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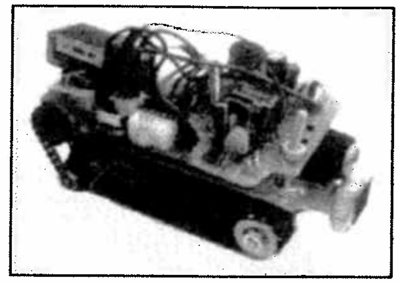

MINIATURE FIGHTING VEHICLES

PRODUCT REPORT

DECEMBER 7, 1998

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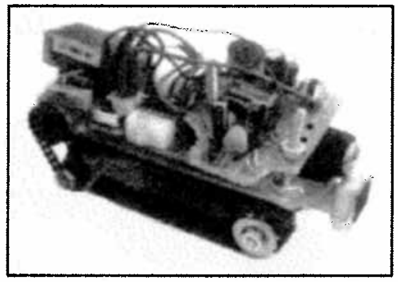

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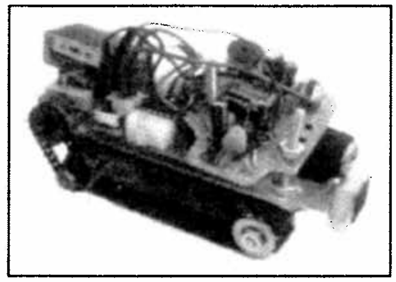


2.0 Specifications

1. The vehicle must be capable of transversing around the entire battle field course ground (including both tunnels) without hitting any of the obstacles (trees, markers, pit, dinosaur, etc.). No human contact can be made with the vehicles once movement has begun.

2. Given laser and sensors must be used at specified positions. Laser must be on the "front" of the vehicle.

3. Vehicle must emit unique and appropriate sound during the firing of the laser.

4. Period of laser and sound must be 1 second.

5. Laser must be modulated at 25 kHz plus and minus 1 kHz. It must be able to be detected from a distance of 4 ft using the standard sensor module.

6. Sensors must be capable of receiving a 25 kHz plus or minus 2 kHz laser signal from a distance of 4 ft from the source.

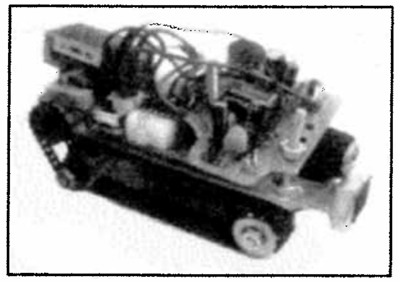
7. After the vehicle is hit, the sound and laser must be turned off until a reset switch is pushed.

8. Vehicles can ram into each other.

9. Vehicle must be able to turn left and right as well as go forward and backward.

10. Battery access must be easy. Batteries changed in less than two minutes after the body is removed. No batteries may be placed in parallel. One battery supply must be used for the entire vehicle.

11. Final construction must be of high quality: Meet neatness requirements or survive 2 ft drop test.



12. Lifetime requirements: Vehicle must be able to move continuously over the instructor's rug for 5 minutes while shooting and making sound.

13. Reliability: The vehicle must be functional for 4 lifetimes per hour (batteries may be replaced between lifetimes).

14. Speed control O.K. but not required.

15. Sockets must be used for laser hit sensors, IC's and transistors. The lens portion of the photodiode must be directed outward.

16. Stranded wire must be used to interconnect all modules. All modules including the servos and RC receiver must be interconnected using high quality connectors or quick connectors.

17. Connectors must be used on the laser wires so that the laser can be disconnected from the circuit during soldering of any connected components.

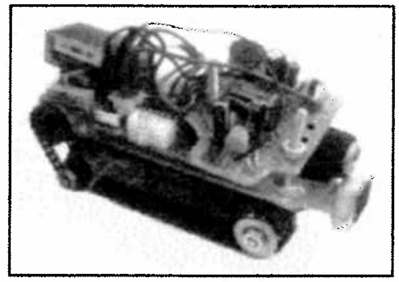
18. An on/off button or power switch must be provided and easily accessible.

19. A reset switch must be provided and easily accessible.

20. No module including the servos shall be permanently connected to the chassis to allow for greater serviceability. For example, gluing the servo case to the chassis is not acceptable. Screws in materials should not be used since repeated use results in stripping. Nuts and bolts are O.K., nuts glued into a plexi-glass frame is also O.K. Double sided tape is unacceptable. Glue should not be used near the gears.

21. The wheels should be serviceable.

22. The antenna must not consist of a mere wrapping of the wire around the body or chassis. It must be clean and neat.

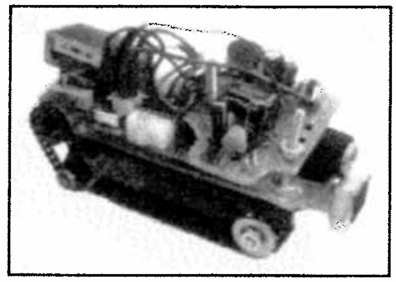


23. Power Source: Light source not required (solar cells). The batteries used should not be taped together or contained by any other crude means. Either a commercial or custom case(s) should be used.

24. If tank motion is used (no steering servo), then the transmitter control must be modified for ease of use.

25. Cost: Maximum cost is about $150 (Kettering University cost). This cost does include the battery but not shipping and handling. It does not include the cost of solder, wire (unless special order such as silver, litz wire, gold), glue, outside packaging, printed circuit, wire wrap, PCB, or perforated boards. It does include the cost of components such as resistors, transistors, transformers, IC's, batteries, battery holders, chip holders, switches, and ferrite materials. Duplicate parts may be ordered for testing purposes. These duplicate parts will not be considered part of the total cost.

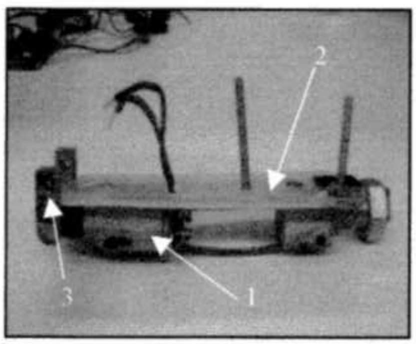
26. The final product delivered to the customer should be completely functional and should meet all specifications.



