that the HCS12 internal flash memory is the only nonvolatile program memory provided on the board, single Chip Mode is default. All other Modes can be enabled under software control from this mode of operation.

The MODE option jumper may be installed by the user by cutting the hard trace and applying 2 header pins with a shunt jumper. With the shunt jumper removed, the Reset mode will then be Normal Expanded Wide. (Note: mask set 1K79X and earlier will not fetch the Reset vector from external memory in this mode).

OSC_SEL

The OSC_SEL option jumper is not installed on the CML12S-DP256 board. The default configuration is for the provided 4MHz reference crystal to provide the HCS12 oscillator. If the user requires an external clock to be applied, two header pins and shunt jumper can be applied to select the alternate clock source. User should refer to the HCS12 User Guide and CML12S board schematic for proper application of the external clock.

ROM_OFF

The ROM_OFF option jumper is not installed on the CML12S-DP256 board. The default configuration is that the internal flash memory of the HCS12 is enabled at Reset. The user must add external nonvolatile memory to the CML12S board to take advantage of this option. If the external memory is applied, the user may install the two header pins and shunt jumper to select internal or external memory use form Reset.

JP1 and JP2

JP1 and 2 option jumpers provide an easy method of connecting or isolating the HCS12 SCI0 and SCI1 serial channel RXD pins respectfully from the provided on-board RS232 transceiver. To apply the RXD pins on the SCI channels for other user applications requires that the transceiver driver be removed from the HCS12 pin. User may then apply signals to the respective pins at the MCU PORT connector without driver conflict. Please note that the on-board monitor(s) require HCS12 SCI channel 0 (JP1 installed) for user interface.

CUT-AWAY OPTIONS 1 - 6

CUT-AWAY options allow the user to disconnect dedicated HCS12 I/O port resources from development board peripherals. The CUT-AWAY options also allow for establishing the connection again by installing surface mount 1206 size 0 ohm resistors or mod wire with the use of a soldering iron. Normal operation of the development board generally does not require any manipulation of the CUT_AWAY options.

#1 Cut-Away: HCS12 Port S5/MOSI signal to the LCD_PORT shift register.

#2 Cut-Away: HCS12 Port S7/SS0 signal to the LCD_PORT shift register.

#3 Cut-Away: HCS12 Port S6/SCK signal to the LCD_PORT shift register.

#4 Cut-Away: HCS12 Oscillator Crystal ground, if another crystal is applied by the user this connection may require a capacitor to be installed. Refer to the HCS12 CGM module information.

#5 Cut-Away: HCS12 Port M0/CAN_RXD0 signal to the CAN port transceiver.

#6 Cut-Away: CAN Port Transceiver enable connection to ground. This connection enables the CAN Port transceiver output to the CAN bus at all times. If the user wants to apply output enable or slew rate control to the transceiver, this option should be cut and 1206 size resistor applied for slew rate or a HCS12 I/O port applied for output enable control. See the PCA82C250 data sheet for application information.

PORTS AND CONNECTORS

TB1 and J1 Power

The TB1 and J1 connectors provide power input to the board or if J1 is used for input, TB1 maybe used to source additional circuitry. The J1 power jack accepts a standard 2.0 ~ 2.1mm center barrel plug connector (positive voltage center) to provide the +VIN supply of +7 to +20 VDC @ 80ma minimum (+9VDC nominal). TB1 provides access to the +VIN, GND (power ground), HCS12 core VDD, and +5V power supplies. The CML12Sxxx power supply will provide 50ma of +5V for user application. +VIN input power should only be applied by J1 or TB1, not both or a supply conflict may occur and the CML12Sxxx board could be damaged. The VDD supply is for reference or external 2.5V input only and should not be loaded by external circuitry or damage to the HCS12 device may occur.

MCU_PORT

+5V	60	59	GND
PT7	58	57	PT6
PT5	56	55	PT4
PT3	54	53	PT2
PT1	52	51	PT0
** PK0	50	49	PK1 **
** PK2	48	47	PK3 **
** PK4	46	45	PK5 **
GND	44	43	+5V
PP1	42	41	PP0
PP3	40	39	PP2
PP5	38	37	PP4
PP7	36	35	PP6
** PM1	34	33	PM0 **
PM3	32	31	PM2
PM5	30	29	PM4
PM7	28	27	PM6
PJ1	26	25	PJ0
PJ7	24	23	PJ6
** PS7	22	21	PS6 **
** PS5	20	19	PS4 **
** PS3	18	17	PS2 **
** PS1	16	15	PS0 **
GND	14	13	+5V
GND	12	11	VREGEN
** PB7/D7	10	9	PB6/D6 **
** PB5/D5	8	7	PB4/D4 **
** PB3/D3	6	5	PB2/D2 **
** PB1/D1	4	3	PB0/D0 **
GND	2	1	+5V

The **MCU_PORT** provides access to the peripheral features and I/O lines of the HCS12.

