ROCKET ON A ROPE TESTER

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Jesse Kuhn

April 2015

Thesis Advisor: Professor Janak Dave, Ph.D.
ABSTRACT

Some fuzes arm under a specific acceleration profile, like the firing of a rocket. In order to simulate this arming environment, a rocket on a rope tester was created. This outdoor testing package uses Estes model rocket engines to accelerate a vehicle down parallel cables and a friction brake to slow the rocket vehicle before the end of the cables. For Phase I of testing, a mechanical proof of concept was demonstrated. It was proven that the rocket could be fired using a cluster of engines and stopped by the brake. After testing the distance and time of travel were compared to the theoretical model to give an idea of the demonstrated acceleration. Due to delays with the design of the onboard accelerometer, Phase II of testing will occur at a later date. Phase II testing will include the onboard electronics package and fire the rocket with a seven engine cluster. During Phase I testing, both a one engine and three engine test occurred. The rocket vehicle traveled 98 feet in the first launch in a time of approximately 4 seconds. In the second launch the rocket traveled 99 feet in approximately 2 seconds. Rocket vehicle travel time differed from the model by 4.25% in both cases. The travel distance differed by 2.22% and 8.00% respectively. By increasing the tension in the cables, and lessening the starting friction that the brake exerts, the results of Phase II should more closely match the theoretical model. Although they differ slightly, the data and observations collected in Phase I of testing show that the tester will work as expected in the Phase II testing.
# TABLE OF CONTENTS

TABLE OF CONTENTS........................................................................................................II

LIST OF TABLES.................................................................................................................. III

INTRODUCTION AND RESEARCH...................................................................................... 1

   PROBLEM STATEMENT................................................................................................. 1
   INTERVIEWS.................................................................................................................. 1
   SIMILAR CONCEPTS .................................................................................................... 1
   PRODUCT OBJECTIVES ............................................................................................... 5

DESIGN ............................................................................................................................... 6

   DESIGN SELECTION .................................................................................................... 6
   DESIGN CALCULATIONS .............................................................................................. 7
   ASSEMBLY VIEWS ....................................................................................................... 12

FABRICATION AND ASSEMBLY ....................................................................................... 15

   ROCKET VEHICLE ...................................................................................................... 15
   FRICTION BRAKE ...................................................................................................... 17
   CABLE SUPPORTS ...................................................................................................... 18
   ELECTRONICS PACKAGE ......................................................................................... 19
   IGNITION SYSTEM .................................................................................................... 21

TESTING AND PROOF OF DESIGN .............................................................................. 23

   TESTING METHODS ................................................................................................... 23
   RESULTS ..................................................................................................................... 25

PROJECT MANAGEMENT ................................................................................................. 30

   BUDGET ....................................................................................................................... 30
   BILL OF MATERIALS .................................................................................................. 31
   SCHEDULE .................................................................................................................. 32

CONCLUSION .................................................................................................................... 34

WORKS CITED .................................................................................................................. 36

APPENDIX A RESEARCH ................................................................................................. 37

APPENDIX B PRODUCT OBJECTIVES ........................................................................... 42

APPENDIX C SCHEDULE ................................................................................................. 43

APPENDIX D BUDGET [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ........... 44

APPENDIX E PROOF OF DESIGN .................................................................................. 45

APPENDIX F NATIONAL ASSOCIATION OF ROCKETRY ROCKET ENGINE THRUST DATA ......................................................................................................................... 46

APPENDIX G FINITE ELEMENT ANALYSIS RESULTS [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ................................................................................................. 50

APPENDIX H ELECTRICAL DATASHEETS .................................................................... 51

APPENDIX I TECHNICAL DRAWING PACKAGE [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ........................................................................................................... 52
APPENDIX J DRAWING CHANGES [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] .......................................................... 53
APPENDIX K TEST PLAN [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] .. 54
APPENDIX L TEST SETUP PHOTOS .......................................................................................................................... 55

LIST OF FIGURES
Figure 1 Model C350 Centrifuge ................................................................................................................................. 2
Figure 2 Rocket Sled Track ........................................................................................................................................... 2
Figure 3 Northrop Corp. Patent Sketch .................................................................................................................... 3
Figure 4 RDECOM RoaR Test ...................................................................................................................................... 4
Figure 5 Design Sketches ........................................................................................................................................... 6
Figure 6 Rocket Free Body Diagram ........................................................................................................................... 7
Figure 7 Cable Sag Free Body Diagram .................................................................................................................. 8
Figure 8 Arrestment Rope Free Body Diagram ........................................................................................................... 9
Figure 9 Bottom Wing FEA [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ... 11
Figure 10 Top Wing FEA [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ...... 11
Figure 11 Rocket Fixture Model ............................................................................................................................. 12
Figure 12 Arrestment Lanyard Model ...................................................................................................................... 12
Figure 13 Friction Brake Model ............................................................................................................................. 13
Figure 14 Launch Post Model and End Post Model .................................................................................................. 14
Figure 15 Rocket Vehicle Brass Insert, Right Side .................................................................................................. 15
Figure 16 Rocket Exhaust Plate (Left) and Engine Holder (Right) ........................................................................... 16
Figure 17 Rocket Vehicle .......................................................................................................................................... 16
Figure 18 Friction Brake (no stabilizers) .................................................................................................................. 17
Figure 19 Arrestment Lanyard .................................................................................................................................. 18
Figure 20 Launch Post (Right) and End Post (Left) ................................................................................................. 19
Figure 21 Rocket Vehicle Electronics Package ...................................................................................................... 20
Figure 22 Wiring Diagram of Auxiliary Components ............................................................................................... 21
Figure 23 Ignition System with shunt in place .......................................................................................................... 22
Figure 24 Tester Setup ............................................................................................................................................. 23
Figure 25 Test Flow Chart ........................................................................................................................................ 24
Figure 26 Rocket Slide Test ...................................................................................................................................... 25
Figure 27 Tensioner .................................................................................................................................................. 26
Figure 28 Forward Exhaust Plate Damage ............................................................................................................ 27
Figure 29 Rocket Vehicle Wing Damage ............................................................................................................... 28
Figure 30 Rocket Vehicle Vent Damage ............................................................................................................. 29
Figure 31 Data Comparison .................................................................................................................................. 34

LIST OF TABLES
Table 1 Product Objectives ......................................................................................................................................... 5
Table 2 Test Log ......................................................................................................................................................... 29
Table 3 Budget [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ................................................................. 30
Table 4 Bill of Materials [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] ...... 31
Table 5 Schedule ...................................................................................................................................................... 33
INTRODUCTION AND RESEARCH

PROBLEM STATEMENT

L-3 Fuzing and Ordnance Systems (L-3 FOS) requires extensive testing of new products before they can go into production. However, the options for simulating the quick acceleration of a rocket motor are limited. In most cases, special centrifuges must be designed. L-3 FOS has authorized this project to assess the viability of creating a rocket powered tester on a cable to test linearly accelerated products.

INTERVIEWS

Because of the proprietary nature of this project, I conducted interviews with only L-3 FOS employees. This allowed me to fully discuss all applications of the design and also allowed for a greater understanding of onsite production abilities and safety concerns. Further information about the personnel interviewed can be found in Appendix A.

Bryan Mannon was my co-op supervisor during my eight month co-op rotation at L-3 FOS in their Internal Research and Development group. He felt that trying to create the linear step accelerator with rockets may be unrealistic and hard to keep safe and accurate. Instead, he suggested using a pulley system which would drop a weight and pull the test unit quickly down a cable.

Marc Worthington is the IRAD engineer who suggested this project initially. He had previously received approval from Environmental Health and Safety (EHS) to create a rocket sled track. While the newer idea of putting the tester on a cable would be cheaper, he was concerned that EHS would require more safety features that could offset the cost savings.

Dave Mengle is a Test fixture Designer and test technician for the airgun system at L-3 FOS. He believed that the airgun could achieve the acceleration required to test the system, which would mean that a new test system would not be required. Unfortunately the length of the airgun would mean that the quick deceleration at the end would likely damage any electrical components inside the test slug.

SIMILAR CONCEPTS

On high production rate jobs, a centrifuge tester can be used with special fixturing for testing acceleration levels. Centrifuges, like the ones sold by Space Electronics shown in Figure 1, are used on high rate production jobs because of the expensive equipment required. For example, to get power to a unit being tested, a battery and electronics must be mounted on the centrifuge table or expensive slip rings must be attached to run cable off of the table. If too much equipment is needed on board to simulate other environments, then a larger centrifuge must be purchased.
Rocket Sled Testers are used by many facilities such as the track at Sandia National Laboratories shown in Figure 2. By miniaturizing the system, it can be made more affordable and be built in a footprint onsite. A critical aspect of a rocket sled is the need for all electronic components to be mounted on the sled and powered by battery. Because of that, more propellant will be needed, increasing cost and safety concerns (4).

Northrop Corporation created plans (Figure 3) for a linear acceleration test facility in the 50’s that could still be used today. The facility was to be used for testing ballistic missile components. It would need to be adapted on a smaller scale for this role at L-3 FOS. The benefit of this system was the lack of an explosive element. The acceleration was created using pulleys, and pistons. This would be a safer alternative but based on the complexity of the facility compared to a rocket track, it would be much more expensive (6).
Rocket on a Rope (RoaR) Tests are used for research and development purposes by the United States government. The rockets used by Research Development and Engineering Command (RDECOM) are capable of much higher speeds and acceleration. The general design of their rocket bodies and test system can be emulated at a smaller scale. The basic shape and setup of their rocket system can be seen in Figure 4 RDECOM RoaR Test.
Figure 4 RDECOM RoaR Test
**PRODUCT OBJECTIVES**

Table 1 below shows an arrangement of the product objectives listed in descending order. Safety and no damage to test unit have been deemed the most critical customer requirement and the ability to adjust the design to test future products has been deemed the least critical. During the design phase these objectives were modified to meet changes to the overall design. These changes are noted in the table. The full list which includes the original customer requirements and their product objectives can be found in Appendix B Product Objectives.

<table>
<thead>
<tr>
<th>Table 1 Product Objectives</th>
</tr>
</thead>
</table>

1. **Safety 20%**
   - a. Cage system around tester (Eliminated because tester is outside)
   - b. Alert before firing
   - c. Emergency Stop at end of track
   - d. Fixture will lock test unit into the fixture during use
   - e. Low to ground
   - f. Meets EHS standards of L-3 FOS

2. **No damage to test unit 20%**
   - a. Breaking System for device on tester
   - b. Fixture will lock test unit into the fixture during use

3. **Repeatable Tests 17.5%**
   - a. Rocket Calculations
   - b. Verification of acceleration by external camera (Eliminated because acceleration will be measured by onboard accelerometer)
DESIGN

DESIGN SELECTION

Design selection was driven by low weight, low cost materials, and the ability to adjust testing apparatus and maintain repeatable results for the test.

Initially two concepts were created for the location of the test article (payload) in relation to the rocket, as shown in Figure 5 Design Sketches.

Based on the size of the unit being tested, the payload will be put inside the rocket body. The lower drawing in Figure 5 also shows a concept for stopping the rocket after the test is concluded. An arresting hook could be used in a similar fashion to an aircraft carrier, catching a line connected to a damper to slow and stop the rocket before it hits the end of the cable track. Ultimately, this design was discarded in order to minimize the weight of the rocket. Instead, a separate vehicle will be placed on the track with a rope attached to a braking system on the ground. The rocket will run into this vehicle after it has finished its engine burn and the two vehicles moving together combined with the braking system will stop the rocket. The braking system uses an adjustable friction force to stop the two vehicles.

The initial concepts for the rocket body included fins for stabilization as it moved down a single cable. Further research showed that the precedence for this manner of testing typically used a two cable system with the rocket centered between them to control the orientation of the rocket (8).

The final design chosen uses multiple Estes model rocket engines to propel a rocket-like vehicle down two cables run between two posts. The use of multiple engines is required in order to provide adequate thrust over a short duration, due to the small length of track available. The cables have been preloaded to remove sag. The payload is inside this vehicle.
as well as the necessary electronics to verify the correct acceleration was achieved. Once the engines have burned their fuel the braking system will stop the rocket. The calculations that verify the success of the chosen components can be found in the next section.

**DESIGN CALCULATIONS**

The design calculations for the project were broken down into three categories: Rocket, Cable, and Arrestment. Because of the proprietary nature of the results determined by these calculations, only the equations used will be recorded in this report.

To achieve the acceleration required for a successful test it is necessary to calculate the thrust and drag forces the rocket will experience, as shown in Figure 6 Rocket Free Body Diagram.

![Figure 6 Rocket Free Body Diagram](image)

The drag on the rocket vehicle directly correlates to the velocity of the rocket vehicle.

Velocity:

\[ v_f = v_i + a \Delta t \]

Where \( v \) is the velocity of the rocket at a specific instance of time.

Drag Force:

\[ F_{Drags} = .5 \cdot c_d \cdot \rho_{air} \cdot A \cdot v^2 \]

Where \( A \) is the cross sectional area of the rocket.

Total Mass of Rocket:

\[ m_{rocket} = N \cdot m_{engine} + m_{body} + m_{payload} \]

Where \( N \) is the number of engines used in the rocket. The weight varies per type of engine.

Static Friction Force:

\[ F_s = g \cdot m_{rocket} \cdot \mu_s \]

This value will decrease as the rocket begins to move and the static coefficient of friction is replaced with the kinetic coefficient of friction.
Resultant Force on Rocket:

\[ ma = F_T \times N - F_d - F_s \]

Where \( N \) is the number of engines used in the rocket. The force of thrust is the extrapolated thrust value provided by an Estes engine at a specific moment of time (See Appendix F National association of rocketry Rocket Engine Thrust Data). The thrust varies per type of engine.

Acceleration of the Rocket:

\[ a_{\text{rocket}} = \frac{F_R}{m_{\text{rocket}}} \]

A distance was chosen for maximum track length based on space available at L-3 FOS’s facility. The nature of this test does not allow supports to be run along this track; therefore cable sag must be identified and minimized. Figure 7 represents the lowest point of the cable, the middle. The sag from the two posts to this point can be determined using the catenary curve equation.