3.0 Design Methodology

In this section the different components and subassemblies that make up the miniature fighting vehicle "Dread the Tread" are described. The ideas that led to the various vehicle component designs are also discussed.

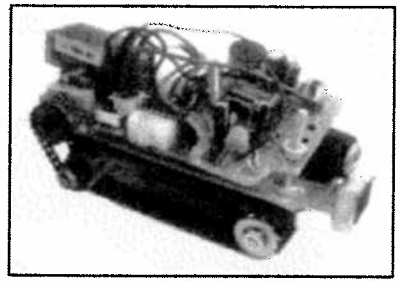
- **Chassis**



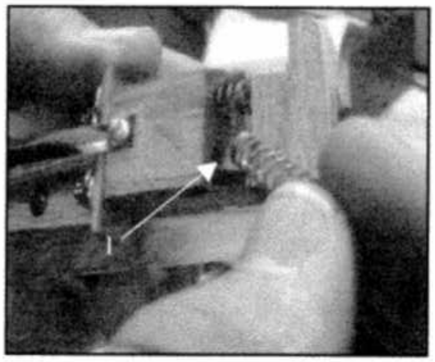
Wood was chosen for the base of the chassis. A lightweight wood such as balsa was contemplated, but after some trial and error it was evident that a strong and durable wood was necessary. Oak was chosen for its incredible strength. Using the oak, unnecessary wood could be cut away to gain real estate for other required vehicle components while still retaining exceptional chassis support (#1).

For the electrical component platform, a flat piece of rectangular Plexiglas (#2) was used. The Plexiglas was chosen because of its durability and transparent attributes. Besides improving the appearance, mechanical drive problems could be detected by taking advantage of the transparent property. This visual access proved to be very beneficial for detecting problems when the mechanical team was debugging the drive system.

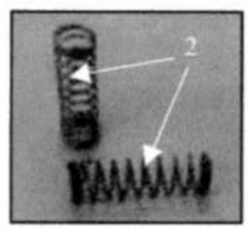
The rear part of the chassis was designed to mount the two servomotors. It was important to leave clearance for the tread in the event that it would ride up over the alignment stops. In order for the motor mounts to secure the adjacent servomotors symmetrically while still lining up the chain driven sprockets, precise motor mounts were necessary. Oak was used to create these motor mounts, because it provided the necessary strength to fasten securely the servos to the chassis (#3).



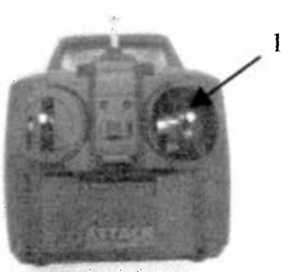
- **Suspension System**



The suspension system is made up of two springs located in the chassis with a perpendicular slot for play in the axle location (#1). The suspension system was implemented to assist in the installation or removal of the tread from the track. Also, the variable suspension system provided a margin of tolerable error on the axle placement that would still result in sufficient tension on the tread. Various springs were tested on the prototype vehicle before finally reaching success with the double suspension seen in the rear of the vehicle in the base of the chassis. The two springs were necessary because they distribute balanced tension on both tread tracks. Furthermore, the springs were chosen to be weak enough to provide a small force that would result in some slack in the tread. The tread's slack is crucial for staying on its track. The prototypes implementing a tight tread exhibited too great of a load for the servos, and the treads often bound up on the tracks (#2).



- **Steering System**



Tank drive was appropriately chosen for the steering system. Each tread is independently driven by it's own servomotor. This is exceptionally beneficial for turning because it has the ability to turn 360 degrees with the center of the vehicle as its pivot point.

It was necessary to modify the remote controls in order to use this steering scheme. To do that, the controller was disassembled, then a clearing was cut away to allow for a 90 degree rotation on the right throttle (#1). Finally, the rotated controller was super-glued onto the internal electrical board.

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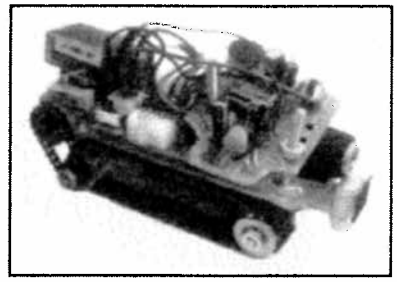
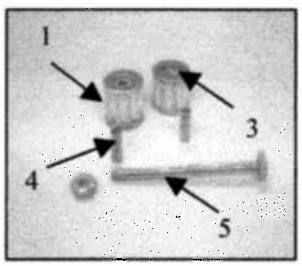
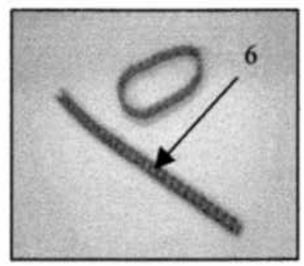


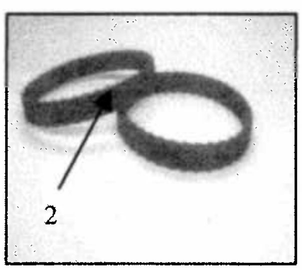
- **Drive System**

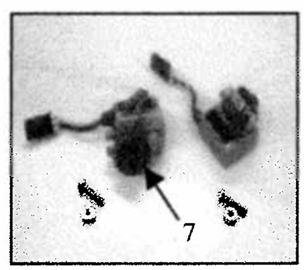
The drive system was the most crucial mechanical component of the vehicle. The alignment of the wheels, tread, and drive chain were critical. Problems resulting from misalignment include the tractor tread rolling off the wheels, the chain coming off the sprockets, and the excessive friction produced. The friction could lead to premature battery failure. To combat these problems, precision timing parts from Stock Drive Products were used.