** Note signals with alternate connections on the development board:

PB0 - 7 [D0 - 7] provide address / data on the expanded HCS12.

PK0 - 5 [XA14 - XA19] provide high order paged address lines on the expanded HCS12.

PM0 - 1 [CAN RXD0, TXD0] CAN channel 0 to CAN Port transceiver.

PS0 - 1 [COM Port RXD0, TXD0]

PS2 - 3 [JP3 Port RXD1, TXD2]

PS4 - 7 [SPI Port] provides LCD_PORT serial interface.

ANALOG PORT

PAD0/AN0	1	2	PAD8/AN8
PAD1/AN1	3	4	PAD9/AN9
PAD2/AN2	5	6	PAD10/AN10
PAD3/AN3	7	8	PAD11/AN11
PAD4/AN4	9	10	PAD12/AN12
PAD5/AN5	11	12	PAD13/AN13
PAD6/AN6	13	14	PAD14/AN14
PAD7/AN7	15	16	PAD15/AN15
VRH	17	18	VRL
VDDA	19	20	GND

The **ANALOG** port provides access to the Port AD0 and Port AD1 Analog-to-Digital input lines.

PAD0 – PAD15 HC12 Port AD0-15 is an input port or AN0 - AN15 A/D Converter inputs.

VRH / VRL HC12 A/D Converter Reference Pins. See HCS12 A/D User guide. To provide an external reference voltage, R3 and R4 need to be removed to apply external VRH or VRL respectfully. See schematic.

BUS_PORT

GND	1	2	D11/PA3
PA2/D10	3	4	D12/PA4
PA1/D9	5	6	D13/PA5
PA0/D8	7	8	D14/PA6
A0	9	10	D15/PA7
A1	11	12	A2
A10	13	14	A3
OE*	15	16	A4
A11	17	18	A5
A9	19	20	A6
A8	21	22	A7
A12	23	24	A13
WE*	25	26	A14
PE3/LSTRB*	27	28	A15
PE5/MODA	29	30	PE7/NOACC **
PE6/MODB	31	32	PE1/IRQ*
+5V	33	34	PE0/ XIRQ*
PE2/RW	35	36	RESERVED
PE4/ECLK	37	38	RESERVED
GND	39	40	RESET*

The **BUS_PORT** supports off-board memory devices while the HCS12 is in expanded mode.

PA0/D8 - PA7/D15 High Byte Data Bus in Wide Expanded Mode. Port A in Single Chip Mode.

A0 – A15 Latched Memory Addresses 0 to 15.

OE* Memory Output Enable signal, Active Low. Valid with ECLK and R/W high.

WE* Memory Write Enable signal, Active Low. Valid with ECLK high and R/W low.

RESET* HCS12 active low RESET signal.

KEYPAD / PORT H

The KEYPAD / PORT H connector provides interface for the HCS12 port H or applying a keypad such as the Axiom Mfg. HC-KP. When applied as a KEYPAD connector, the interface is for a passive 4 x 4 matrix (16 key) keypad device.

1	PH0
2	PH1
3	PH2
4	PH3
5	PH4
6	PH5
7	PH6
8	PH7

This interface is implemented as a software key scan. Pins PH0-3 are used as column drivers which are active high outputs. Pins PH4-7 are used for row input and will read high when their row is high.

See the file **`Key12Dx.ASM`** for an example program using this connector.

P_COM1 and P_COM2

1	1		6
TXD0	2	6	7
RXD0	3	7	8
4	4	8	9
GND	5	9	X

The **COM-1** port has a Female DB9 connector that interfaces to the HCS12 internal SCI0 serial port via the U11 RS232 transceiver. It uses a simple 2 wire asynchronous serial interface and is translated to RS232 signaling levels. **1,4,6 connected and 7,8 connected**

JP1 will isolate the SCI0 RXD pin from the transceiver.