![Figure 7 Cable Sag Free Body Diagram](image)

Cable Weight per Unit Length:

\[ \frac{m}{l} = \frac{m_{\text{cable}}}{l_{\text{track}}} \]

Cable Sag:

\[ s = \left[ \left( \frac{m_{\text{cable}}}{l_{\text{track}}} \right) \times F_g \right] \times \cosh \frac{l_{\text{track}}}{2 \times \left[ \left( \frac{m_{\text{cable}}}{l_{\text{track}}} \right) \times F_g \right]} - 1 \]

Where \( F_g \) is the force perpendicular to cable length, in this case gravity and \( T \) is the tension.
added to the cable.

The actual amount of cable required due to sag between posts, is determined by:

\[ l_{\text{cable}} = 2 \cdot \left[ \left( \frac{m_{\text{cable}}}{l_{\text{track}}} \right) \cdot F_g \right] \cdot \sinh \left( \frac{l_{\text{track}}}{2 \cdot \left( \frac{m_{\text{cable}}}{l_{\text{track}}} \right) \cdot F_g} \right) \]

With this information a reasonable amount of preload can be applied to the cable to minimize sag.

Cable tension is created by applying torque to turnbuckles affixed to one side of the track setup:

\[ F_T = \frac{T}{\text{Engagement Length} \times \text{Thread Diameter}} \]

The arrestment system used in this tester relies on friction force for braking power. Mass is applied to a wooden beam that exerts a force on a rope that is attached to the arresting vehicle. The amount of mass required to stop the moving vehicles before the end of the track must be determined. The forces exerted on the arrestment rope can be seen in Figure 8.

![Figure 8 Arrestment Rope Free Body Diagram](image)

The forward momentum of the rocket after engine burn is represented by \(mv\). \(F_f\) is a combination of air resistance and friction from the rocket sliding along the cable. In this calculation, the nylon webbing is considered to be massless and does not contribute to friction on the rocket. \(F_x\) is the friction force from the webbing running through the brake that slows down the rocket.

When the rocket has finished firing, the mass of the engines has changed. The new total
mass must be determined:

\[ m_{rocket} = N \times m_{engine} + m_{body} + m_{payload} \]

This new mass is used to calculate both the momentum and friction from the cable on the rocket vehicle.

The friction force exerted by the brake is determined by the mass resting on the webbing:

\[ F_f = g \times m_{on\ brake} \times \mu_{wood/nylon} \]

The friction force is exerted on the rocket at an angle as the rocket travels down the cable and the x-component of the force must be calculated:

\[ F_x = F_f \times \cos \theta \]

Theta is the angle between the brake and the rocket, as shown in Figure 8. Theta changes at every instance as the rocket vehicle moves down the cable.

The deceleration of the rocket vehicle is calculated by adding the x-component of friction to the resultant force calculated previously:

\[ ma = F_T \times N - F_d - F_s - F_x \]

Because the rocket engines are no longer firing, this creates a large force opposing forward motion and results in rapid deceleration that eventually stops the rocket.

The overall distance traveled by the rocket vehicle can be calculated by totaling the distance traveled over each increment of time:

\[ d_{traveled} = \sum v \times \Delta t + .5 \times a \Delta t^2 \]

The amount of space required for breaking can be adjusted by the amount of weight placed on the brake. If too much weight is placed on the brake the stress from the deceleration can damage the rocket vehicle.

A finite element analysis study was conducted to determine if the expected forces on the rocket vehicle would be too strong for the material and cause damage or failure. Force was applied to the top and bottom pieces of the rocket vehicle at the most extreme edges of the wings, which would be the worst case position of the braking lanyard making contact with the vehicle. The study determined that the rocket vehicle could withstand forces approximately three times as strong. Visual results of analysis are shown in Figure 9 and Figure 10. Additional data can be found in Appendix G Finite Element Analysis Results.
Figure 9 Bottom Wing FEA [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]

Figure 10 Top Wing FEA [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]
**ASSEMBLY VIEWS**

This RoaR Tester is comprised of five mechanical subassemblies. Isometric views of each subassembly and the final assembly are listed below. The cable length in the final assembly has been shortened for clarity. The technical drawing package for this tester can be found in Appendix I Technical Drawing Package.

![Rocket Fixture Model](image1)

**Figure 11 Rocket Fixture Model**

![Arrestment Lanyard Model](image2)

**Figure 12 Arrestment Lanyard Model**
Figure 13 Friction Brake Model
Figure 14 Launch Post Model and End Post Model
FABRICATION AND ASSEMBLY

Four of the five mechanical subassemblies required some fabrication. No fabrication was required to attach the cable portion to the posts. The electrical subassembly also did not require any fabrication as it was all built with commercial off the shelf (COTS) components.

ROCKET VEHICLE

The rocket vehicle consists of four [MATERIAL] 3D printed components and four sets of upper and lower brass inserts. The body is made of an upper and lower rocket portion, a rear exhaust plate, and tubes to hold the rocket engines. [MATERIAL] was chosen as the rocket vehicle material due to high durability and a greater resistance to heat than normal 3D print material. The [MATERIAL] components were printed out of house by a company called Proto Labs. The brass inserts were machined on a mill here at the L-3 FOS facility. The inserts fit together to lock the rocket vehicle onto the cable. To help guide the cable smoothly, they have been countersunk on the leading side. In order to ensure successful operation of the rocket vehicle, it was critical that these inserts line up correctly and the countersink was centered between them. Figure 15 shows the upper and lower sections of the insert and the matching halves of the countersink. While all four upper sections are identical, the right and left side lower portions are mirrored to help hold the rocket vehicle together. By removing a third screw, the top portion of the rocket vehicle body can be removed while the rocket vehicle is attached to the test cable.

Figure 15 Rocket Vehicle Brass Insert, Right Side
Fabrication of the inserts took approximately ten hours. Final sanding of the 3D printed body to ensure it fit together properly took approximately six hours. Figure 17 shows the fully assembled rocket vehicle.
**Friction Brake**

The friction brake used to slow the rocket was constructed out of wood. A circular saw was used to cut the wood. The wood was assembled using an impact drill and 10X2.5” coated wood screws. The reel for the webbing was constructed using a five gallon bucket as a guide and PVC pipe to provide the center. The fabrication of the brake took approximately 3 hours for a 2 man team. Figure 18 shows the brake without the horizontal stabilizer beams that are staked to the ground attached.

![Friction Brake (no stabilizers)](image)

At the end of the Nylon webbing, a stainless steel lanyard is attached. This is the arrestment lanyard that the rocket vehicle collides with during braking. This lanyard connects the brake and webbing to the test cables. The Nylon webbing is wrapped around the lanyard and bolted. The stainless steel rings attached to the lanyard are attached to the cable during the testing process. Figure 19 shows the arrestment lanyard assembly.
In order to provide the proper support structure to attach the supports posts, a concrete pad was poured for each post. The dimensions of the pad were 1’X 2’X 3’. It was critical to go down to a depth below the frost line to ensure the pads did not shift in the future. A layer of gravel was also placed below the concrete to help establish a solid and level base. Before the concrete had hardened, wooden dowels were inserted to mark the locations that anchors would be placed for the posts. By inserting the dowels, it prevented the need to drill through the concrete and instead meant drilling out just the dowel pins, saving time. Pouring the pads for the posts took a three man team approximately nine hours. To drill out the dowels and insert the anchors took an additional hour and a half.

The two support posts were constructed entirely out of stainless steel. The main sections of the posts came as one piece of square tube and were cut into a two foot and four foot section. The difference in height allowed for final adjustments to be made once they were attached to the bases and placed on the pads.

The launch post consisted of the four foot section of square tubing with a plate attached on the side, where the turnbuckles and cable attach, and one on the bottom that was bolted into the cement pad. The height of the plate was determined by running surveying string from the shorter end post and marking the height where it reached the Launch Post. Figure 20 shows the two posts in a side by side comparison.
The end post consisted of the two foot section of square tubing. The cable does not connect to the end post; instead, it goes through two eyelets attached to a plate on the back of it. To prevent the cable from bending at a sharp angle and damaging itself, a half cylinder was attached to the back plate to provide a radial section to guide the cable. To prevent the cable slipping off of this radius during the tensioning process, two bars were attached to the sides.

All pieces of the posts were welded together by a certified welder at L-3 FOS. Drilling for bolt holes and eyelets were done onsite as well. Fabrication of both posts took approximately six hours.

**Electronics Package**

The electronic portion of this tester is a two part wireless system. A USB powered microcontroller known as a JeeLink attaches to a laptop and acts as a radio frequency (RF) receiver. A second controller, a JeeNode, is inside the rocket vehicle and acts as a transmitter. Connected to the transmitter is an 11V lithium polymer battery pack, an
accelerometer, and a memory board. This allows the rocket vehicle to transmit real-time data on its acceleration during testing as well as store it for download at a later time. Figure 21 shows the interior electronics of the rocket vehicle. In order to power the electronics system as well as a fuze, the voltage of the battery is higher than the maximum amount of voltage the board can receive. Therefore, voltage regulators are used to step down the voltage to the required 3.3V. A light and switch are also incorporated to allow the system to be shut off easily and make it possible to determine the power state visually. Figure 22 shows the wiring diagram for the components that connect to the JeeNode. Data sheets for all electrical components can be found in Appendix H Electrical Datasheets.
Soldering together all the components and connecting them to the COTS JeeNode took approximately 5 hours. A second JeeNode had to be ordered because the first one was damaged and stopped functioning.

**IGNITION SYSTEM**

The standard Estes Pro Series II Launch Controller has been modified to incorporate a shunt. The cables were cut and a D-Sub Miniature 9-Pin Connector was put in place on either end. An additional connector was created with a wire running between two pins, creating a shunt. When this cable is plugged into the ignition system cable it will prevent an electrical current igniting any igniters attached to it. Figure 23 shows the cable and controller with the shunt attached.
Figure 23 Ignition System with shunt in place
TESTING AND PROOF OF DESIGN

TESTING METHODS

The original plan for testing this proof of concept called for setting up the supports and cables and then firing the rocket vehicle with all engines. Due to issues getting the onboard electronics to work correctly, this plan was modified to incorporate two phases of testing. Both phases will use the Rocket on a Rope Proof of Concept Test Plan created for L-3 FOS. This document may be found in Appendix K Test Plan.

Phase I will be a mechanical proof of concept. The test system will be installed and low speed rocket firing will occur. A rocket will be fired with one C engine present. If the rocket is successful, the test will be repeated with one C11-0 engine and two B6-0 engines. The purpose of this testing will be to show that the rocket can safely travel down the track and be stopped by the brake. The second firing will also prove that the engines can be reliably clustered. This testing does not require the use of the working board and accelerometer. Engine ignition will be recorded using a high speed camera and hand cameras will record the overall test. Figure 24 shows the tester location and setup. The yellow arrow identifies the test direction and length. The red triangle is the halfway mark of the test track, where the brake is located. The blue ovals represent hand camera locations and the purple star is the location of the high speed camera.

![Figure 24 Tester Setup](image)

During these tests, the time the rocket vehicle is in motion and the distance traveled will be recorded. This data will be compared to the theoretical model to determine its validity. If the data is similar, the estimated acceleration forces can be determined as well.

Phase II will be performed using the working electronic package. The rocket vehicle will be fired with three C11-0 engines and then again with five C11-0 engines and two B6-0 engines.
The onboard electronics will transmit real-time data to the receiver attached to the laptop. This data will then be plotted graphically by a program called Processing, giving us an accurate acceleration curve. This data will then be compared to the theoretical model to improve its accuracy and determine any inconsistencies. In addition to the working electronics, this phase of testing will incorporate any changes determined to be necessary after Phase I. A summary of the steps needed to complete a test is shown in Figure 25.
RESULTS

On April 29th, initial cable tensioning occurred. The cables were pulled tight by hand, then attached to the turnbuckles and tensioned. Even fully tightened, the turnbuckles were not sufficient to remove a significant amount of slack from the cables. The rocket vehicle was attached to the cable and proved able to slide easily when pushed by hand. This preliminary setup is shown in Figure 26.

In order to increase the preload on the cable, the L-3 FOS supervising engineer, Marc Worthington, created a tensioner device, shown in Figure 27. The cable is pulled around the metal rod extending from the arm and pulled tight by a ratchet pull. This created a preload prior to the tightening of the turnbuckles. This device was implemented on the second test attempt.
On May 1st, Phase I testing occurred. Using the tensioning device before tightening the turnbuckles greatly increased the tension in the cable. Although two of the concrete anchors showed signs of beginning to pull out, testing was authorized to continue for the day. Any further testing was postponed until after this issue was addressed.

In both the single engine (Estes C11-0) and three engine (Estes C11-0 and B6-0) tests the rocket vehicle successfully accelerated with all engines firing and then was stopped by the brake. Successful engine ignition in the cluster was verified using the high speed camera. In the first test, the rocket vehicle traveled the 98 feet distance to the brake in approximately four seconds. It did not move the arrestment lanyard and webbing. In the second test, the rocket vehicle traveled the distance in approximately two seconds. It moved the arrestment lanyard and webbing one foot, for a total of 99 feet of travel.

After each test, the rocket vehicle was inspected for damage. After the first test, small droplets of melted [MATERIAL] were discovered on the center spacer of the forward exhaust plate. The amount of melted material increased in the second test. Although the melted material balled up, there was no discernible change in material thickness of the plate. Figure 28 shows the damage after the second test.
Additionally, after the second test, on the front of the rocket vehicle wings, the cable had dug into the [MATERIAL] creating a small groove on either side of the rocket. The location of the damage is circled in Figure 29.
The material around the B6 engine vents had also been discolored by the heat. The damage is shown in Figure 30. Although it is not able to be inspected because of the location, it is likely that the same discoloration occurred around the C11 center engine vents.
After the conclusion of testing, material data recorded on paper was transferred to the digital test log. Table 2 shows the test log and recorded data.