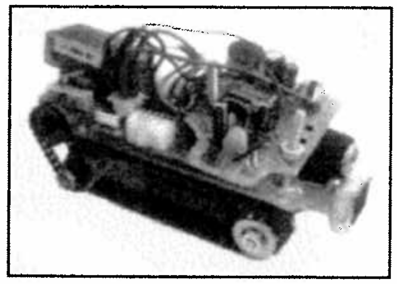




The tractor treads use 1/5 pitch timing pulleys (#1) as wheels in conjunction with 1/5 pitch double sided timing belts (#2). The pulleys were fitted with retaining washers in order to ensure that the timing belt would not become dislodged (#3). The axles were made from a one foot section of 1/8" hardened precision shaft. The bearing used to reduce friction are brass sleeves (#4) that fit over the 1/8" hardened axle (#5). To drive the tractor treads, the team decided to use sub-miniature plastic chain (#6). By using the chain and its corresponding sprockets, a gear ratio could be used to increase the tank's top speed (#7).







- **Modulation Circuit**

The modulation circuit used is based on the previous term's modulation circuit. The circuit is a 556 timer which incorporates two 555 timers. The first timer circuit uses resistors and capacitors that provide a 50% duty cycle. The first timer is used to start and stop the second timer by use of the reset pin for the second timer.

The second timer is set to a frequency of 25 kHz with and allowed range of ±2 kHz. With the resistor and capacitor values the operating frequency of the laser is 25.04 kHz. The resistor and capacitor values are provided on the schematic of the circuit.

The modifications to the previous year's circuit were simple and necessary to fulfill the requirements of the project. The major issue was using only one power source. The electrical team had anticipated a large voltage drop from engaging the servomotors. To help counter this, the team had placed a 470 μF capacitor across the entire modulation circuit. The team also placed a 100 μF capacitor across the laser connections to try and keep the laser intensity from decreasing. This was not enough. During the integration phase the team discovered that the servomotors are responsible for a very large voltage drop across the entire circuit. The 470 μF capacitor was not enough to compensate for the drop in voltage. More capacitance was then added across the module. This was not working so capacitance was added across the servomotors, the cause of the problem. Even this required a large capacitance value and major portions of real estate. The problem was still present with over 6000 μF. Another solution had to be sought.

With the problem still present the electrical team leader took a step back and evaluated the problem. The problem being that the modulation circuit periodically dropped out when the servomotors were in full operation. The reset on the 50% duty cycle timer was dropping low. A reset was used as a low voltage input on this terminal causing the cycle to stop until the reset button on the latch circuit is pressed. The solution was to add a capacitor across the reset to ground. The team added the capacitor and was then able to remove all of the other capacitors used to keep the voltage stable. This appears to be the perfect solution. The solution also increased the response time of the photodiodes.

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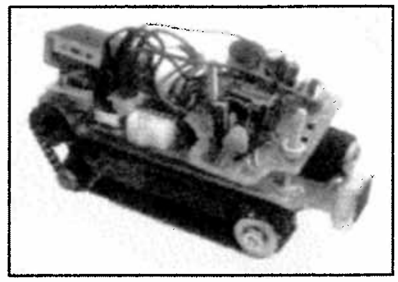
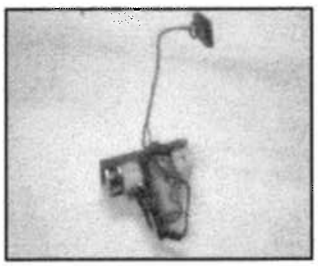


The team decided to leave one 1000 μF capacitor across the servomotors. This was done to ensure the battery would meet the lifetime specification of five minutes continuous draw. This capacitor will also help compensate for the draw when the battery is low.

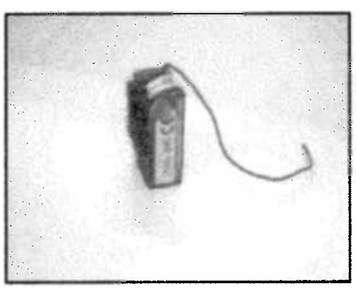
- **Power Module**



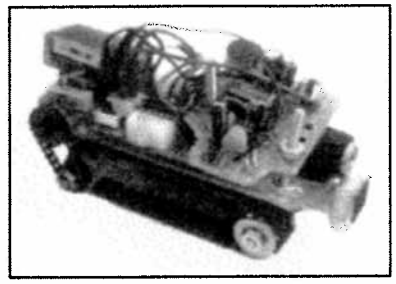
The power module is just a simple solution to making the power distribution modular. The ability to connect and disconnect power to each module was required. A main power switch was also a requirement. This is accomplished by using two sockets. The first socket is for the main power leads from the battery. The second is for supplying power to each module and the servomotors.

The power module incorporates the leads for the servomotors. This is also where the 1000 μF capacitor is located. The servomotor leads could have been hard wired, but then the entire module would have to be powered to debug the servomotors and the wiring connection. With the leads anyone can test the servomotors without connecting the entire power module.

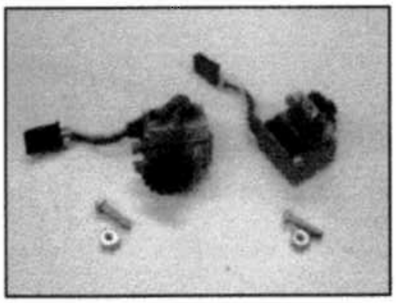
- **Receiver**



The receiver is a purchased unit. It operates at a frequency of 75.430 MHz. There is a crystal in the receiver that filters out all other frequencies. The antenna was originally two feet long. It was shortened for a cleaner appearance. One drawback of the shortened antenna is the range of the receiver. The range is significantly shorter. The transmitter must be kept close for the car to function properly.

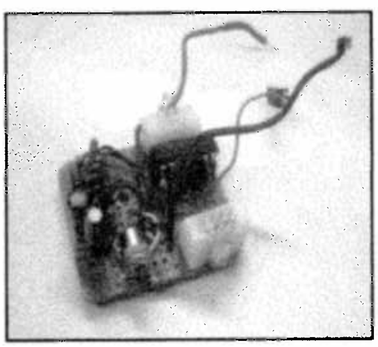


- **Servomotors**



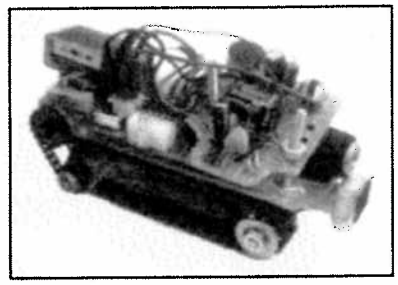
The servomotors are also purchased equipment. They were intended for use as a steering motors and not drive motors. They required significant modification. The exposed drive is actually attached to a 5 kΩ potentiometer. This potentiometer was used to set the zero or straight alignment of the motor. The leads to the internal potentiometer were disconnected and then attached to an external potentiometer. There were also two mechanical stops that had to be removed. The new external potentiometers were chosen for their accuracy and are 20 turn, 5 kΩ rated potentiometers.