The 1,4,6,7,8, and 9 pins provide RS232 flow control and status. These are connected on the on the bottom of the development board to provide NULL status to the host. User may isolate pins and provide flow control or status connection to the host by applying HCS12 I/O signals and **RS232 level conversion.**

P_COM2

P_COM2 is a 3 pin header that provides the HCS12 SCI1 serial port translated to RS232 signal levels. A solder cup DB9 style connector may be installed with wires and connector to apply this channel. JP2 option will isolate the SCI RXD pin from the transceiver.

P_COM2 pin connections:

Pin 1 = TXD

Pin 2 = RXD

Pin 3 = GND / common

CAN PORT

This port provides a CAN Bus interface associated with HCS12 CAN channel 0. The port has a CAN Transceiver (Philips PCA82C250) capable of up to 1M Baud data rate. The user may isolate the HCS12 CAN channel 0 from the transceiver by CUT-AWAY option 5.

CAN Port Connections

1	GND
2	CAN-H
3	CAN-L
4	+5V

The CAN Port connector provides an interface to the MSCAN12 channel 0 in the HCS12 microcontroller.

CAN BUS TRANSMIT ENABLE

The CAN port transceiver transmit driver is enabled for maximum drive and minimum slew rate by default. The drive and slew rate may be adjusted by cutting CUT-AWAY #6 and adding a 1206 size surface mount resistor, see the PCA82C250 data sheet for more information.

CAN Bus transceiver transmit enable control can be applied to the port by the RS tie pad. The user should select an available HCS12 I/O port to perform the transmit enable function and connect it from the MCU_PORT pin to RS pad as required. **The CUT_AWAY #6 must be open to apply transmit enable control.** The transmit enable signal to the CAN transceivers is active logic low.

CAN BUS TERMINATION

The CAN port provides RC11,12, and 13 1206 SMT size termination resistors on the bottom of the CML12Sxxx board that are not installed at the factory. The termination resistors provide optional bias and termination impedance for the CAN bus connected to the CAN Port. Type of wire media, data rate, length of wire, and number of CAN bus nodes can all effect the requirement or value of the termination for the CAN bus. User should refer to particular application for termination requirements.

RC11 CAN-H Bias Resistor: Provides bias to ground potential.

RC13 CAN-L Bias Resistor: Provides bias to +5V potential.

RC12 CAN Termination Resistor: Provides end point termination between CAN-H and CAN-L signal.

P1 - P4 HCS12 Header Ring

P1 - P4 provide a header ring for all I/O of the HCS12 device. These connectors are not installed. User should refer to the CML12S board schematic diagram for connector pin connections. All HCS12 I/O is available from the other I/O Ports on the board.

LCD_PORT

The LCD_PORT interface is connected to the HCS12 SPI-0 port and applies a serial shift register to convert the data to parallel interface for LCD input. This is required due to the fast timing characteristics of the HCS12 data bus and the slow timing of the standard LCD Modules. Example LCD Port assembly language driver software is provided on the support CD to demonstrate typical LCD module operation using this technique.

The interface supports all OPTREX™ DMC series and similar displays with up to 80 characters in 4 bit bus mode and provides the most common pinout for a dual row rear mounted display connector. The LCD module VEE or contrast potential is 0 Volts on this board. The LCD module type should be TN (Standard Twist) style and Reflective to support this VEE potential. The Axiom Mfg. HC-LCD is also compatible. The LCD Module is configured in a Write only mode, it is not possible to read current cursor position or the busy status back from the module.

LCD_PORT Connector

+5V	2	1	GND	SPI data bit definitions to LCD Port:
RS	4	3	VEE-GND	D0 - D3 = DB4 - 7, LCD data
EN	6	5	R/W-GND	D4 - D5 = Spare pins S1 and S2, not connected
DB1	8	7	DB0	D6 = RS, 0 = LCD Command, 1 = LCD Data
DB3	10	9	DB2	D7 = EN, 1 = LCD enable.
DB5	12	11	DB4	DB0 -DB3 are not applied and have 10K pull-down
DB7	14	13	DB6	resistance.

NOTES:

1) The LCD write requires 3 SPI transfers. Transfer 1 provides data 0 - 3 and RS (register select) value. Transfer 2 provides the same data with the EN (D7) bit set. Transfer 3 provides same data with the EN bit clear.

2) Resistor R25 can be removed to apply and external VEE potential.

3) CUT-AWAY 1 - 3 provide a means to isolate the LCD Port from the HCS12 SPI channel.

BDM PORT

The BDM port is a 6 pin header compatible with the Motorola Background Debug Mode (BDM) Pod. This allows the connection of a background debugger for software development, programming and debugging in real-time without using HC12 I/O resources.