**Figure 30 Rocket Vehicle Vent Damage**

After testing, the cables were taken down in preparation for modifications to provide stronger support. All additional photos taken during the test setup process can be found in Appendix L Test Setup Photos.
PROJECT MANAGEMENT

BUDGET

L-3 Fuzing and Ordnance Systems allotted a maximum of [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION] for this project initially. The original expected cost of this project is [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]. This money will be allotted to the fabrication and construction of the testing track and the tester itself, including labor. The budget, Table 3, has been based on product costs from my experience with 3D printing and the cost of materials on McMaster-Carr (7). L-3 FOS provided the labor cost for hours provided. Labor rates are proprietary information.

Table 3 Budget [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]

At the completion of Phase I of the project, the final amount spent on materials for the tester was [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]. The complete breakdown of this cost is outlined in Table 4 in the Bill of Materials section of the report.
BILL OF MATERIALS

The parts required to build this tester are listed in Table 4, sorted by subassembly.

Table 4 Bill of Materials [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]
SCHEDULE

To complete this project on time an initial schedule has been laid out, Table 5. By December all design calculations will be completed. As calculations are completed on a component, it will be modeled. During December the technical drawing package will be completed. When the New Year begins materials will be ordered and fabrication will begin as they arrive on site. This schedule will allow all aspects of the project to be completed and tested before the tech expo in April. The schedule of this project will be updated over time to show the actual dates of completion for the goals set.

Design Phase Update:

Table 5 has been updated to reflect the dates of completion of all work done prior to the end of the design phase. Yellow dates are expected work time and completion. Red dates are actual work time and completion that occurs after the expected completion date. Green dates are on dates that matched the schedule. Blue dates are dates that occurred prior to completion.

Test Phase Update:

Table 5 has been completed to reflect final standing for the project. Setbacks with the electronics package caused major test delays the prevented the advisor demonstration from occurring. Additionally, because of the time required to make modification to the test setup for Phase II, it will occur at a later time after submittal of this report.
## Table 5 Schedule

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Review (Advisor)</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report Draft Due</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report Due</td>
<td></td>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proof of Design Agreement (Advisor)</td>
<td></td>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept Selection (Advisor)</td>
<td></td>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Calculations (Track)</td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D Model (Track)</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D Model (Test Fixture)</td>
<td></td>
<td></td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Calculations (Rocket)</td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Calculations (Arrestment System)</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D Model (Arrestment System)</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bill of Materials</td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Drawing Package</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Materials</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fabricate Components</td>
<td></td>
<td></td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Presentation to Faculty</td>
<td></td>
<td></td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build Tester</td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Report to Advisor</td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Tester</td>
<td></td>
<td></td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Test</td>
<td></td>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstration to Advisor</td>
<td></td>
<td></td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TechExpo</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Presentation to Faculty</td>
<td></td>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Report Review With Advisor</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Submitted to Library</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

Phase I testing was a success. The system worked as expected with minimal wear on the rocket vehicle and track. In addition to proving that everything worked mechanically, the testing supported the theoretical model. Using the recorded video, an estimate of the flight time of the rocket vehicle was determined. In the first test, the rocket vehicle was expected to travel the distance to the break in 3.83 seconds. This matches with the approximation of 4 seconds measured with the stop watch with a percent error of 4.25%. In the second test, the expected time of 2.09 seconds matches the 2 second approximation. This also has a percent error of 4.25%. In future testing, time will be monitored using the onboard electronics, giving a more accurate value for time in flight.

The distance the rocket vehicle travel was also recorded during testing. The rocket vehicle in the first test was expected to travel 100.23 feet. In the test it traveled 98 feet. This is a percent error of 2.22%. In the second test it traveled 99 feet instead of the expected 107.61 feet. This is a percent error of 8.00%. The data is compared graphically in Figure 31. These discrepancies can likely be attributed to the friction from the brake. The braking friction appears to be higher than expected and the webbing is not being pulled from the reel. Instead, the rocket vehicle is experience a hard stop. As the rocket speed increases, if the brake is not modified, it will continue to experience larger discrepancies from the model, which assumed the braking force came solely from the mass placed on the webbing and not from the reel itself.

![Theoretical vs Experimental Data](image)

Figure 31 Data Comparison

Because the rockets are hitting the brake in a time period similar to the expected time, it can be assumed that they are experiencing an acceleration that is close to the theoretical acceleration. This means that the rocket vehicle accelerated to an approximate peak G force
of 3 and 5 in the tests.

Before Phase II testing can occur, a few issues must be addressed. The support posts must be modified to withstand a higher tension force on the cable. Guide wires should be attached to each post to counteract the cable pulling the posts together. The anchor holes must also be re-drilled into the concrete to ensure that the anchors cannot come out of the ground. In hindsight, j-bolts should have been used to anchor the posts for a stronger hold. The cable tensioner must be improved as well to provide a larger pretension force. This can be achieved by increasing the length of the arm.

In order to acquire a better understanding of the braking process, a camera should be setup to record a close up of the rocket vehicle hitting the brake. This may provide additional information on other forces at play, specifically if the Nylon webbing stretches and retracts, skewing distance measurements.

While not mandatory for Phase II testing, some modifications to the rocket vehicle may improve reusability. If the areas affected by the forward exhaust plate and engine tubes of the rocket worsen as the number of engines increase, additional testing could be done to determine if increasing the vent size would lessen the wear.

The damage to the front wings of the rocket vehicle creates debris that can be caught in the inserts. Because there is little wear to the inserts themselves, there is no safety concern. This may increase friction and slow the rocket vehicle down. In order to lessen the effects, it may be necessary to increase the diameter of the holes. Alternatively, the brass insert width could be increased so that a majority of the wing is brass and not the softer [MATERIAL].
WORKS CITED
APPENDIX A RESEARCH

(08/15/2014) Interview with Bryan Mannon, Mechanical Engineer IV, Internal Research and Development
L-3 Fuzing and Ordnance Systems, 3975 McMann Road Cincinnati OH, 45245

Co-op supervisor, previously worked as a manufacturing supervisor.
Suggested if it is not feasible to use rocket motors that a pulley system could create required forces. It would using a falling mass to create the required force and pull the test unit down a horizontal cable. He felt this would be a simpler way to complete the task without the use of a rocket motor, which would allow for better repeatability. Worried about slowing the tester unit down without an extended track or damaging the unit.

(08/18/2014) Interview with Marc Worthington, Mechanical Engineer IV, Internal Research and Development L-3 Fuzing and Ordnance Systems, 3975 McMann Road Cincinnati OH, 45245

Lead Engineer on IRAD programs.
Received approval last year to create a rocket sled tester.
Concerned EHS would require safety cage around cable tester which would increase cost, wondered if putting it low to ground would decrease safety requirement.

(09/18/2014) Interview with Dave Mengle, Mechanical Test Technician, Test Fixture Designer L-3 Fuzing and Ordnance Systems, 3975 McMann Road Cincinnati OH, 45245

In charge of Airgun Tester, 15+ years of tool design
Suggested the test could be done in the airgun, would require a larger test slug with onboard electronics.
Downside of this approach would be likely destruction of the test unit during the testing process as the airgun would not have enough track to slow down.
A new catcher system with a more extreme brake would have to be developed to save any part of the unit or electronics.
Centrifuge Tester

PRODUCT OVERVIEW
From calibrating accelerometers to studying the constraints of mechanical and electrical components under constant acceleration, Space Electronics offers both precision centrifuges with the best stability and lower cost alternatives.
For combined environmental testing we offer advanced centrifuges that feature vibration capabilities, temperature variations, and vacuum chambers.
Space Electronics distributes Actidyne centrifuges in North America. Actidyne is the world leader in centrifuges, manufacturing the widest range of centrifuges available today.

HIGHLIGHTED BENEFITS
Our centrifuges use a unique design that provides key advantages:

• **AC Brushless Drive** - We offer both direct drive centrifuges for precise control and belt drive for lower cost models. All models are based on the most advanced AC brushless drive technology. This provides maintenance free operation.
• **Connection with payload** - Electrical slip rings, optical fiber rotary joint and modems, and fluid rotary joints are available to connect stationary control hardware to the rotating test assembly.
• **Safety** - Our centrifuges incorporate a number of safety features, both at hardware and software level. The centrifuge enclosure is made of high strength steel and is outfitted with interlocks which inhibit operation of the system in the event an access door is left open.
• **Controller** - We only make digital control systems, using industrial grade programmable controllers or the Actidyne ND controller for best accuracy and real-time profile control. DC linear acceleration and sinusoidal g profiles are available.
• **Remote Interfaces** - Optional remote interfaces are available (Ethernet, IEEE 488, USB, RS232, RS422, Analog Input / Output).

[http://www.space-electronics.com/Products/centrifuge](http://www.space-electronics.com/Products/centrifuge)
09/08/2014

Does not allow for quick acceleration to simulate rocket motor without additional fixturing

All Electronics must be mounted on table or require expensive slip rings to run cabling off of table

Ideally larger to hold more equipment
Rocket Sled Tester

The relationship between acceleration, velocity, and distance traveled by a test item can be simulated in a variety of ways. Positive and negative acceleration levels up to 1000's of g's are possible.

Would be built at a much smaller scale
Requires all electrics onboard
Needs rockets to provide acceleration (cost/safety)
Would Require External electronics to verify acceleration

09/08/2014

Instrumentation
The Rocket Sled Track incorporates exceptional instrumentation capabilities, including telemetry, hardened on-board data recorders, hardwired data acquisition systems, high speed video, flash x-ray, and film cameras. These systems gather data from a variety of instruments and transducers. Time-space-position information (TSPI) systems acquired data up to 1kHz with a 1 ft accuracy. Data acquisition systems are capable of acquiring data at sample rates up to 1MHz.
This invention relates to a test facility apparatus and more particularly to a novel test facility adapted to subject a test specimen or the like to periods of controlled acceleration and deceleration.

The test facility as disclosed herein is primarily intended to simulate accelerations encountered during the launching phase of an air-breathing missile by means of JATO type rockets; however, it is to be understood that it may be utilized for other and similar purposes. Maximum accelerations encountered during the flight of a missile of the above type normally occur during the launching phase thereof. It is, therefore, during this initial acceleration phase that shock-sensitive apparatus carried by the missile, e.g. guidance system apparatus, etc. is damaged and malfunctions if at all. Although greater accelerations may be encountered during the terminal dive phase of the missiles flight these latter accelerations are not important insofar as a successful flight is concerned.

http://www.google.com/patents/US3001393
09/08/2014

Could be used at a smaller scale

Develops way to decelerate unit to prevent damage

Uses pulley and piston movement for acceleration no explosives required
Rocket-on-a-Rope Testing

Uses two cable system for stability. Sleeves prevent heat damage to cables. Capable of Mach speeds. Test article placed in rocket or hung from below.

**CAPABILITIES TO DATE**

- Velocities > Mach 2 (710 m/s)
- Launch weights up to 100 lbs
- Release test articles from rope for free-flight environment using linear shape charge rope cutters
- Detonate warheads in flight at precise location using high-voltage screen boxes or ESAD
- Spin warhead independent of rocket motor prior to launch for tactical environment
- Impact MOUT targets for fuze testing
- Velocity predictions within 3 percent
APPENDIX B PRODUCT OBJECTIVES

1. **Safety 20%**
   a. Cage system around tester
   b. Alert before firing
   c. Emergency Stop at end of track
   d. Fixture will lock test unit into the fixture during use
   e. Low to ground
   f. Meets EHS standards of L-3 FOS

2. **Low Cost 15%**
   a. Additive Manufacturing of fixture on test track
   b. Uses only two support posts
   c. Will use COTS rockets for acceleration
   d. Material Selection

3. **Onboard Data Recording 12.5%**
   a. Fixture will allow batteries and PCBs to be mounted onto the fixture and connected to test unit

4. **Repeatable Tests 17.5%**
   a. Rocket Calculations
   b. Verification of acceleration by external camera

5. **No damage to test unit 20%**
   a. Breaking System for device on tester
   b. Fixture will lock test unit into the fixture during use

6. **Tester can be setup outdoors 10%**
   a. Able to be dismantled after testing
   b. Supports will be able to endure inclement weather
   c. Material Selection

7. **Adjustable for different products 5%**
   a. Adjustable height of line
   b. Will use interchangeable tester fixtures on the same track
# APPENDIX C SCHEDULE

## Original Schedule:

<table>
<thead>
<tr>
<th>Jesse Kuhn</th>
<th>Linear Acceleration Tester</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TASKS</strong></td>
<td></td>
</tr>
<tr>
<td>Content review (advisor)</td>
<td>9</td>
</tr>
<tr>
<td>Report Draft Due</td>
<td>6</td>
</tr>
<tr>
<td>Report Dude</td>
<td>13</td>
</tr>
<tr>
<td>Proof of Design Agreement (advisor)</td>
<td>17</td>
</tr>
<tr>
<td>Concepts/Selection (advisor)</td>
<td>17</td>
</tr>
<tr>
<td>Design Calculations (Track)</td>
<td>30</td>
</tr>
<tr>
<td>3D Model - (Track)</td>
<td>6</td>
</tr>
<tr>
<td>3D Model - (Test Fixture)</td>
<td>14</td>
</tr>
<tr>
<td>Design Calculations (Rocket)</td>
<td>27</td>
</tr>
<tr>
<td>Design Calculations (Braking System)</td>
<td>25</td>
</tr>
<tr>
<td>3D Model - (Braking System)</td>
<td>12</td>
</tr>
<tr>
<td>Bill of Materials</td>
<td>19</td>
</tr>
<tr>
<td>Technical Drawing Package</td>
<td>5</td>
</tr>
<tr>
<td>Order Materials</td>
<td>12</td>
</tr>
<tr>
<td>Fabricate Components</td>
<td>23</td>
</tr>
<tr>
<td>Design Presentation to Faculty</td>
<td>30</td>
</tr>
<tr>
<td>Build Tester</td>
<td>6</td>
</tr>
<tr>
<td>Design Report to Advisor</td>
<td>6</td>
</tr>
<tr>
<td>Test Tester</td>
<td>20</td>
</tr>
<tr>
<td>Modification</td>
<td>2</td>
</tr>
<tr>
<td>Final Test</td>
<td>13</td>
</tr>
<tr>
<td>Demonstration to Advisor</td>
<td>24</td>
</tr>
<tr>
<td>Tech Expo</td>
<td>3</td>
</tr>
<tr>
<td>Project Presentation to Faculty</td>
<td>11</td>
</tr>
<tr>
<td>Project Report Review with Advisor</td>
<td>18</td>
</tr>
<tr>
<td>Library .pdf file in BB</td>
<td>23</td>
</tr>
</tbody>
</table>
APPENDIX D BUDGET [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]
APPENDIX E PROOF OF DESIGN

Criteria to be met:

1. Testing
   a. The tester will reach the target environment in order to arm the onboard Safe and Arm device being tested.
   b. The tester will meet the requirements of JOTP-052 (Joint Ordnance Test Procedure) Guideline for Qualification of Fuzes, Safe and Arm (S&A) Devices, and Ignition Safety Device (ISD).
   c. While on the cable, tester can be opened to make adjustments to payload.