- **Demodulating Circuit**



The demodulating circuit is used to detect the lasers of the opponents. Since a battle can not be simulated unless all the player's lasers are adjusted to the same frequency, the demodulating circuit is also adjusted to 25 kHz, plus and minus a small tolerance of 2 kHz. The demodulating circuit is set for 19-27 kHz. The Pulse Demodulating Circuit uses a LM567 chip that senses the 25 kHz laser signal via photodiodes. Once a laser signal is sensed, the output of the chip goes low.

The demodulating circuit is the same design as the previous year with slight modification. For example, the resistor on pin 5 is 47 kΩ and the capacitor from pin 6 to ground is .001 μF. This combination will give the tolerance of 25 +/- 2 kHz. In addition to the pin 5 and pin 6 adjustments, the 1 kΩ resistor shunting the output was changed to 2.7 kΩ. Six V_{dc} powers the demodulation circuit.



The major problem with the building and testing of the demodulation circuit was obtaining the precise values needed for the frequency specification. Many different orders of magnitudes were used but finally the appropriate ones were found.

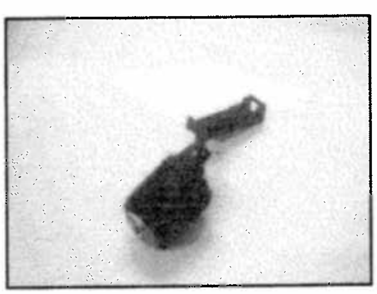
- **Latching Circuit**

The latching circuit simulates the act of being "hit" by the enemy. When shot by the opponent, the demodulating circuit sends a low output to the 7400 Quad NAND TTL latching circuit. The 7400 is wired so that if the input goes low the output goes low and stays low until it is manually reset. Once a low signal is sensed, the output of the 7400 sends a low signal to the reset of the 556 Timer, thus turning off the laser and sound. There is a pushbutton installed in the circuit to reset the circuit. The TTL circuit is being supplied by 6 V_{dc}.

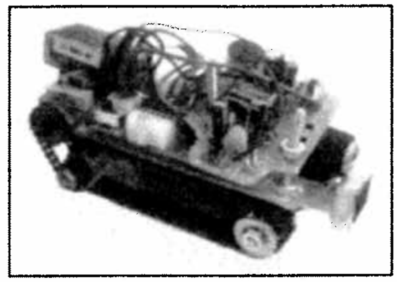
- **Sound Circuit**

The sound circuit is powered and controlled by the 1 Hz 50% duty cycle modulated laser circuit. The sound circuit is simply a 4.2 kHz, 70dB buzzer. The supply voltage range of the buzzer is 4 to 16 Volts. When the modulated laser fires, simultaneously the buzzer sounds. When the demodulating circuit senses a hit, it sends a low signal to the latching circuit. Consequently, the output of the latching circuit goes low. The low output is sent to the modulating circuit, thus turning off the laser and buzzer, signally that you have been "hit."

- **Laser Circuit**

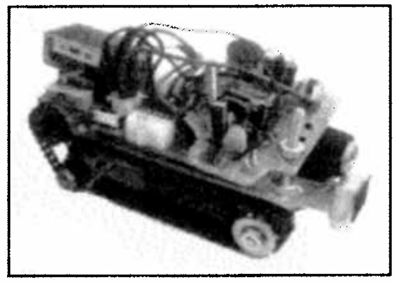


The laser circuit is simply the laser, which is powered by the 25 kHz, 50% duty cycle pulse from the modulating circuit. The output is grounded to complete the circuit. There is a 10 μF capacitor in parallel with the laser to help maintain the voltage, which indirectly increases the intensity of the laser beam. The laser, which was supplied by the instructor, has a rating of 5 mW.



- **Battery**

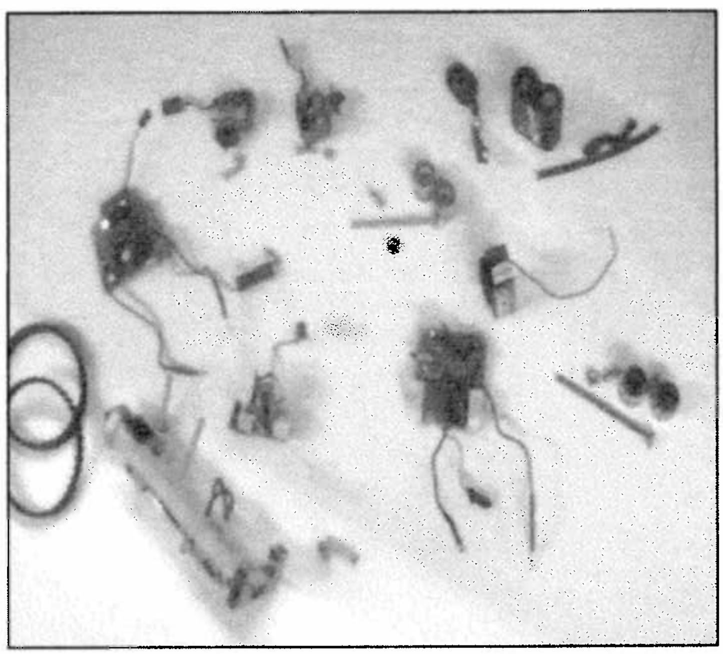
The single power source for the entire system is a 6 V Lithium battery from Radioshack. The rating of the battery is 1300 mAh. The entire system draws approximately 650 mA at full load. As a result, the theoretical lifetime of the power source is two hours.