BGND	1	2	GND	See the HC12 Technical Reference Manual for complete documentation of the BDM.
	3	4	/RESET	
	5	6	+5V	

A Background Debug Module is available from the manufacturer.

TEST POINTS

The following test points are provided on the development board:

EXTAL : HCS12 oscillator or external clock input pin.

XTAL : HCS12 oscillator output pin.

XFC : HCS12 PLL reference voltage and filter.

VDDPLL : HCS12 PLL voltage source test point.

TROUBLESHOOTING

The CML12SXXX board is fully tested and operational before shipping. If it fails to function properly, inspect the board for obvious physical damage first. Ensure that all IC devices in sockets are properly seated. Verify the communications setup as described under GETTING STARTED and see the **Tips and Suggestions** sections following for more information.

The most common problems are improperly configured communications parameters, and attempting to use the wrong COM port.

1. Verify that your communications port is working by substituting a known good serial device or by doing a loop back diagnostic.
2. Verify option jumpers JP1 is installed and MODC is open / idle.
3. Verify Autostart is not enabled. Apply a ground level to the XIRQ signal on the BUS_PORT and press the Reset switch. If the monitor prompts, erase the internal EEprom by performing a BULK command or disable the Autostart by following the procedure in the Autostart chapter.
4. Verify the power source. You should measure a minimum of 9 volts between the GND and +VIN connections on the TB1 power connector with the standard power supply provided.
5. If no voltage is found, verify the wall plug connections to 115VAC outlet and the power connector.
6. Verify the logic power source. You should measure +5 volts between the GND and +5V connections on the TB1 power connector. If the +VIN supply is good and this supply is not +5V, immediately disconnect power from the board. Contact support@axman.com by email for instructions and provide board name and problem.
7. Disconnect all external connections to the board except for COM1 to the PC and the wall plug.
8. Make sure that the RESET line is not being held low.
   Check for this by measuring the RESET Signal on the BUS_PORT.
9. Verify the presence of a 4MHz square wave at the EXTAL pin or 8MHz E clock signal if possible.
10. Contact support@axman.com by email for further assistance. Provide board name and describe problem.

Tips and Suggestions

Following are a number of tips, suggestions, and answers to common questions that will solve many problem users have with the CML12SXXX development system. You can download the latest software from the Support section of our web page at:

www.axman.com

Utilities

- If you're trying to program memory or start the utilities, make sure all jumpers are correct.
- Be certain that the data cable you're using is bi-directional and is connected securely to both the PC and the board. Also, make sure you are using the correct serial port.
- Make sure the correct power is supplied to the board. You should only use a 9 volt, 200mA minimum adapter or power supply. If you're using a power strip, make sure it is turned on.
- Make sure you load your code to an address space that actually exists. See the Memory Map if you're not sure. The MEM_EN and ECS options change the memory map.
- If debugging under Mon12, make sure you're not over-writing internal RAM used by it.
- If you're running in a multi-tasking environment (such as Windows™) close all programs in the background to be certain no serial conflict occurs.

Code Execution

- Under Mon12, breakpoints may not be acknowledged if you use the CALL command. You should use one of the GO command instead.
- Check the Autostart mask and reset vector located in EEprom at 0xFEC - 0xFEF. These 2 words contain the enable mask and address where user application execution will begin when the unit is powered on.
- When running your code stand-alone, you must initialize ALL peripherals used by the micro, including the Stack, Serial Port, and pseudo Interrupt vectors etc.
- You must either reset the COP watchdog timer in the main loop of your code or disable it when not running under Mon12 or BDM mode. The micro may enable this by default and if you don't handle it your code will reset every few 100ms.

TABLE 1: LCD Command and Character Codes

Command codes are used for LCD setup and control of character and cursor position. All command codes are written to LCD panel address $B5F0. The BUSY flag (bit 7) should be tested before any command updates to verify that any previous command is completed. A read of the command address $B5F0 will return the BUSY flag status and the current display character location address.