2. Safety
   a. The tester will meet Environment Health and Safety requirements.
   b. The deceleration of the tester will be controlled.
   c. The tester will prevent accidental firing of rocket.
APPENDIX F NATIONAL ASSOCIATION OF ROCKETRY ROCKET ENGINE THRUST DATA

ESTES C11

CERTIFIED VALUES

Total Impulse: 9.00 newton-seconds
Delays: 0, 3, 5, 7 seconds
Propellant Type: Black Powder
Propellant Mass: 12.0 grams
Casing Dimensions: 24 mm × 70 mm
Certification Date: 2001-June-18
Contest Use Date: 2001-August-17
Certification Type: Model Rocket

STATIC TEST DATA

Date Tested: 2001-June-17
Total Impulse: 8.80 newton-seconds (σ 0.17)
Peak Thrust: 21.73 newtons (σ 0.62)
Burn Time: 0.81 seconds (σ 0.03)
Average Thrust: 10.86 newtons
Mass After Firing: 18.9 grams

<table>
<thead>
<tr>
<th>Delay Time</th>
<th>Average Delay</th>
<th>Measured Delay</th>
<th>Initial Mass</th>
<th>Mfg Recommended Max Lift Off Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>3.65</td>
<td>30.4 g</td>
<td>34.5 g</td>
</tr>
<tr>
<td>5</td>
<td>5.24</td>
<td>6.38</td>
<td>35.5 g</td>
<td>35.7 g</td>
</tr>
</tbody>
</table>

TYPICAL THRUST-TIME CURVE

![Thrust-Time Curve]

REMARKS

Updated: 12/01

© 2001 NAR Standards and Testing Lab
; ESTES C11 RASP.ENG file made from NAR published data
; File produced JANUARY 1, 2002
; The total impulse, peak thrust, average thrust and burn time are
; the same as the averaged static test data on the NAR web site in
; the certification file.  The curve drawn with these data points is as
; close to the certification curve as can be with such a limited
; number of points (32) allowed with wRASP up to v1.6.
C11 24 70 0 5-5-7 0.012 0.0555 0.034
0.066 3.782
0.107 7.566
0.145 10.946
0.183 14.832
0.214 17.618
0.226 18.213
0.256 20.107
0.281 21.208
0.298 21.730
0.306 20.206
0.323 17.321
0.337 14.931
0.358 13.236
0.385 11.947
0.413 11.650
0.468 10.946
0.539 10.450
0.519 10.648
0.683 10.648
0.715 10.648
0.726 10.053
0.746 8.163
0.758 5.773
0.778 3.185
0.795 1.394
0.810 0.000
ESTES B6

CERTIFIED VALUES

Total Impulse: 4.90 newton-seconds
Delays: 0, 2, 4, 6 seconds
Propellant Type: Black Powder
Propellant Mass: 5.6 grams
Casing Dimensions: 18 mm × 70 mm
Certification Date: Continuing
Contest Use Date: Continuing
Certification Type: Model Rocket

STATIC TEST DATA

Date Tested: 95-March 25
Total Impulse: 4.33 newton-seconds (σ 0.08)
Peak Thrust: 12.14 newtons (σ 1.57)
Burn Time: 0.86 seconds (σ 0.15)
Average Thrust: 5.03 newtons
Mass After Firing: 9.7 grams

<table>
<thead>
<tr>
<th>Delay Time</th>
<th>Average Measured Delay</th>
<th>Initial Mass</th>
<th>Mfg Recommended Max Liftoff Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>15.6 g</td>
<td>113.7 g</td>
</tr>
<tr>
<td>2</td>
<td>1.53</td>
<td>18.8 g</td>
<td>127.4 g</td>
</tr>
<tr>
<td>4</td>
<td>3.68</td>
<td>19.1 g</td>
<td>113.2 g</td>
</tr>
<tr>
<td>6</td>
<td>5.44</td>
<td>19.4 g</td>
<td>50.6 g</td>
</tr>
</tbody>
</table>

TYPICAL THRUST-TIME CURVE

REMARKS

Updated: 8/95

© 1998 NAR Standards and Testing
Estes B6 RASP.ENG file made from NAR published data
File produced October 3, 2000
The total impulse, peak thrust, average thrust and burn time are
the same as the averaged static test data on the NAR web site in
the certification file. The curve drawn with these data points is as
close to the certification curve as can be with such a limited
number of points (32) allowed with wRASP up to v1.6.
86 18 70 0.2-4.6 .0056 .01822 E
0.023 0.688
0.057 2.457
0.089 4.816
0.116 7.274
0.148 9.929
0.171 12.140
0.191 11.695
0.200 10.719
0.209 9.240
0.230 7.667
0.255 6.488
0.305 5.505
0.375 4.816
0.477 4.620
0.580 4.620
0.671 4.521
0.746 4.226
0.786 4.325
0.802 3.145
0.825 1.572
0.860 0.000
APPENDIX G FINITE ELEMENT ANALYSIS RESULTS [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]
APPENDIX H ELECTRICAL DATASHEETS
The **JeeNode** is a wireless micro-controller board designed for a variety of Physical Computing tasks. From measuring and reporting temperature, humidity, and other environmental data to tracking and controlling energy consumption around the house. It was inspired by the Arduino Duemilanove and Uno boards, and by the "Real Bare Bones Board" (RBBB) from [Modern Device](http://jeelabs.net/projects/hardware/wiki/jeeboard).

### At a glance

What’s on a JeeNode v6, from left to right:

- 6-pin FTDI-compatible serial I/O port, used for power, re-flashing, and communication
- 3.3V power regulator which accepts 3.5 ... 13V as external power source
- 8-pin combined Power / Serial / I2C / Extended (PSIX) connector
- ATmega328P microcontroller by Atmel, with 16 MHz ceramic resonator
- 2x4-pin combined SPI / ISP connector, with 2 general-purpose I/O lines
- RFM12B wireless RF module for the 433, 868, or 915 MHz ISM band, by Hope RF
- short wire - acts as radio antenna (78, 82, 165 mm long, for 915, 868, 433 MHz, respectively)

And on the long sides of the board: two I/O "ports" each, with one analog/digital I/O, one digital I/O, +3.3V, ground, PWR, and interrupt (IRQ) line. All ports have an identical pinout for use with "plugs".

### Arduino compatibility

**Similarities**

- both run the same OptiBoot bootstrap code, and can therefore run Arduino IDE's sketches (see [Bootstrap Versions](http://jeelabs.net/projects/hardware/wiki/jeeboard))
- same ATmega328P micro-controller as the most popular Arduino's and other "-duinos"

**Differences**

- there’s a 433, 868, or 915 MHz wireless RF module on board
- completely different physical layout, incompatible with Arduino "shields"
- a JeeNode runs internally at 3.3V, not 5V - this also affects all I/O ports & pins
- not all the Arduino pins are brought out on connectors, some pins are assigned fixed roles
- the ISP connector has 2 extra pins, to allow re-using it as SPI bus for 1 or 2 devices
- the TWI bus has been permanently assigned to its own connector
- runs at 16 MHz - but using a slightly less accurate ceramic resonator i.s.o. a crystal
- there are no LEDs, to reduce power consumption when running off batteries

### Design choices

The main reason for creating the JeeNode was that Arduinos are not yet very convenient for 3.3V devices such as the RFM12B module. By including a 3.3V regulator, the JeeNode can be powered from USB with an FTDI cable/board, a DC power adapter, or various types of 3.6 ... 12V batteries.

A second reason was to have a unit which includes wireless connectivity by default. The RFM12B module is a low cost option with sufficient power and range to provide reliable communication around the house - a basic packet protocol can be implemented in under 3 Kb of C code.

The third reason is that it is quite common to run out of power and ground connectors when hooking up a few sensors to an Arduino. While there are nice "proto shields" to overcome this, it seemed logical to try and come up with a different connector scheme for the common case of just a few sensors / actuators. Furthermore, being identical, all four JeeNode ports have the same features and connections, allowing sensors to be re-used and re-combined later on.
Lastly, the JeeNode is designed from the ground up to support very low-power use with batteries.

**Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ATmega328P</td>
</tr>
<tr>
<td>Maximum frequency</td>
<td>16 MHz (down to 3.3V)</td>
</tr>
<tr>
<td>Power consumption</td>
<td>4 µA .. 35 mA</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>3.3V .. 13.0V</td>
</tr>
<tr>
<td>Dimensions</td>
<td>85.9 x 21.1 x 9.9 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>12 g</td>
</tr>
</tbody>
</table>

**Connectors & pinout**

**Port/pin mapping**

<table>
<thead>
<tr>
<th>Port</th>
<th>Name</th>
<th>Extras</th>
<th>Arduino</th>
<th>Signal</th>
<th>Chip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DIO1</td>
<td>-</td>
<td>Digital 4</td>
<td>PD4</td>
<td>pin 6</td>
</tr>
<tr>
<td></td>
<td>AIO1</td>
<td>Analog</td>
<td>Digital 14 / Analog 0</td>
<td>PC0</td>
<td>pin 23</td>
</tr>
<tr>
<td>2</td>
<td>DIO2</td>
<td>PWM (timer 0)</td>
<td>Digital 5</td>
<td>PD5</td>
<td>pin 11</td>
</tr>
<tr>
<td></td>
<td>AIO2</td>
<td>Analog</td>
<td>Digital 15 / Analog 1</td>
<td>PC1</td>
<td>pin 24</td>
</tr>
<tr>
<td>3</td>
<td>DIO3</td>
<td>PWM (timer 0)</td>
<td>Digital 6</td>
<td>PD6</td>
<td>pin 12</td>
</tr>
<tr>
<td></td>
<td>AIO3</td>
<td>Analog</td>
<td>Digital 16 / Analog 2</td>
<td>PC2</td>
<td>pin 25</td>
</tr>
<tr>
<td>4</td>
<td>DIO4</td>
<td>-</td>
<td>Digital 7</td>
<td>PD7</td>
<td>pin 13</td>
</tr>
<tr>
<td></td>
<td>AIO4</td>
<td>Analog</td>
<td>Digital 17 / Analog 3</td>
<td>PC3</td>
<td>pin 26</td>
</tr>
</tbody>
</table>

**Ports 1 .. 4**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PWR</td>
<td>external power</td>
</tr>
<tr>
<td>2</td>
<td>DIO</td>
<td>digital I/O line</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>ground</td>
</tr>
<tr>
<td>4</td>
<td>+3V</td>
<td>regulated +3.3V</td>
</tr>
<tr>
<td>5</td>
<td>AIO</td>
<td>analog I/O line</td>
</tr>
<tr>
<td>6</td>
<td>IRQ</td>
<td>interrupt (tied to INT1)</td>
</tr>
</tbody>
</table>

**SPI / ISP connector**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MISO</td>
<td>master in / slave out</td>
</tr>
<tr>
<td>2</td>
<td>SCK</td>
<td>SPI clock</td>
</tr>
<tr>
<td>3</td>
<td>RST</td>
<td>reset</td>
</tr>
<tr>
<td>4</td>
<td>SEL0</td>
<td>tied to PB0 (A. pin 8)</td>
</tr>
<tr>
<td>5</td>
<td>MOSI</td>
<td>master out / slave in</td>
</tr>
<tr>
<td>6</td>
<td>RST</td>
<td>reset</td>
</tr>
<tr>
<td>7</td>
<td>SEL0</td>
<td>tied to PB1 (A. pin 9)</td>
</tr>
</tbody>
</table>

**FTDI connector**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>ground</td>
</tr>
<tr>
<td>2</td>
<td>N.C.</td>
<td>not connected</td>
</tr>
<tr>
<td>3</td>
<td>PWR</td>
<td>external power</td>
</tr>
<tr>
<td>4</td>
<td>RX</td>
<td>serial receive</td>
</tr>
<tr>
<td>5</td>
<td>TX</td>
<td>serial transmit</td>
</tr>
</tbody>
</table>
6 RTS for bootstrap / reset

PSIX connector

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+3V</td>
<td>regulated +3.3V</td>
</tr>
<tr>
<td>2</td>
<td>RXD</td>
<td>serial receive</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>ground</td>
</tr>
<tr>
<td>4</td>
<td>PWR</td>
<td>external power</td>
</tr>
<tr>
<td>5</td>
<td>SDA</td>
<td>TWI/I2C data</td>
</tr>
<tr>
<td>6</td>
<td>SCL</td>
<td>TWI/I2C clock</td>
</tr>
<tr>
<td>7</td>
<td>TXD</td>
<td>serial transmit</td>
</tr>
<tr>
<td>8</td>
<td>RST</td>
<td>reset</td>
</tr>
</tbody>
</table>

Parts list

<table>
<thead>
<tr>
<th>Part</th>
<th>Value</th>
<th>Details</th>
<th>Digi-Key#</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>10 kΩ</td>
<td>reset pull-up</td>
<td>10KEBK-ND</td>
</tr>
<tr>
<td>C1, C2, C3, C4</td>
<td>0.1 µF</td>
<td>decoupling</td>
<td>BC1160CT-ND</td>
</tr>
<tr>
<td>C5</td>
<td>10 µF</td>
<td>electrolytic, polarity matters!</td>
<td>P966-ND</td>
</tr>
<tr>
<td>IC1</td>
<td>ATmega328-20</td>
<td>can also use older ATmega168</td>
<td>ATMEGA328P-PU</td>
</tr>
<tr>
<td>IC2</td>
<td>MCP1702-33</td>
<td>3.3V LDO linear regulator</td>
<td>MCP1702-3302E/TO</td>
</tr>
<tr>
<td>X1</td>
<td>16 MHz</td>
<td>resonator</td>
<td>X908-ND</td>
</tr>
<tr>
<td>D1</td>
<td>Diode</td>
<td>v5 only - v6 check bridged on bottom side</td>
<td>Not required for V6</td>
</tr>
</tbody>
</table>

Construction hints - RFM12B module

You will see in the picture at the top that some RFM12B module pins are left unsoldered. This is because those pins are for signals that are not used in this design. For example, the module can output a clock signal to be used with an MPU lacking its own clock generator - that does not apply here. If you look at the zoomed false-color snapshot below, only pads with red traces need soldering (hard to see but this includes ANT and GND). If you want to count the pins carefully, then this method is fine. But soldering them all is fine as well.