5.0 Product Assembly

- **Item Checklist**

TANK COMPONENTS	TOOLS
1 - Wood Chassis	1 - 5/16" Nut Driver
2 - Servo-Motors	1 - ¼" Open End Wrench
2 - Timing Belts	1 - 5/16" Open End Wrench
2 - Plastic Chains	1 – Small Screwdriver
2 - Wheels with Sprockets Attached	
2 - Wheels without Sprockets Attached	
4 - Brass Sleeve Bearings	
2 - Axles	
3 - Large Nuts	
2 - Small Screws	
2 - Small Nuts	
2 - Springs	
1 - Receiver	
1 - Remote Control Transmitter	
1 - Laser	
1 - Power Circuit	
1 - Modulation Circuit	
1 - Demodulation Circuit	
1 - 6V Lithium Battery	



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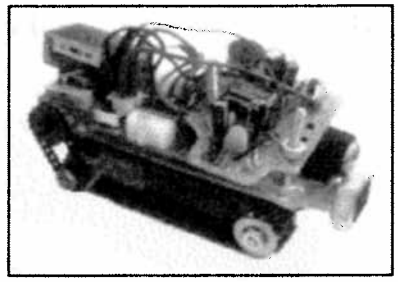
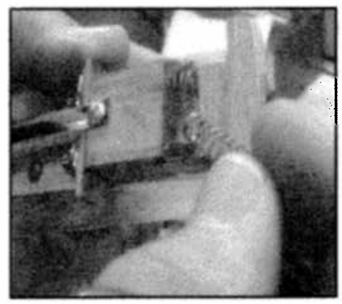


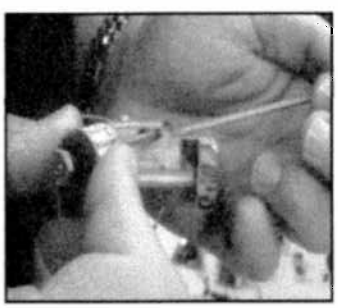
- **Assembly Instructions**

1. First make sure you have all the assembly components listed in the item checklist.

2. Insert the two springs into rear of the base of the chassis.

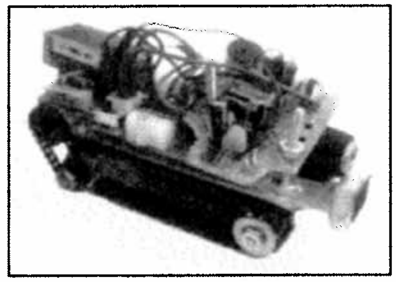


3. Slide a wheel with a sprocket attachment toward the fixed nut, and a brass sleeve bearing, in that order, on the larger of the two axles. *Note… The sprocket will face the outside of the chassis.*



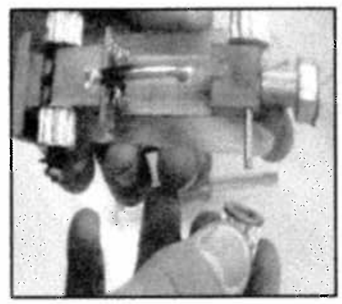
4. Slip the axle through the slot on the rear of the base of the chassis with the wheel assembly on the right of the base. (Use the screwdriver to compress the springs as you slide the shaft inside.) *Note… Both springs should push the axle toward the rear of the vehicle.*

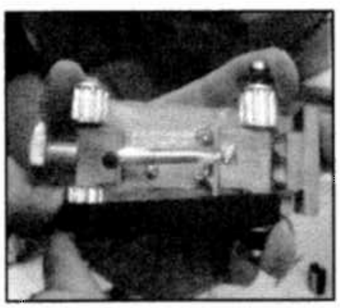
5. Slide a copper sleeve bearing and the other wheel with a sprocket attachment, in that order, on the left side of the rear axle.



6. Thread black nut on the end of the shaft so it is tight. (Unless you have tightened the nut too much, the wheels should spin freely.)

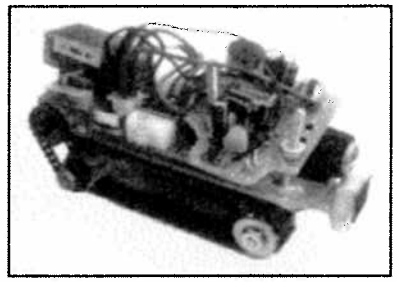
7. Repeat the axle assembly for the front using the last two sleeve bearings and the wheels without the sprocket attachments.



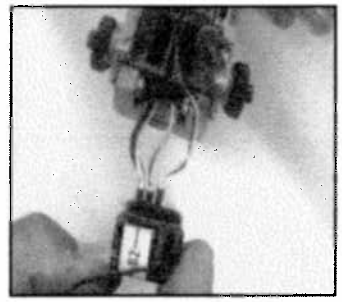


8. Slide the tread belts onto the wheels. (Pinch the rear axle to compress the springs. This will make it easier to position the treads on the sprocketed wheels.) Repeat the procedure for the other side of the vehicle.

9. Feed one of the chains onto the teeth of the sprockets on one of the orange servomotors and the sprocket of the wheel. Hold the orange servomotor and wheel so that the chain has very little slack with a good tension.

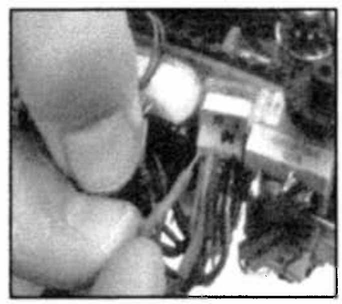


10. Slide the servo, with the chain attached and the yellowish-brown potentiometers glued to the servos facing upward, against the wood mount and bolt it onto the chassis as seen in the adjacent picture.

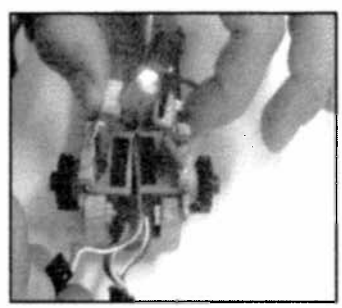


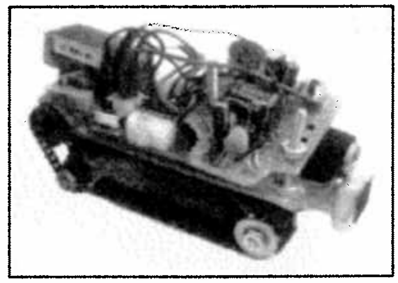
11. Repeat steps 9 & 10 for the other motor.