Command	Code	Delay
Clear Display, Cursor to Home	$01	1.65ms
Cursor to Home	$02	1.65ms
Entry Mode:		
Cursor Decrement, Shift off	$04	40us
Cursor Decrement, Shift on	$05	40us
Cursor Increment, Shift off	$06	40us
Cursor Increment, Shift on	$07	40us
Display Control:		
Display, Cursor, and Cursor Blink off	$08	40us
Display on, Cursor and Cursor Blink off	$0C	40us
Display and Cursor on, Cursor Blink off	$0E	40us
Display, Cursor, and Cursor Blink on	$0F	40us
Cursor / Display Shift: (nondestructive move)		
Cursor shift left	$10	40us
Cursor shift right	$14	40us
Display shift left	$18	40us
Display shift right	$1C	40us
Display Function (default 2x40 size)	$3C	40us
Character Generator Ram Address set	$40-$7F	40us
Display Ram Address and set cursor location	$80- $FF	40us

LCD Character Codes

$20	Space	$2D	-	$3A	:	$47	G	$54	T	$61	A	$6E	n	$7B	{
$21	!	$2E	.	$3B	;	$48	H	$55	U	$62	B	$6F	o	$7C	|
$22	"	$2F	/	$3C	<	$49	I	$56	V	$63	C	$70	p	$7D	}
$23	#	$30	0	$3D	=	$4A	J	$57	W	$64	D	$71	q	$7E	>
$24	$	$31	1	$3E	>	$4B	K	$58	X	$65	E	$72	r	$7F	<
$25	%	$32	2	$3F	?	$4C	L	$59	Y	$66	F	$73	s		
$26	&	$33	3	$40	Time	$4D	M	$5A	Z	$67	G	$74	t		
$27	'	$34	4	$41	A	$4E	N	$5B	[	$68	H	$75	u		
$28	(	$35	5	$42	B	$4F	O	$5C	Yen	$69	I	$76	v		
$29	)	$36	6	$43	C	$50	P	$5D	]	$6A	J	$77	w		
$2A	*	$37	7	$44	D	$51	Q	$5E	^	$6B	K	$78	x		
$2B	+	$38	8	$45	E	$52	R	$5F	_	$6C	L	$79	y		
$2C	,	$39	9	$46	F	$53	S	$60	`	$6D	M	$7A	z		

TABLE 2: MON12 Service Routine Jump Table

```
ADDRESS
ff10        JMP     MAIN            ; warm start
ff13        JMP     BPCLR           ; clear breakpoint table
ff16        JMP     RPRINT          ; display user registers
ff19        JMP     HEXBIN          ; convert ascii hex char to binary
ff1c        JMP     BUFFARG         ; build hex argument from buffer
ff1f        JMP     TERMARG         ; read hex argument from terminal
ff22        JMP     CHGBYT          ; modify memory byte at address in x
ff25        JMP     CHGWORD         ; modify memory word at address in x
ff28        JMP     READBUFF        ; read character from buffer
ff2b        JMP     INCBUFF         ; increment buffer pointer
ff2e        JMP     DECBUFF         ; decrement buffer pointer
ff31        JMP     WSKIP           ; find non-whitespace char in buffer
ff34        JMP     CHKABRT         ; check for abort from terminal
ff37        JMP     UPCASE          ; convert to upper case
ff3a        JMP     WCHEK           ; check for white space
ff3d        JMP     DCHEK           ; check for delimeter
ff40        JMP     ONSCI0          ; initialize i/o device
ff43        JMP     INPUT           ; low level input routine
ff46        JMP     OUTPUT          ; low level output routine
ff49        JMP     OUTLHLF         ; display top 4 bits as hex digit
ff4c        JMP     OUTRHLF         ; display bottom 4 bits as hex digit
ff4f        JMP     OUTA            ; output ascii character in A
ff52        JMP     OUT1BYT         ; display the hex value of byte at X
ff55        JMP     OUT1BSP         ; out1byt followed by space
ff58        JMP     OUT2BSP         ; display 2 hex bytes (word) at x and a space
ff5b        JMP     OUTCRLF         ; carriage return, line feed to terminal
ff5e        JMP     OUTSTRG         ; display string at X (term with $04)
ff61        JMP     OUTSTRG0        ; outstrg with no initial carr ret
ff64        JMP     INCHAR          ; wait for and input a char from term
ff67        JMP     VECINIT         ; initialize RAM vector table
```