It is important to mount the module sitting squarely in position. The pad spacing is necessarily small so if the module is skewed, there is a risk of a solder short between pad positions, hidden just under the edge of the module. A good technique is to solder a single corner pin first, check that the alignment at each pad is good (adjust the skew if required). Next solder the diagonally opposite corner, check again, then solder up at least the remaining required pins.

The antenna (Ant) is required and can be a simple 1/4-wavelength piece of wire soldered at the ANT position:

- for 433 MHz, use a 165 mm wire
- for 868 MHz, use a 82 mm wire
- for 915 MHz, use a 78 mm wire

The wire supplied with the kit is a little longer to allow for trimming - simply bend a cm. or two back on itself at the floating end of the wire and cut to length only when adjustment is complete. Note that the lengths quoted allow for the short PCB track length on the module and some stray...
capacitance in this area - the actual lengths for best performance are not critical to the last few mm.

Without access to some measurement system, simply trim to the length for the corresponding Band entry shown above - that is close enough for most systems.

If you have access to a field strength meter, or are using the software "NRFMon-nano Spectrum Analyzer", you can adjust this temporary "shortening" for maximum effective output power (take care not to disturb the aerial position between tests for consistency - the radiation pattern is affected by all conductors within about one wavelength of any part of the aerial including hands!)

The ground (GND) connection is not required when using a simple, single wire aerial. The GND pad is reserved for when the aerial is mounted remotely through a length of co-axial cable. Solder the outer sheath of the coax here, leaving the shortest length of unshielded inner white insulation that is practical.

Bootstrap Versions

As of mid-Jan 2012, JeeNodes ship with OptiBoot 4.4, which is compatible with Uno boards (the previous bootstrap was for Duemilanove's). Check you have the correct board type selection in the Arduino IDE (usually the wrong setting generates error avrdude: stk500_getsync(): not in sync: resp=0x00)

Related weblog posts

- All posts tagged - JeeNode
- 2009-11-06 - Activity LED
- 2010-09-25 - Meet the JeeNode v5
- 2010-09-26 - Assembling the JeeNode v5
- 2010-11-24 - More box options
- 2010-12-06 - No more diode!
- 2011-05-01 - Meet the JeeNode v6
- 2011-06-08 - How the JeeNode evolved
- 2011-06-21 - MCP1702 current draw
- 2011-06-26 - Current measurements
- 2011-12-03 - Same RFM12B's, but flatter
- 2011-12-19 - The JeeNode, as seen from 15.24 km
- 2012-01-24 - The PWR vs the +3V pin
- 2013-03-22 - JeeNode v6 reference

Attachments

- binout.png (50 KB) jcv, 2012-06-25 07:29
- jnv6.png (111 KB) jcv, 2012-06-25 07:33
- jlpcb-128.sch (263 KB) myra, 2012-07-17 16:03
- jlpcb-128.brd (39.5 KB) myra, 2012-07-17 16:03
- jlpcb-128.png (82.1 KB) myra, 2012-07-17 16:03
- jlpcb-128.pdf (35.8 KB) myra, 2012-07-17 16:03
- RFM12B_pads.png - RFM12B pin/pad layout (22.4 KB) martynj, 2013-02-19 18:41
ATTENTION
OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
DISCHARGE
SENSITIVE
DEVICES

Features

- Outstanding material efficiency.
- Reliable and rugged.
- RoHS compliant.

Descriptions

- The Blue source color devices are made with InGaN Light Emitting Diode.
- Electrostatic discharge and power surge could damage the LEDs.
- It is recommended to use a wrist band or anti-electrostatic glove when handling the LEDs.
- All devices, equipments and machineries must be electrically grounded.

Package Dimensions

Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the leads emerge from the package.
4. The specifications, characteristics and technical data described in the datasheet are subject to change without prior notice.
Selection Guide

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Dice</th>
<th>Lens Type</th>
<th>( I_{v} (\text{mod}) ) ( @ 20\text{mA} )</th>
<th>Viewing Angle [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP7083QBD/G</td>
<td>Blue (InGaN)</td>
<td>Blue Diffused</td>
<td>( 180 )</td>
<td>( 281/2 )</td>
</tr>
</tbody>
</table>

Notes:
1. \( 281/2 \) is the angle from optical centerline where the luminous intensity is 1/2 of the optical peak value.
2. Luminous intensity/ luminous Flux: +/-15%.
3. Luminous intensity value is traceable to the CIE127-2007 compliant national standards.

Electrical / Optical Characteristics at \( TA=25°C \)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Device</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda_{\text{peak}} )</td>
<td>Peak Wavelength</td>
<td>Blue</td>
<td>461</td>
<td>nm</td>
<td>( I_{f}=20\text{mA} )</td>
<td></td>
</tr>
<tr>
<td>( \lambda_{D} ) [1]</td>
<td>Dominant Wavelength</td>
<td>Blue</td>
<td>465</td>
<td>nm</td>
<td>( I_{f}=20\text{mA} )</td>
<td></td>
</tr>
<tr>
<td>( \Delta \lambda_{1/2} )</td>
<td>Spectral Line Half-width</td>
<td>Blue</td>
<td>25</td>
<td>nm</td>
<td>( I_{f}=20\text{mA} )</td>
<td></td>
</tr>
<tr>
<td>( C )</td>
<td>Capacitance</td>
<td>Blue</td>
<td>100</td>
<td>pF</td>
<td>( V_{f}=0\text{V}, f=1\text{MHz} )</td>
<td></td>
</tr>
<tr>
<td>( V_{F} ) [2]</td>
<td>Forward Voltage</td>
<td>Blue</td>
<td>3.3</td>
<td>4</td>
<td>V</td>
<td>( I_{f}=20\text{mA} )</td>
</tr>
<tr>
<td>( I_{R} )</td>
<td>Reverse Current</td>
<td>Blue</td>
<td>50</td>
<td>( \mu\text{A} )</td>
<td>( V_{R}=5\text{V} )</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.
3. Wavelength value is traceable to the CIE127-2007 compliant national standards.
4. Excess driving current and/or operating temperature higher than recommended conditions may result in severe light degradation or premature failure.

Absolute Maximum Ratings at \( TA=25°C \)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Blue</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power dissipation</td>
<td>120</td>
<td>mW</td>
</tr>
<tr>
<td>DC Forward Current</td>
<td>30</td>
<td>mA</td>
</tr>
<tr>
<td>Peak Forward Current [1]</td>
<td>150</td>
<td>mA</td>
</tr>
<tr>
<td>Reverse Voltage</td>
<td>5</td>
<td>V</td>
</tr>
<tr>
<td>Operating/Storage Temperature</td>
<td>-40°C To +85°C</td>
<td></td>
</tr>
<tr>
<td>Lead Solder Temperature [2]</td>
<td>260°C For 3 Seconds</td>
<td></td>
</tr>
<tr>
<td>Lead Solder Temperature [3]</td>
<td>260°C For 5 Seconds</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.
3. 3mm below package base.
Blue WP7083QBD/G

- **Relative Radiant Intensity**
  - Wavelength $\lambda$ (nm)
  - Relative Intensity vs. Wavelength

- **Forward Current (mA)**
  - $I_f$ vs. Forward Voltage

- **Luminous Intensity (cd)**
  - Relative Value at $I_f$ vs. Forward Current

- **Ambient Temperature $T_a$ (°C)**
  - Forward Current Derating Curve

- **Spatial Distribution**
  - Spatial Intensity vs. Spatial Angle
Terms and conditions for the usage of this document

1. The information included in this document reflects representative usage scenarios and is intended for technical reference only.

2. The part number, type, and specifications mentioned in this document are subject to future change and improvement without notice. Before production usage customer should refer to the latest datasheet for the updated specifications.

3. When using the products referenced in this document, please make sure the product is being operated within the environmental and electrical limits specified in the datasheet. If customer usage exceeds the specified limits, Kingbright will not be responsible for any subsequent issues.

4. The information in this document applies to typical usage in consumer electronics applications. If customer's application has special reliability requirements or have life-threatening liabilities, such as automotive or medical usage, please consult with Kingbright representative for further assistance.

5. The contents and information of this document may not be reproduced or re-transmitted without permission by Kingbright.

6. All design applications should refer to Kingbright application notes available at [http://www.KingbrightUSA.com/ApplicationNotes](http://www.KingbrightUSA.com/ApplicationNotes)
PRECAUTIONS

1. Storage conditions:
   a. Avoid continued exposure to the condensing moisture environment and keep the product away from rapid transitions in ambient temperature.
   b. LEDs should be stored with temperature ≤ 30°C and relative humidity < 60%.
   c. Product in the original sealed package is recommended to be assembled within 72 hours of opening. Product in opened package for more than a week should be baked for 30 (+10/-0) hours at 85 ~ 100°C.

2. The lead pitch of the LED must match the pitch of the mounting holes on the PCB during component placement. Lead-forming may be required to insure the lead pitch matches the hole pitch. Refer to the figure below for proper lead forming procedures. (Fig. 1)

```
   ○ ○ ○ Correct mounting method  ◯ ◯ ◯ Incorrect mounting method
```

Note 1–3: Do not route PCB trace in the contact area between the leadframe and the PCB to prevent short-circuits.

3. When soldering wires to the LED, each wire joint should be separately insulated with heat-shrink tube to prevent short-circuit contact. Do not bundle both wires in one heat shrink tube to avoid pinching the LED leads. Pinching stress on the LED leads may damage the internal structures and cause failure. (Fig. 2)

```
   ○ ○ ○ FIG. 2
```

4. Use stand-offs (Fig. 3) or spacers (Fig. 4) to securely position the LED above the PCB.

```
   FIG. 3  FIG. 4
```

5. Maintain a minimum of 3mm clearance between the base of the LED lens and the first lead bend. (Fig. 5 and 6)

6. During lead forming, use tools or jigs to hold the leads securely so that the bending force will not be transmitted to the LED lens and its internal structures. Do not perform lead forming once the component has been mounted onto the PCB. (Fig. 7)
7. Do not bend the leads more than twice. (Fig. 8)

8. During soldering, component covers and holders should leave clearance to avoid placing damaging stress on the LED during soldering.

9. The tip of the soldering iron should never touch the lens epoxy.

10. Through-hole LEDs are incompatible with reflow soldering.

11. If the LED will undergo multiple soldering passes or face other processes where the part may be subjected to intense heat, please check with Kingbright for compatibility.

12. Recommended Wave Soldering Profiles:

![Wave Soldering Profile Graph]

Notes:
1. Recommend pre-heat temperature of 105°C or less (as measured with a thermocouple attached to the LED pins) prior to immersion in the solder wave with a maximum solder bath temperature of 260°C.
2. Peak wave soldering temperature between 245°C ~ 255°C for 3 sec (5 sec max).
3. Do not apply stress to the epoxy resin while the temperature is above 85°C.
4. Fixtures should not incur stress on the component when mounting and during soldering process.
5. SAC 305 solder alloy is recommended.
6. No more than one wave soldering pass.
Features:
- General purpose resistor ideal for commercial/industrial applications
- Flame retardant coatings standard
- Flameproof version available as CFF
- Panasert available on selected sizes; contact factory
- Auto sequencing/insertion compatible
- CFM (mini) ideal choice when size constraints apply
- Cut and formed product is available on select sizes; contact factory
- Standard lead wire for CF/CFM is copper plated steel, with 100% tin over plate
- 100% tin plate on copper wire is available as type CFQ/CFQM
- RoHS compliant / lead-free

### Electrical Specifications

<table>
<thead>
<tr>
<th>Type / Code</th>
<th>Power Rating (Watts) @ 70ºC</th>
<th>Maximum Working Voltage (1)</th>
<th>Maximum Overload Voltage</th>
<th>Dielectric Withstanding Voltage</th>
<th>Resistance Temperature Coefficient per Ohmic Range</th>
<th>Ohmic Range (Ω) and Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF18</td>
<td>0.125W</td>
<td>250V</td>
<td>500V</td>
<td>350V</td>
<td>&lt;10Ω = ±400ppm/ºC</td>
<td>10 - 1M</td>
</tr>
<tr>
<td>CF14</td>
<td>0.25W</td>
<td>350V</td>
<td>600V</td>
<td>350V</td>
<td>10Ω to 9.99Ω = 0 ~ -400ppm/ºC</td>
<td>1 - 1M</td>
</tr>
<tr>
<td>CF12</td>
<td>0.5W</td>
<td>350V</td>
<td>700V</td>
<td>600V</td>
<td>10KΩ to 99KΩ = 0 ~ -500ppm/ºC</td>
<td>10 - 1M</td>
</tr>
<tr>
<td>CF1</td>
<td>1W</td>
<td>500V</td>
<td>1,000V</td>
<td>600V</td>
<td>100KΩ to 999KΩ = 0 ~ -850ppm/ºC</td>
<td>1 - 1M</td>
</tr>
<tr>
<td>CF2</td>
<td>2W</td>
<td>500V</td>
<td>1,000V</td>
<td>600V</td>
<td>1MΩ and above = 0 ~ -1500ppm/ºC</td>
<td>1 - 10M</td>
</tr>
<tr>
<td>CFM14</td>
<td>0.25W</td>
<td>250V</td>
<td>500V</td>
<td>350V</td>
<td>1MΩ and above = 0 ~ -1500ppm/ºC</td>
<td>1 - 10M</td>
</tr>
<tr>
<td>CFM12</td>
<td>0.5W</td>
<td>350V</td>
<td>600V</td>
<td>350V</td>
<td>1MΩ and above = 0 ~ -1500ppm/ºC</td>
<td>1 - 10M</td>
</tr>
<tr>
<td>CFM1</td>
<td>1W</td>
<td>600V</td>
<td>1,000V</td>
<td>600V</td>
<td>1MΩ and above = 0 ~ -1500ppm/ºC</td>
<td>1 - 10M</td>
</tr>
</tbody>
</table>

(1) Lesser of √PR or maximum working voltage.