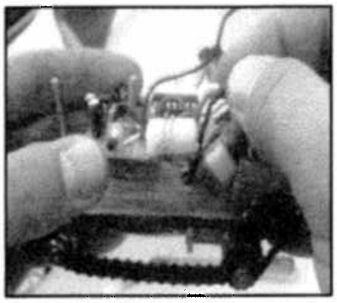
12. Get the small power circuit with the large gray capacitor and make sure the wires coming from under the circuit are connected to the terminal bus between the capacitor and the on / off switch. The black wire goes to the negative side of the bus and the red wire goes to the positive. *Note … The polarities of the two terminal buses are marked on their sides.*



13. Stand the power circuit up against the servos with the on / off switch on the right side of the car.







14. Slide the demodulation circuit onto the top of the Plexiglas platform. There is a clearance hole to slide the bolt through. The demodulation circuit has the reset switch lying on its side facing toward the left side of the car. *Note … It is a tight fit between the demodulation and power circuits, but the clearance notch in the demodulation circuit will leave sufficient clearance for the main power wires to be routed from the battery to the power bus.*

15. Insert the photodiodes into the middle two pinouts in the outer row. Ensure the lens are pointing inward. Now bend the photodiodes over so that the lens are facing outward and are approximately 37 mm from the ground.

16. Insert the red and white wire connections from the demodulation circuit into the power bus next to the switch on the power circuit. *Note … The red (positive) wire goes to any of the front four holes on the bus, and the black (negative) wire goes to any of the four rear terminals on the bus.*

17. Insert the red and black wires coming from under the chassis from the main power source into the bus on the left side of the power circuit. *Note … The terminals are reversed this time, so the positive is toward the rear of the vehicle and the negative is toward the front.*

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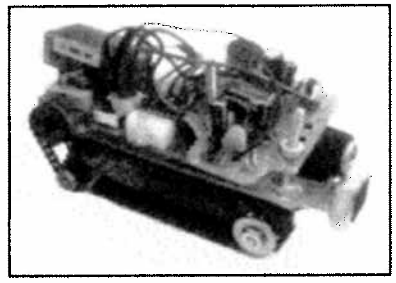
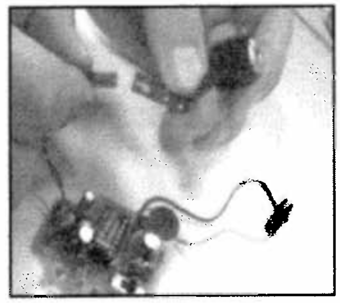
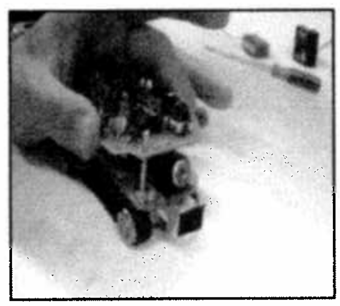
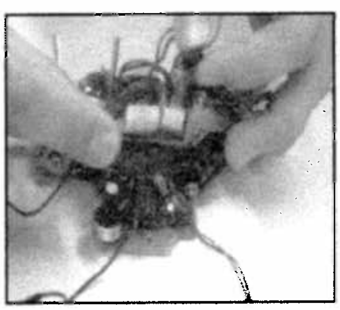


18. Before installing the modulation circuit onto the vehicle, connect the laser to the circuit with the clip connections that have the red and black wires.



19. While positioning the laser onto the Velcro at the front of the platform, slide the modulation circuit down both bolts. Position the laser connection behind the laser. *Note … The black speaker with the hole in the middle is positioned on the modulation circuit toward the rear of the vehicle on the left side. The front bolt slides through the furthest hole on the right of the modulation circuit.*





20. Connect the demodulation and the modulation circuits together with the green clip connections.

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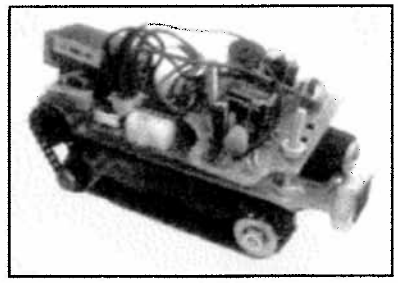
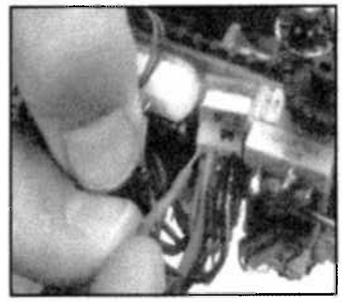
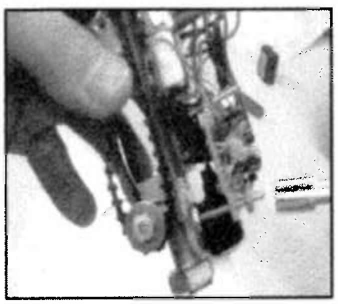


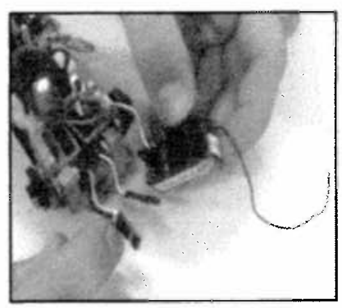
21. Insert the modulation circuit power connections into the power bus on the right side of the power circuit by the on/off switch. *Note … Be sure to put the red wire in one of the front four terminals and the black wire in one of the back four terminals.*

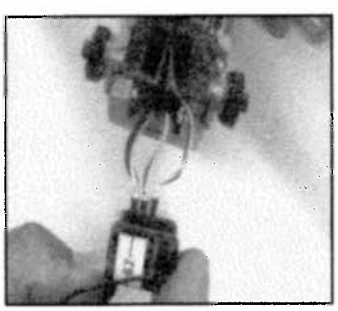




22. Tighten the modulation circuit down snug to the laser with the last remaining nut on the front bolt. Be sure not to over tighten the circuit board because of the possibility of breaking the board.