TABLE 3: MON12 Interrupt Table

MON12 Ram Interrupt Vector	HCS12 Interrupt Vector Address	MON12 TRAP code	Vector Source
3F8C	FF8C	02	PWME
3F8E	FF8E	04	PTPI
3F90	FF90	06	C4TX
3F92	FF92	08	C4RX
3F94	FF94	0A	C4ERR
3F96	FF96	0C	C4WU
3F98	FF98	0E	C3TX
3F9A	FF9A	10	C3RX
3F9C	FF9C	12	C3ERR
3F9E	FF9E	14	C3WU
3FA0	FFA0	16	C2TX
3FA2	FFA2	18	C2RX
3FA4	FFA4	1A	C2ERR
3FA6	FFA6	1C	C2WU
3FA8	FFA8	1E	C1TX
3FAA	FFAA	20	C1RX
3FAC	FFAC	22	C1ERR
3FAE	FFAE	24	C1WU
3FB0	FFB0	26	C0TX
3FB2	FFB2	28	C0RX
3FB4	FFB4	2A	C0ERR
3FB6	FFB6	2C	C0WU
3FB8	FFB8	2E	FEPRG
3FBA	FFBA	30	EEPRG
3FBC	FFBC	32	SPI2
3FBE	FFBE	34	SPI1
3FC0	FFC0	36	I2C
3FC2	FFC2	38	BDLC
3FC4	FFC4	3A	CRGC
3FC6	FFC6	3C	CRGL
3FC8	FFC8	3E	PACBO
3FCA	FFCA	40	MCNT
3FCC	FFCC	42	PTHI
3FCE	FFCE	44	PTJI
3FD0	FFD0	46	ADC1
3FD2	FFD2	48	ADC0
3FD4	FFD4	4A	SCI1
3FD6	FFD6	4C	SCI0
3FD8	FFD8	4E	SPI0
3FDA	FFDA	50	PACAI
3FDC	FFDC	52	PACAO
3FDE	FFDE	54	TOF
3FE0	FFE0	56	TC7
3FE2	FFE2	58	TC6
3FE4	FFE4	5A	TC5
3FE6	FFE6	5C	TC4
3FE8	FFE8	5E	TC3
3FEA	FFEA	60	TC2
3FEC	FFEC	62	TC1
3FEE	FFEE	64	TC0
3FF0	FFF0	66	RTI
3FF2	FFF2	68	IRQ
3FF4	FFF4	6A	XIRQ
3FF6	FFF6	6C	SWI
3FF8	FFF8	6E	TRAP
3FFA	FFFA	70	COP
3FFC	FFFC	72	CLM
	FFFE		RESET

CML-9S12DP512

Description: Low cost development system for the MC9S12DP512

Product Image:

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Product Summary: The CML-912SDP512 is a low cost development system for the Motorola MC9S12DP512 Microcontroller. The board provides operation in Single-Chip Mode with the Expanded Wide Bus available for expansion and development memory access. The system is supplied with Monitor / Debugger installed with programming support utilities. Features provide for easy selection of operation mode, flash programming, BDM operation, keypad and LCD module connections, and prototyping. All required power supplies and support software is included to complete and program an application.

Features: • MC9S12DP512 Features:
Upward code compatible w/ 68HC11
4K Bytes EEPROM
512K Byte Flash EEPROM
14K Byte SRAM
2 Enhanced SCI Ports
3 SPI Port (Synchronous Serial)
5 CAN 2.0 A or B Interface
Two 8 Channel 10 Bit Analog Converters
Background Debug Port
Enhanced 16 bit Timer w/ 8 channels
of capture or compare
16 Bit Pulse Accumulator
8 PWM Channels
Two 8 bit Key Wake-up ports

PLL Clock Oscillator Support
RTC and COP features
Up to 91 I/O
• 4Mhz reference oscillator for up to 24MHz operation.
• External Memory: 256K Bytes (128K x 16) SRAM
• COM1 Port HC12 SCI0 w/ RS232 and DB9S connector
• COM2 Port HC12 SCI1 w/ RS232 and 3 pin header
• INDICATORS Power and RESET.
• BUS-PORT 40 Pin Socket Header
• MCU I/O PORT - 60 pin Socket Header
• Analog Port 20 pin Socket Header
• CAN PORT CAN 0 I/O with 1M Baud Transceiver
• LCD Module and Keypad Ports
• Solderless Prototype Area and Connections
• Easy Power Connection and Tap points
• Back Ground Debug (BDM) Port 6 Pin standard

Specifications: • 7 to 25VDC input to 5V Power Supply
• Operating Power: 60ma @ 5V
Package Contents: The Axiom development system provides for low cost software debugging with the use of a Debug Monitor installed in the internal or external memory. Operation allows the user to locate code in the On-Board RAM, set Break Points, Trace, and display or modify registers or memory. After code is operational the user may relocate the code and program the MC9S12DP512 internal Flash for dedicated operation of new software. No additional hardware or software is required. Board is compatible with standard HC12 BDM pods and software compilers that provide an integrated debug interface.