### Mechanical Specifications

<table>
<thead>
<tr>
<th>Type / Code</th>
<th>A Body Length</th>
<th>B Body Diameter</th>
<th>C Lead Length(Bulk)</th>
<th>D Lead Diameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF18</td>
<td>0.130 ± 0.012</td>
<td>0.067 ± 0.012</td>
<td>1.102 ± 0.118</td>
<td>0.018 ± 0.003</td>
<td>inches</td>
</tr>
<tr>
<td>CF14</td>
<td>0.236 ± 0.012</td>
<td>0.091 ± 0.012</td>
<td>1.102 ± 0.118</td>
<td>0.022 ± 0.003</td>
<td>inches</td>
</tr>
<tr>
<td>CF12</td>
<td>0.355 ± 0.039</td>
<td>0.106 ± 0.020</td>
<td>1.102 ± 0.118</td>
<td>0.028 ± 0.002</td>
<td>inches</td>
</tr>
<tr>
<td>CF1</td>
<td>0.433 ± 0.039</td>
<td>0.177 ± 0.020</td>
<td>1.181 ± 0.118</td>
<td>0.028 ± 0.002</td>
<td>inches</td>
</tr>
<tr>
<td>CF2</td>
<td>0.591 ± 0.039</td>
<td>0.197 ± 0.020</td>
<td>1.339 ± 0.157</td>
<td>0.028 ± 0.002</td>
<td>inches</td>
</tr>
<tr>
<td>CFM14</td>
<td>0.130 ± 0.012</td>
<td>0.067 ± 0.012</td>
<td>1.102 ± 0.118</td>
<td>0.018 ± 0.003</td>
<td>inches</td>
</tr>
<tr>
<td>CFM12</td>
<td>0.236 ± 0.012</td>
<td>0.091 ± 0.012</td>
<td>1.102 ± 0.118</td>
<td>0.022 ± 0.003</td>
<td>inches</td>
</tr>
<tr>
<td>CFM1</td>
<td>0.354 ± 0.020</td>
<td>0.138 ± 0.020</td>
<td>1.102 ± 0.118</td>
<td>0.028 ± 0.002</td>
<td>inches</td>
</tr>
</tbody>
</table>
CF/CFM Series
Carbon Film Resistor

Stackpole Electronics, Inc.
Resistive Product Solutions

Performance Characteristics

<table>
<thead>
<tr>
<th>Test</th>
<th>Standard / Method</th>
<th>Typical Results</th>
<th>Test Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Noise</td>
<td>MIL-STD 202, Method 308</td>
<td>1Ω ~ 91KΩ</td>
<td>100KΩ ~ 910KΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1MΩ ~ 22MΩ</td>
<td>10KΩ ~ 91KΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15μV/V</td>
<td>0.32μV/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.54μV/V</td>
<td>0.2μV/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4μV/V</td>
<td>0.6μV/V</td>
</tr>
<tr>
<td>Short Time Overload</td>
<td>JIS C5201-1, IEC60115-1, 4.13</td>
<td>&lt; ± 0.25%</td>
<td>≤ ± (0.75% + 0.05Ω)</td>
</tr>
<tr>
<td>Resistance to Solder Heat</td>
<td>JIS C5201-1, IEC60115-1, 4.18</td>
<td>&lt; ± 0.3%</td>
<td>≤ ± (0.50% + 0.05Ω)</td>
</tr>
<tr>
<td>Rapid Change of Temperature</td>
<td>JIS C5201-1, IEC60115-1, 4.19</td>
<td>&lt; ± 0.3%</td>
<td>≤ ± (1.00% + 0.05Ω)</td>
</tr>
<tr>
<td>Endurance at 70°C</td>
<td>JIS C5201-1, IEC60115-1, 4.25.1</td>
<td>&lt; ± 1.0%</td>
<td>R&lt;100KΩ ≤ ± (2.0% + 0.05Ω)</td>
</tr>
<tr>
<td>Terminal Strength</td>
<td>MIL-STD 202, Method 211</td>
<td>&lt; ± 0.20%</td>
<td>R≥100KΩ ≤ ± (3.0% + 0.05Ω)</td>
</tr>
<tr>
<td>Damp Heat (Steady state)</td>
<td>JIS C5201-1, IEC60115-1, 4.24</td>
<td>&lt; ± 1.5%</td>
<td>≤ ± (0.50% + 0.05Ω)</td>
</tr>
</tbody>
</table>

Operating Temperature Range: -55°C to +155°C

Power Derating Curve:

![Power Derating Curve Image]

Single Pulse Power:

![Single Pulse Power Image]

Typical performance for reference only.
CF/CFM Series
Carbon Film Resistor

Stackpole Electronics, Inc.
Resistive Product Solutions

Repetitive Pulse Data:

If repetitive pulses are applied to resistors, pulse wave form must be less than “Pulse limiting voltage”, “Pulse limiting current” or “Pulse limiting wattage” calculated by the formula below.

\[
V_p = K \sqrt{P \times R \times T/t}
\]
\[
I_p = K \sqrt{P/R \times T/t}
\]
\[
P_p = K^2 \times P \times T/t
\]

Where:
- \(V_p\): Pulse limiting voltage (V)
- \(I_p\): Pulse limiting current (A)
- \(P_p\): Pulse limiting wattage (W)
- \(P\): Power rating (W)
- \(R\): Nominal resistance (ohm)
- \(T\): Repetitive period (sec)
- \(t\): Pulse duration (sec)
- \(K\): Coefficient by resistors type (refer to below matrix)

\[\text{[Vr: Rated Voltage (V), Ir: Rated Current (A)]}\]

Note 1: If \(T>10 \rightarrow T = 10\) (sec), \(T/t>1000 \rightarrow T/t = 1000\)

Note 2: If \(T>10\) and \(T/t>1000\), “Pulse Limiting power (Single pulse) is applied

Note 3: If \(V_p<V_r\) (\(I_p<I_r\) or \(P_p<P\)), \(V_r\) (\(I_r, P\)) is \(V_p\) (\(I_p, P_p\))

Note 4: Pulse limiting voltage (Current, Wattage) is applied at less than rated ambient temperature. If ambient temperature is more than the rated temperature (70º), please decrease power rating according to “Power Derating Curve”

Note 5: Please assure sufficient margin for use period and conditions for “Pulse limiting voltage”

Note 6: If the pulse waveform is not square wave, please judge after transform the waveform into square wave according to the “Waveform Transformation to Square Wave”.

<table>
<thead>
<tr>
<th>Coefficient (K) Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor Type</td>
</tr>
<tr>
<td>RNF, RNMF</td>
</tr>
<tr>
<td>CF, CFM, HDM</td>
</tr>
<tr>
<td>ASR, SPR, ASRM, SPRM</td>
</tr>
<tr>
<td>RSPF, RSPL</td>
</tr>
<tr>
<td>RSF, RSMF</td>
</tr>
<tr>
<td>FRN</td>
</tr>
</tbody>
</table>
Waveform Transformation to Square Wave

1. Discharge curve wave with time constant “t” → Square wave

2. Damping oscillation wave with time constant of envelope “t” → Square wave

3. Half-wave rectification wave → Square wave

4. Triangular wave → Square wave

5. Special wave → Square wave
CF/CFM Series  
Carbon Film Resistor

Current Noise:

![Graph showing current noise levels against nominal resistance]

### Lead-Tape Specifications: Reeled in accordance with EIA-296-F

<table>
<thead>
<tr>
<th>Type / Code</th>
<th>Qty per Reel</th>
<th>A max (1)</th>
<th>B max</th>
<th>C</th>
<th>D(2)</th>
<th>Tape</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF18, CFM14</td>
<td>5,000</td>
<td>2.508</td>
<td>63.70</td>
<td>13.504</td>
<td>343.00</td>
<td>0.197 ± 0.020</td>
<td>5.00 ± 0.50</td>
</tr>
<tr>
<td>CF14, CFM12</td>
<td>5,000</td>
<td>2.638</td>
<td>67.00</td>
<td>13.504</td>
<td>343.00</td>
<td>0.197 ± 0.020</td>
<td>5.00 ± 0.50</td>
</tr>
<tr>
<td>CF12, CFM1</td>
<td>5,000</td>
<td>2.736</td>
<td>69.50</td>
<td>13.504</td>
<td>343.00</td>
<td>0.197 ± 0.020</td>
<td>5.00 ± 0.50</td>
</tr>
<tr>
<td>CF1</td>
<td>2,000</td>
<td>2.972</td>
<td>75.50</td>
<td>13.504</td>
<td>343.00</td>
<td>0.197 ± 0.020</td>
<td>5.00 ± 0.50</td>
</tr>
<tr>
<td>CF2</td>
<td>1,000</td>
<td>3.130</td>
<td>79.50</td>
<td>13.504</td>
<td>343.00</td>
<td>0.394 ± 0.020</td>
<td>10.00 ± 0.50</td>
</tr>
</tbody>
</table>

### Dimension "E":
This is a non-critical dimension that does not have a tolerance in the standard.

Range of diameters is from 0.547 inches (13.90 mm) to 1.500 inches (38.10 mm)

1. Reference value only. The "A" dimension shall be governed by the overall length of the taped component.
   The distance between flanges shall be 0.059 inches (1.50 mm) to 0.315 (8.00 mm) greater than the overall component.
2. The given dimension "D" expresses the standard width spacing. A 26mm narrow spacing is available as option "N" packaging code.
   Contact factory for more details.

---

www.seielect.com  
marketing@seielect.com

This specification may be changed at any time without prior notice.  
Please confirm technical specifications before you order and/or use.
# CF/CFM Series
## Carbon Film Resistor

Stackpole Electronics, Inc.
Resistive Product Solutions

Radial Lead Taping Specification – Pana-Sert (PCF14)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>PANA-SERT</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Resistor body length</td>
<td>0.256 ± 0.020</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.50 ± 0.50</td>
<td>mm</td>
</tr>
<tr>
<td>C</td>
<td>Height of bending</td>
<td>0.098 ± 0.020</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.50 ± 0.50</td>
<td>mm</td>
</tr>
<tr>
<td>D</td>
<td>Resistor body diameter</td>
<td>0.091 ± 0.008</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.30 ± 0.20</td>
<td>mm</td>
</tr>
<tr>
<td>D₀</td>
<td>Sprocket-hole diameter</td>
<td>0.157 ± 0.012</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.00 ± 0.30</td>
<td>mm</td>
</tr>
<tr>
<td>F</td>
<td>Resistor lead spacing</td>
<td>0.197 ± 0.039</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.00 ± 1.00</td>
<td>mm</td>
</tr>
<tr>
<td>H</td>
<td>Height to bottom of resistor</td>
<td>0.748 ± 0.039</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19.00 ± 1.00</td>
<td>mm</td>
</tr>
<tr>
<td>H₀</td>
<td>Height to lead clinch</td>
<td>0.630 ± 0.020</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.00 ± 0.50</td>
<td>mm</td>
</tr>
<tr>
<td>H₁</td>
<td>Height of resistor</td>
<td>1.122 max.</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28.50 max.</td>
<td>mm</td>
</tr>
<tr>
<td>h</td>
<td>Resistor alignment</td>
<td>0 ± 0.079</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0±5°)</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ± 2.00</td>
<td>mm</td>
</tr>
<tr>
<td>h₁</td>
<td>Resistor alignment</td>
<td>0 ± 0.079</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0±5°)</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 ± 2.00</td>
<td>mm</td>
</tr>
<tr>
<td>I</td>
<td>Lead protrusion</td>
<td>0.079 max.</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.00 max.</td>
<td>mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>PANA-SERT</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Cutout Length(1)</td>
<td>0.433 max.</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.00 max.</td>
<td>mm</td>
</tr>
<tr>
<td>P</td>
<td>Resistor pitch(1)</td>
<td>0.500 ± 0.039</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.70 ± 1.00</td>
<td>mm</td>
</tr>
<tr>
<td>P₀</td>
<td>Sprocket-hole pitch(1)</td>
<td>0.500 ± 0.012</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.70 ± 0.30</td>
<td>mm</td>
</tr>
<tr>
<td>P₁</td>
<td>Sprocket-hole center to lead center</td>
<td>0.152 ± 0.028</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.85 ± 0.70</td>
<td>mm</td>
</tr>
<tr>
<td>P₂</td>
<td>Sprocket-hole center to resistor center(1)</td>
<td>0.250 ± 0.051</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.35 ± 1.30</td>
<td>mm</td>
</tr>
<tr>
<td>T</td>
<td>Thickness (chipboard and tape)</td>
<td>0.028 ± 0.008</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.70 ± 0.20</td>
<td>mm</td>
</tr>
<tr>
<td>W</td>
<td>Chipboard width(1)</td>
<td>0.709 ± 0.039</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.00 ± 1.00</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>/ -0.020</td>
<td>mm</td>
</tr>
<tr>
<td>W₀</td>
<td>Hold-down tape width</td>
<td>0.49 min.</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.50 min.</td>
<td>mm</td>
</tr>
<tr>
<td>W₁</td>
<td>Sprocket-hole position</td>
<td>0.354 ± 0.030</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.00 ± 0.75</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>/ -0.50</td>
<td>mm</td>
</tr>
<tr>
<td>W₂</td>
<td>Hold-down tape position</td>
<td>0.118 max.</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.00 max.</td>
<td>mm</td>
</tr>
</tbody>
</table>