23. Insert the connections for the receiver power from the power circuit into the receiver. *Note … This connection is marked with a yellow dot. The red wire is the center, and the white is closest to the dot.*





24. Insert the power connections from the right servo-motor into the middle connection on the receiver.

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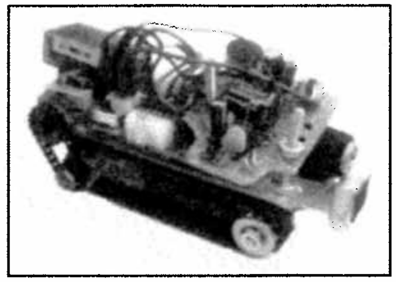
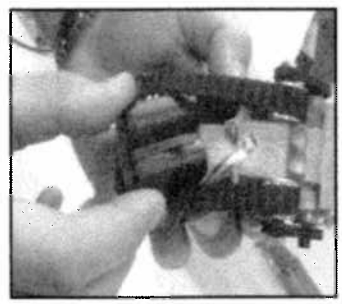
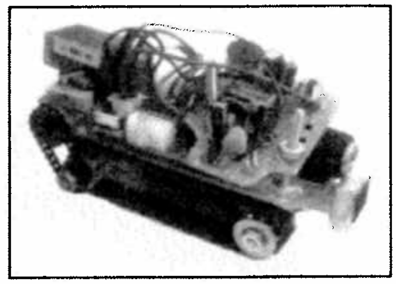


25. Insert the power connections from the left servo-motor into the last connection on the receiver. *Note … This connection is the one that is closest to a corner on the receiver.*

26. Flip the receiver over and attach it to the Velcro on the motors, wedging it carefully between the two potentiometers.

27. Insert the battery into the bottom of the chassis between the treads and under the clip that holds the battery in. Be sure to insert the battery with the curved side facing down toward the ground.





27. Troubleshooting

- **Electrical Symptoms**

Symptom	Probable Cause	Remedy
• Car will not move while sound and laser are not working	• Power switch is off • Battery may be dead • Battery inserted backwards • Bad wire from battery to power module check continuity • Broken solder on power module	• Turn power switch on • Check voltage across battery • Adjust position of battery • Jumper / replace wire • Resolder joint
• Car will not move but sound and laser are working	• Servo Power connection is backwards, white wire is on left red is in center • Servo leads not plugged in • Broken servo lead wire • Transmitter has no power	• Turn plug around • Plug in leads to power bus • Check continuity and replace wire • Replace transmitter batteries
• Sound and laser quit when car is moving	• Dead battery • Capacitor on modulation circuit bad	• Replace battery • Check capacitor on pin #4 of the LM556
• Sound works but Laser does not	• Laser not connected • Laser leads broken	• Connect laser to laser bus • Check continuity of leads and solder joints

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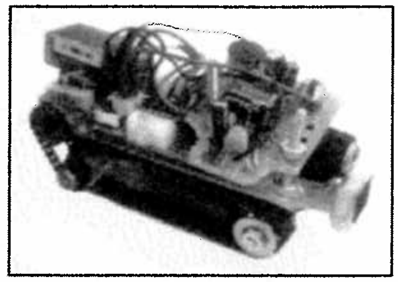

Symptom	Probable Cause	Remedy
• Car moves without input	• Trim pots off • Trim pots on servos leads are broken	• Adjust trim pots on servos and / or on controller • Resolder leads
• Laser & sound do not stop when photodiode is hit with laser	• Damaged photodiode • Photodiode improperly installed • Damaged 7400 chip on demodulation board • Damaged photodiode socket • Demodulation circuit not connected	• Replace photodiode • Install properly (polarity sensitive). See assembly. • Replace chip • Check soldering connections • Connect green wire • Connect power leads to power bus • Check continuity of green wires on both modulation and demodulation board • Check solder joints of green wire

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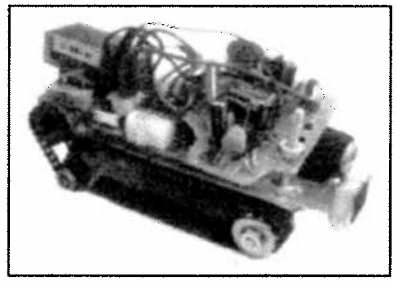
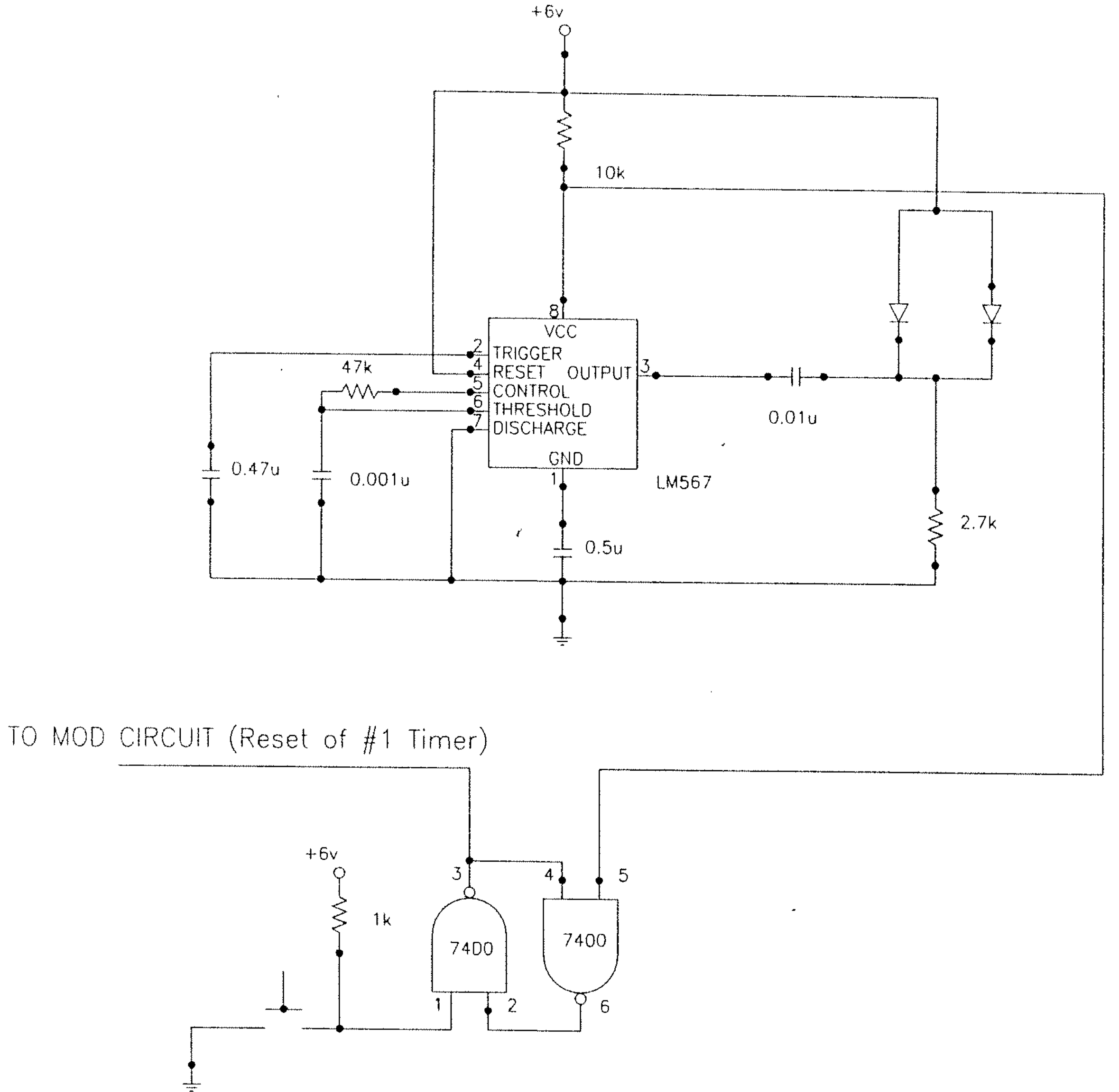