*This specification may be changed at any time without prior notice.*

Please confirm technical specifications before you order and/or use.
# CF/CFM Series Carbon Film Resistor

Stackpole Electronics, Inc.
Resistive Product Solutions

## How to Order

<table>
<thead>
<tr>
<th>Product Series</th>
<th>Size</th>
<th>Power Rating</th>
<th>Tolerance</th>
<th>Code</th>
<th>Description</th>
<th>Size</th>
<th>Quantity</th>
<th>Resistance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>18</td>
<td>0.125W</td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>1,000</td>
<td>Four characters with the multiplier used as the decimal holder.</td>
<td></td>
</tr>
<tr>
<td>CFF</td>
<td>14</td>
<td>0.25W</td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>5,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFM</td>
<td>12</td>
<td>0.5W</td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>2,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCF</td>
<td>1</td>
<td>1W</td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCFM</td>
<td>2</td>
<td>2W</td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>10 ohm = 10R0, 10.2 Kohm = 10K2, 1 Mohm = 1M00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFQ</td>
<td></td>
<td></td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>5,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFQM</td>
<td></td>
<td></td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>2,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCFQ</td>
<td></td>
<td></td>
<td></td>
<td>CF18, CFM14, CF14, CFM12</td>
<td>CF1, CF2, CF12, CFM1, CF1, CF2</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### How to Order

1. **C** - Product Series
2. **F** - Size
3. **1** - Power Rating
4. **2** - Tolerance
5. **J** - Code
6. **T** - Description
7. **1** - Size
8. **0** - Quantity
9. **0** - Resistance Value
10. **K** - Product Series

- **B**: Bulk
- **T**: Tape and Reel
- **A**: Ammo

- **Resistive Product Solutions**: Panasert CF12, PCF14, PCFM12
- **Tape and Reel**: CF1, CF2
- **Ammo**: CF18, CFM14, CF14, CFM12

### Notes
- Four characters with the multiplier used as the decimal holder.
- Panasert CF12, PCF14, PCFM12
- CF1, CF2
- CF18, CFM14, CF14, CFM12

---

This specification may be changed at any time without prior notice. Please confirm technical specifications before you order and/or use.
■特 長  FEATURES
● 定格電流 500mA に対応
● 2.54mm ピッチへの連続取り付けが可能
● RoHS 指令対応

● Correspond to rating current 500mA
● Possible to continue mounting with 2.54mm pitch
● RoHS compliant

■ 型式表示  PART NUMBER DESIGNATION

シリーズ名 Series name  CL - SA - 1 2  C - 0 2
回路数 No. of bits 1:1 回路 1 pole
接点数 No. of positions 2:2 損点 2 positions

端子形状 Shape of terminal  
C: PC 端子 PC terminal  
C4: PC 端子-R/4 (ライトアングル) PC terminal-R/A(Right angle)

※ご注文に際しては、型式一覧表をご確認ください。
Please refer to the LIST OF PART NUMBERS when placing orders.
### PACKAGING SPECIFICATION

- **CLA-12C-02**
- **CLA-SA-12C-22**
- **CLA-SA-12C4-02**
- **CLA-SA-12C4-22**

### ELECTRICAL CHARACTERISTICS

- **Load life**
  - Non-switching: 60 s
  - DC50 V
  - 10,000 MΩ minimum
  - 10,000 MΩ minimum (DC100 V)

- **Contact resistance**
  - AC500 V
  - 60 s

- **Soldering heat**
  - 380 ± 10 °C
  - 3 ~ 4 s

### MECHANICAL CHARACTERISTICS

- **Stroke**
  - 1.6 mm

- **Operation force**
  - 2.5 ± 1.5 N (0.26 ± 0.15 kgf)

- **Rated load**
  - 2,000 cycles

- **Load life**
  - 10,000 cycles

- **Soldering heat**
  - Manual soldering:
  - 380 ± 10 °C
  - 3 ~ 4 s
OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>

OUTLINE DIMENSIONS

Unless otherwise specified, tolerance: ±0.3 (Unit: mm)

SIZE OF P.C.B. PROCESSING (Unit: mm)

PACKAGING SPECIFICATIONS

<p>Unless otherwise specified, tolerance: ±0.3 (Unit: mm)</p>
MC78LXXA / LM78LXXA
3-Terminal 0.1 A Positive Voltage Regulator

Features
• Maximum Output Current of 100 mA
• Output Voltage of 5 V, 6 V, 8 V, 12 V, and 15 V
• Thermal Overload Protection
• Short-Circuit Current Limiting
• Output Voltage Offered in ±5% Tolerance

Description
The MC78LXXA / LM78LXXA series of fixed-voltage monolithic integrated circuit voltage regulators are suitable for applications that required supply current up to 100 mA.

Ordering Information

<table>
<thead>
<tr>
<th>Product Number</th>
<th>Package</th>
<th>Packing Method</th>
<th>Output Voltage Tolerance</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM78L05ACZ</td>
<td>TO-92</td>
<td>Bulk</td>
<td>±5%</td>
<td>0 to +125°C</td>
</tr>
<tr>
<td>LM78L05ACZX</td>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM78L05ACZXA</td>
<td>Ammo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM78L12ACZ</td>
<td>Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM78L12ACZX</td>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L05ACP</td>
<td>Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L05ACPXA</td>
<td>Ammo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L06ACP</td>
<td>Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L08ACP</td>
<td>Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L15ACP</td>
<td>Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L15ACPXA</td>
<td>Ammo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L05ACD</td>
<td>Rail</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L05ACDX</td>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L05ACHX</td>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC78L08ACHX</td>
<td>Tape &amp; Reel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at $T_A = 25^\circ C$ unless otherwise noted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_I$</td>
<td>Input Voltage</td>
<td>$V_O = 5\text{ V to }8\text{ V}$</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_O = 12\text{ V to }15\text{ V}$</td>
<td>35</td>
</tr>
<tr>
<td>$T_J$</td>
<td>Operating Junction Temperature Range</td>
<td>0 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>$T_{STG}$</td>
<td>Storage Temperature Range</td>
<td>-65 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>$R_{IJC}$</td>
<td>Thermal Resistance, Junction-Case</td>
<td>TO-92</td>
<td>50</td>
</tr>
<tr>
<td>$R_{BJA}$</td>
<td>Thermal Resistance, Junction-Air</td>
<td>TO-92</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SOT-89</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8-SOIC</td>
<td>160</td>
</tr>
</tbody>
</table>
### Electrical Characteristics (MC78L05A / LM78L05A)

\( V_I = 10 \, V, \, I_O = 40 \, mA, \, 0^\circ C \leq T_J \leq 125^\circ C, \, C_I = 0.33 \, \mu F, \, C_D = 0.1 \, \mu F \), unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_O )</td>
<td>Output Voltage</td>
<td>( T_J = 25^\circ C )</td>
<td>4.8</td>
<td>5.0</td>
<td>5.2</td>
<td>V</td>
</tr>
<tr>
<td>( \Delta V_O )</td>
<td>Line Regulation(1)</td>
<td>( T_J = 25^\circ C )</td>
<td>7 , V \leq V_I \leq 20 , V</td>
<td>8</td>
<td>150</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 , V \leq V_I \leq 20 , V</td>
<td>6</td>
<td>100</td>
<td>mV</td>
</tr>
<tr>
<td>( \Delta V_O )</td>
<td>Load Regulation(1)</td>
<td>( T_J = 25^\circ C )</td>
<td>1 , mA \leq I_O \leq 100 , mA</td>
<td>11</td>
<td>60</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 , mA \leq I_O \leq 40 , mA</td>
<td>5.0</td>
<td>30.0</td>
<td>mV</td>
</tr>
<tr>
<td>( V_O )</td>
<td>Output Voltage</td>
<td>( 7 , V \leq V_I \leq 20 , V )</td>
<td>1 , mA \leq I_O \leq 40 , mA</td>
<td>5.25</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( 7 , V \leq V_I \leq V_{MAX}^{(2)} )</td>
<td>1 , mA \leq I_O \leq 70 , mA</td>
<td>4.75</td>
<td>5.25</td>
</tr>
<tr>
<td>( I_Q )</td>
<td>Quiescent Current</td>
<td>( T_J = 25^\circ C )</td>
<td>2.0</td>
<td>5.5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>( \Delta I_Q )</td>
<td>Quiescent Current Change</td>
<td>With Line</td>
<td>8 , V \leq V_I \leq 20 , V</td>
<td>1.5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With Load</td>
<td>1 , mA \leq I_O \leq 40 , mA</td>
<td>0.1</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>( V_N )</td>
<td>Output Noise Voltage</td>
<td>( T_A = 25^\circ C, , 10 , Hz \leq f \leq 100 , kHz )</td>
<td>40</td>
<td></td>
<td></td>
<td>\mu V/Vo</td>
</tr>
<tr>
<td>( \Delta V_O/\Delta T )</td>
<td>Temperature Coefficient of ( V_O )</td>
<td>( I_O = 5 , mA )</td>
<td>-0.65</td>
<td></td>
<td></td>
<td>mV/°C</td>
</tr>
<tr>
<td>( R_R )</td>
<td>Ripple Rejection</td>
<td>( f = 120 , Hz, , 8 , V \leq V_I \leq 18 , V, , T_J = 25^\circ C )</td>
<td>41</td>
<td>80</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>( V_D )</td>
<td>Dropout Voltage</td>
<td>( T_J = 25^\circ C )</td>
<td>1.7</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

**Notes:**

1. The maximum steady-state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represents pulse test conditions with junction temperature as indicated at the initiation of tests.
2. Power dissipation \( P_D \leq 0.75 \, W \).
### Electrical Characteristics (MC78L06A)

$V_I = 12\, \text{V}, I_O = 40\, \text{mA}, 0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}, C_I = 0.33\, \mu\text{F}, C_O = 0.1\, \mu\text{F},$ unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>5.75</td>
<td>6.0</td>
<td>6.25</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Line Regulation$^{(3)}$</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>8.5 $V_I$ $\leq 20, \text{V}$</td>
<td>64</td>
<td>175</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9 $V_I$ $\leq 20, \text{V}$</td>
<td>54</td>
<td>125</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Load Regulation$^{(3)}$</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1 mA $\leq I_O \leq 100, \text{mA}$</td>
<td>12.8</td>
<td>80.0</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mA $\leq I_O \leq 70, \text{mA}$</td>
<td>5.8</td>
<td>40.0</td>
<td>mV</td>
</tr>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>$8.5, \text{V} \leq V_I \leq 20, \text{V}, 1, \text{mA} \leq I_O \leq 40, \text{mA}$</td>
<td>5.7</td>
<td>6.3</td>
<td>6.3</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$8.5, \text{V} \leq V_I \leq V_{MAX}^{(4)}, 1, \text{mA} \leq I_O \leq 70, \text{mA}$</td>
<td>5.7</td>
<td>6.3</td>
<td>6.3</td>
<td>V</td>
</tr>
<tr>
<td>$I_O$</td>
<td>Quiescent Current</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>5.5</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_J = 125^\circ\text{C}$</td>
<td>3.9</td>
<td>6.0</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$\Delta I_O$</td>
<td>Quiescent Current Change</td>
<td>$9, \text{V} \leq V_I \leq 20, \text{V}$</td>
<td>1.5</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1, \text{mA} \leq I_O \leq 40, \text{mA}$</td>
<td>0.1</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_N$</td>
<td>Output Noise Voltage</td>
<td>$T_A = 25^\circ\text{C}, 10, \text{Hz} \leq f \leq 100, \text{kHz}$</td>
<td>40</td>
<td>$\mu\text{V/Vo}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta V_O/\Delta T$</td>
<td>Temperature Coefficient of $V_O$</td>
<td>$I_O = 5, \text{mA}$</td>
<td>0.75</td>
<td>mV/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$RR$</td>
<td>Ripple Rejection</td>
<td>$f = 120, \text{Hz}, 10, \text{V} \leq V_I \leq 20, \text{V}, T_J = 25^\circ\text{C}$</td>
<td>40</td>
<td>46</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>$V_D$</td>
<td>Dropout Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1.7</td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

3. The maximum steady-state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represents pulse test conditions with junction temperature as indicated at the initiation of tests.

4. Power dissipation $P_D \leq 0.75\, \text{W}$. 
## Electrical Characteristics (MC78L08A)

\( V_I = 14 \text{ V}, I_O = 40 \text{ mA}, 0^\circ \text{C} \leq T_J \leq 125^\circ \text{C}, C_I = 0.33 \mu \text{F}, C_O = 0.1 \mu \text{F}, \text{unless otherwise specified.} \)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_O )</td>
<td>Output Voltage</td>
<td>( T_J = 25^\circ \text{C} )</td>
<td>7.7</td>
<td>8.0</td>
<td>8.3</td>
<td>V</td>
</tr>
<tr>
<td>( \Delta V_O )</td>
<td>Line Regulation(^{(5)})</td>
<td>( T_J = 25^\circ \text{C} )</td>
<td>10.5 V ( \leq V_I \leq 23 \text{ V} )</td>
<td>10</td>
<td>175</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11 V ( \leq V_I \leq 23 \text{ V} )</td>
<td>8</td>
<td>125</td>
<td>mV</td>
</tr>
<tr>
<td>( \Delta V_O )</td>
<td>Load Regulation(^{(5)})</td>
<td>( T_J = 25^\circ \text{C} )</td>
<td>1 mA ( \leq I_O \leq 100 \text{ mA} )</td>
<td>15</td>
<td>80</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mA ( \leq I_O \leq 40 \text{ mA} )</td>
<td>8</td>
<td>40</td>
<td>mV</td>
</tr>
<tr>
<td>( V_O )</td>
<td>Output Voltage</td>
<td>10.5 V ( \leq V_I \leq 23 \text{ V} )</td>
<td>1 mA ( \leq I_O \leq 40 \text{ mA} )</td>
<td>7.6</td>
<td>8.4</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 mA ( \leq I_O \leq 70 \text{ mA} )</td>
<td>7.6</td>
<td>8.4</td>
<td>V</td>
</tr>
<tr>
<td>( I_Q )</td>
<td>Quiescent Current</td>
<td>( T_J = 25^\circ \text{C} )</td>
<td>2.0</td>
<td>5.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>( \Delta I_Q )</td>
<td>Quiescent Current Change</td>
<td>11 V ( \leq V_I \leq 23 \text{ V} )</td>
<td>1.5</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta I_Q )</td>
<td>Quiescent Current Change</td>
<td>1 mA ( \leq I_O \leq 40 \text{ mA} )</td>
<td>0.1</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_N )</td>
<td>Output Noise Voltage</td>
<td>( T_A = 25^\circ \text{C}, 10 \text{ Hz} \leq f \leq 100 \text{ kHz} )</td>
<td>60</td>
<td>( \mu \text{V/Vo} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta V_O/\Delta T )</td>
<td>Temperature Coefficient of ( V_O )</td>
<td>( I_O = 5 \text{ mA} )</td>
<td>-0.8</td>
<td>mV/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( RR )</td>
<td>Ripple Rejection</td>
<td>( f = 120 \text{ Hz}, 11 \text{ V} \leq V_I \leq 21 \text{ V}, T_J = 25^\circ \text{C} )</td>
<td>39</td>
<td>70</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>( V_D )</td>
<td>Dropout Voltage</td>
<td>( T_J = 25^\circ \text{C} )</td>
<td>1.7</td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

5. The maximum steady-state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represents pulse test conditions with junction temperature as indicated at the initiation of tests.

6. Power dissipation \( P_D \leq 0.75 \text{ W} \).
### Electrical Characteristics (MC78L12A / LM78L12A)

$V_I = 19\, \text{V}, I_O = 40\, \text{mA}, 0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}, C_I = 0.33\, \mu\text{F}, C_O = 0.1\, \mu\text{F}$, unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>11.5</td>
<td>12.0</td>
<td>12.5</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Line Regulation</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>14.5 V $\leq V_I \leq 27$ V</td>
<td>20</td>
<td>250</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Line Regulation</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>16 V $\leq V_I \leq 27$ V</td>
<td>15</td>
<td>200</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Load Regulation</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1 mA $\leq I_O \leq 100$ mA</td>
<td>20</td>
<td>100</td>
<td>mV</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Load Regulation</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1 mA $\leq I_O \leq 40$ mA</td>
<td>10</td>
<td>50</td>
<td>mV</td>
</tr>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>14.5 V $\leq V_I \leq 27$ V</td>
<td>1 mA $\leq I_O \leq 40$ mA</td>
<td>11.4</td>
<td>12.6</td>
<td>V</td>
</tr>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>14.5 V $\leq V_I \leq V_{MAX}$</td>
<td>1 mA $\leq I_O \leq 70$ mA</td>
<td>11.4</td>
<td>12.6</td>
<td>V</td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent Current</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>2.1</td>
<td>6.0</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>$\Delta I_Q$</td>
<td>Quiescent Current Change</td>
<td>With Line</td>
<td>16 V $\leq V_I \leq 27$ V</td>
<td>1.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>$\Delta I_Q$</td>
<td>Quiescent Current Change</td>
<td>With Load</td>
<td>1 mA $\leq I_O \leq 40$ mA</td>
<td>0.1</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>$V_N$</td>
<td>Output Noise Voltage</td>
<td>$T_A = 25^\circ\text{C}, 10, \text{Hz} \leq f \leq 100, \text{kHz}$</td>
<td>80</td>
<td>$\mu\text{V}/V_o$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta V_O/\Delta T$</td>
<td>Temperature Coefficient of $V_O$</td>
<td>$I_O = 5$ mA</td>
<td>-1.0</td>
<td>mV/$^\circ\text{C}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>Ripple Rejection</td>
<td>$f = 120, \text{Hz}, 15, \text{V} \leq V_I \leq 25, \text{V}, T_J = 25^\circ\text{C}$</td>
<td>37</td>
<td>65</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>$V_D$</td>
<td>Dropout Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1.7</td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

7. The maximum steady-state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represents pulse test conditions with junction temperature as indicated at the initiation of tests.

8. Power dissipation $P_D \leq 0.75\, \text{W}$. 

© 2002 Fairchild Semiconductor Corporation

www.fairchildsemi.com

MC78LXXA / LM78LXXA Rev. 1.1.0 6
## Electrical Characteristics (MC78L15A)

$V_I = 23\, \text{V}$, $I_O = 40\, \text{mA}$, $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$, $C_I = 0.33\, \mu\text{F}$, $C_O = 0.1\, \mu\text{F}$, unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>14.4</td>
<td>15.0</td>
<td>15.6</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Line Regulation $(^9)$</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>17.5 $\leq V_I \leq 30$</td>
<td>25</td>
<td>300</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$20 \leq V_I \leq 30$</td>
<td>20</td>
<td>250</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>$\Delta V_O$</td>
<td>Load Regulation $(^9)$</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1 $\leq I_O \leq 100$</td>
<td>25</td>
<td>150</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 $\leq I_O \leq 40$</td>
<td>12</td>
<td>75</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>$V_O$</td>
<td>Output Voltage</td>
<td>$17.5 \leq V_I \leq 30$</td>
<td>1 $\leq I_O \leq 40$</td>
<td>14.25</td>
<td>15.75</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$17.5 \leq V_I \leq V_{\text{MAX}} (^{10})$</td>
<td>1 $\leq I_O \leq 70$</td>
<td>14.25</td>
<td>15.75</td>
<td>V</td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent Current</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>2.1</td>
<td>6.0</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>$\Delta I_Q$</td>
<td>Quiescent Current Change</td>
<td>With Line</td>
<td>20 $\leq V_I \leq 30$</td>
<td>1.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>With Load</td>
<td>1 $\leq I_O \leq 40$</td>
<td>0.1</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>$V_N$</td>
<td>Output Noise Voltage</td>
<td>$T_A = 25^\circ\text{C}$, $10, \text{Hz} \leq f \leq 100, \text{kHz}$</td>
<td>90</td>
<td></td>
<td>$\mu\text{V/V}_O$</td>
<td></td>
</tr>
<tr>
<td>$\Delta V_O/\Delta T$</td>
<td>Temperature Coefficient of $V_O$</td>
<td>$I_O = 5$ mA</td>
<td>-1.3</td>
<td></td>
<td>$\mu\text{V/}^\circ\text{C}$</td>
<td></td>
</tr>
<tr>
<td>$RR$</td>
<td>Ripple Rejection</td>
<td>$f = 120, \text{Hz}$, $18.5 \leq V_I \leq 28.5, \text{V}$, $T_J = 25^\circ\text{C}$</td>
<td>34</td>
<td>60</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>$V_D$</td>
<td>Dropout Voltage</td>
<td>$T_J = 25^\circ\text{C}$</td>
<td>1.7</td>
<td></td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

9. The maximum steady-state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represents pulse test conditions with junction temperature as indicated at the initiation of tests.

10. Power dissipation $P_D \leq 0.75$ W.
Typical Application

Notes:
13. To specify an output voltage, substitute voltage value for “XX”.
14. \( C_i \) is required if the regulator is located an appreciable distance from the power supply filter. Though \( C_o \) is not needed for stability, it improves transient response. Bypass capacitors are recommended for optimum stability and transient response and should be located as close as possible to the regulator.

Figure 2. Typical Application
Physical Dimensions

Figure 3. 3-Lead, SOT-89, JEDEC TO-243, Option AA

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild's worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

Always visit Fairchild Semiconductor's online packaging area for the most recent package drawings:
http://www.fairchildsemi.com/packaging/

For current tape and reel specifications, visit Fairchild Semiconductor's online packaging area:
Figure 4. 3-Lead, TO-92, MOLDED STD STRAIGHT LEAD (NO EOL CODE)

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild’s worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

Always visit Fairchild Semiconductor’s online packaging area for the most recent package drawings:
http://www.fairchildsemi.com/packaging/

For current tape and reel specifications, visit Fairchild Semiconductor’s online packaging area:
http://www.fairchildsemi.com/packaging/tr/to92pdd_tr.pdf
Physical Dimensions (Continued)

TO-92 Formed Lead For T&R and Ammo Packing

Figure 5. 3-Lead, TO-92, MOLDED 0.200 IN LINE SPACING LD FORM (J61Z OPTION)

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild's worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

Always visit Fairchild Semiconductor's online packaging area for the most recent package drawings:
http://www.fairchildsemi.com/packaging/

For current tape and reel specifications, visit Fairchild Semiconductor's online packaging area:
Figure 6. 8-Lead, SOIC, JEDEC MS-012, 0.150” NARROW BODY

Package drawings are provided as a service to customers considering Fairchild components. Drawings may change in any manner without notice. Please note the revision and/or date on the drawing and contact a Fairchild Semiconductor representative to verify or obtain the most recent revision. Package specifications do not expand the terms of Fairchild’s worldwide terms and conditions, specifically the warranty therein, which covers Fairchild products.

Always visit Fairchild Semiconductor’s online packaging area for the most recent package drawings:
http://www.fairchildsemi.com/packaging/

For current tape and reel specifications, visit Fairchild Semiconductor’s online packaging area:
ANTI-COUNTERFEITING POLICY

Counterfeiting of semiconductor parts is a growing problem in the industry. All manufacturers of semiconductor products are experiencing counterfeiting of their parts. Customers who inadvertently purchase counterfeit parts experience many problems such as loss of brand reputation, substandard performance, failed applications, and increased cost of production and manufacturing delays. Fairchild is taking strong measures to protect themselves and their customers from the proliferation of counterfeit parts. Fairchild strongly encourages customers to purchase Fairchild parts either directly from Fairchild or from Authorized Fairchild Distributors who are listed by country on our web page cited above. Products customers buy either from Fairchild directly or from Authorized Fairchild Distributors are genuine parts, have full traceability, meet Fairchild's quality standards for handling and storage and provide access to Fairchild's full range of up-to-date technical and product information. Fairchild and our Authorized Distributors will stand behind all warranties and will appropriately address any warranty issues that may arise. Fairchild will not provide any warranty coverage or other assistance for parts bought from Unauthorized Sources. Fairchild is committed to combat this global problem and encourage our customers to do their part in stopping this practice by buying direct or from authorized distributors.

PRODUCT STATUS DEFINITIONS

<table>
<thead>
<tr>
<th>Datasheet Identification</th>
<th>Product Status</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance Information</td>
<td>Formative / In Design</td>
<td>Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.</td>
</tr>
<tr>
<td>Preliminary</td>
<td>First Production</td>
<td>Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.</td>
</tr>
<tr>
<td>No Identification Needed</td>
<td>Full Production</td>
<td>Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.</td>
</tr>
<tr>
<td>Obsolete</td>
<td>Not In Production</td>
<td>Datasheet contains specifications on a product that is discontinued by Fairchild Semiconductor. The datasheet is for reference information only.</td>
</tr>
</tbody>
</table>

TRADemarks

The following includes registered and unregistered trademarks and service marks, owned by Fairchild Semiconductor and/or its global subsidiaries, and is not intended to be an exhaustive list of all such trademarks.

ZCool™
AccuPower™
AX-CAP™
BitSIC™
Build it Now™
CorePLUS™
CorePOWER™
CRossVOLT™
CTL™
Current Transfer Logic™
DEUXPEED™
Dual Cool™
EcoSPARK™
EfficientMax™
ESBC™
Fairchild®
Fairchild Semiconductor®
FACT Quiet Series™
FACT™
FAST™
FastvCore™
FETBench™
FPS™
F-PFS™
FRFET™
Global Power Resource™
GreenBridge™
Green FPS™
Green FPS™ e-Series™
Gmax™
GTO™
IntelliMAX™
ISOPLANAR™
Making Small Speakers Sound Louder and Better™
MegaBuck™
MICROCOUPLER™
MicroFET™
MicroPak™
MicroPak2™
MillerDrive™
MotionMax™
msSaver™
OptoHi™
OPTOLOGIC™
OPTOPLANAR®
PowerTrench™
PowerXS™
Programmable Active Droop™
QFET™
QS™
Quiet Series™
RapidConfigure™
Saving our world, 1mW/W/kW at a time™
SignalWise™
SmartMax™
SMART START™
Solutions for Your Success™
SPM®
STEALTH™
SuperFET®
SuperSOT-3
SuperSOT-6
SuperSOT-8
SupreMOS®
SyncFET™
Sync-Lock™
SYSTEM GENERAL®
TinyBoost™
TinyBuck™
TinyCalc™
TinyLogic™
TinyOPTO™
TinyPower™
TinyPWM™
TinyWire™
TrueSIC™
TriFault Detect™
TRUECURRENT™
µSerDes™
UHC™
Ultra FRFET™
UniFET™
VCO™
VisualMax™
VoltagePlus™
XS™

* Trademarks of System General Corporation, used under license by Fairchild Semiconductor.

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS. THESE SPECIFICATIONS DO NOT EXPAND THE TERMS OF FAIRCHILD’S WORLDWIDE TERMS AND CONDITIONS, SPECIFICALLY THE WARRANTY THEREIN, OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS. THESE SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE. USERS ARE FURTHER INSTRUCTED TO READ THE FULL TERMS AND CONDITIONS OF THE EXPRESS LIMITED WARRANTY IN THE SPECIFIC PRODUCT MANUAL OR SPECIFICATION SHEET FOR ANY EXCEPTIONS OR EXCEPTIONS THAT MAY APPLY.

LIFE SUPPORT POLICY

FAIRCHILD’S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.

2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.
APPENDIX J DRAWING CHANGES [EXTRACTED FOR PUBLIC DOMAIN PUBLICATION]
APPENDIX L TEST SETUP PHOTOS