- **Mechanical Symptoms**

Symptom	Probable Cause	Remedy
• Tractor Tread will not stay on the wheels	• Washer missing from wheel • Rear axle bent • Debris in wheels	• Super glue a new washer • Replace axle with 1/8" shaft and 6/32 threads • Clean wheels with wire brush
• Servo does not turn the tread	• Sprocket broke off of the servo • Chain link damaged • Sprocket not connected to the rear wheel • Servo burned out	• Super glue a new sprocket • Replace section of chain • Super glue a new sprocket • Replace servo (HP 50)



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DEMODULATION BOARD

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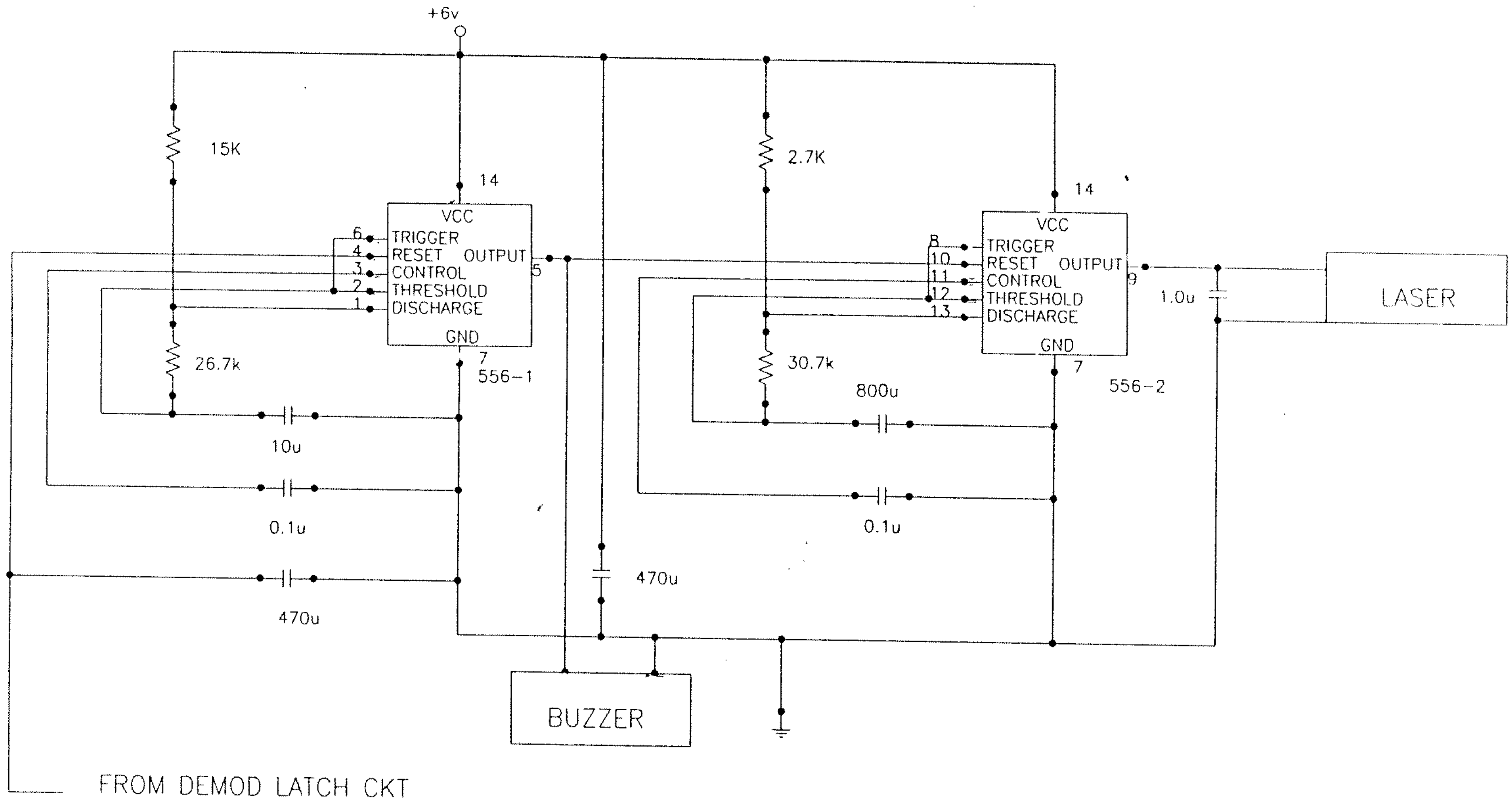

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MODULATION BOARD

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