The Complete Tagger

Concerning the hobby of Tagging and the playing thereof.

Being a collection of hints and

Modifications for tag compatible equipment.

Containing therein many diverse circuits and ideas.

Second Edition

More complete than ever yet published.

Based on the laser tag as played non-commercially in the U.K.

The Complete Tagger

Second Edition

Pre-press Version: -1.11.06

This version should be considered void as soon as the next one is out.

Check http://www.hugme.com/games/tag/tct.html for latest version.

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Introduction

This is the Second Edition of "The Complete Tagger". The original was put together by Mark Arnold, as a special FIREFIGHT supplement. Because, unlike the original, this edition is intended to be distributed mainly as a PDF file on disk and over the Internet there will undoubtedly be more than one version. If you want to print a copy out if you print it on A4 paper, double sided. The PDF is formatted with this in mind and allows for a left hand binding. If you want to check you have the latest, compare the version number inside the front cover with the version on the web sites that host it.

I have re-typed parts of the original to improve the quality of the reproduction, and in an attempt to reduce the size of the file. While re-typing parts I have corrected some of the things in it I thought were typographical/spelling errors. However I have undoubtedly added many of my own. Sorry!

This document has been put together in order to collate the many technical advances that have been made in the world of tagging and so make them assessable to all members of the hobby.

Many of the modifications in the booklet require some electronics skill, but don't let this put you off. The electronic circuits included here are not difficult to make, requiring some basic equipment, patience and care. If you have had no previous experience of electronics then I suggest read the 'Electronics for the Innocent' section first and if at anytime something is not clear, flip back there. Because many people have contributed to the information and circuits you may find the same type of information expressed in different ways or formats.

There are modifications in this document for most of the types of commercial Lazer Tag compatible weaponry about and also ideas for sensors as well. With original equipment becoming harder to obtain, there is an increased numbers of circuits for those who want to build from scratch.

Most groups agree that if you are going to improve any standard weapon, then this should be done in conjunction with building a larger body, having a louder sound system and bright muzzle flash. There is also a current trend which adds enjoyment for all, of putting magazine counters in machine gun type weapons. These counters disable the gun for a variable period of time, once its "magazine" has been emptied. The length of disable time depends on the size of the magazine.

All this may seem a momentous amount of work for a beginner to the hobby to undertake, and so it is. However all of the groups I play with are quite understanding to anyone who is using a gun that has not been finished, i.e. only has some of the above properties. The most important thing to do is to start with a strong large gun body that will leave you with ample room to fit in any additional circuits or battery packs that you may require in the future, and when I say big, think BIG! Good access to the insides is also very important and should be thought about well in advance.

What you use to make the body is up to you, wood, plastic tubing, electronics hobby boxes, toy guns, milliput and A.B.S. plastic sheeting have all been put to good use. Remember that if you are going to use a long range lens system with the gun, you will need to anticipate the size of the lens in the gun design. Most people build the gun around the lens.

Thank you to all the clubs and individuals who have contributed to this document either directly or indirectly through the Internet or "FIREFIGHT" magazine, and to those who have helped me edit and assemble it.

Finally, although we hope that the information in this document is correct, it is not guaranteed, and any constructions or modifications are completely at your own risk. If you want to keep up to date one what's happening, subscribe to the excellent FIREFIGHT. Good Luck!

Dave "Cannon Fodder" Challenor

A word of warning on the subject of lasers.

By Dave Bodger

There are now some quite reasonably priced units available from suppliers such as Maplins, which may make them appear appealing. If you have ever thought of fitting one to your tag gun for use as a real targeting laser - PLEASE DO NOT. Because of the widespread use of telescopic sights on many guns, even a low powered laser is hazardous to people's eyes. Once the beam has been concentrated another 10 or more times by a scope, the intensity is enough to do permanent damage to someone's retina. A 1mW Class II laser, the weakest sold by Maplins, is NOT eye safe!

As far as I am aware, ALL lasers are BANNED in all LRP tag games. Even if someone produced what they thought was an "eye safe" laser, the game organisers would have no way of determining the safety of such a device on the day. Unfortunately the standard method of checking the safety of LRP weapons (being hit with it yourself) is not acceptable here. (Hmm - let's just shine this laser in your eyes for a few minutes and see if you go blind !)

The lasers used in games such as Quasar and Laser Quest are Class I, and so low powered that you can hardly see them in anything other than total darkness; also telescopic sights are not used in those games and the targeting area is the chest, not the head as it is in LRP tag games so the risk of prolonged eye exposure and consequent damage is reduced.

The word "Laser" in the name "Laser Tag" is there just for effect. The infra red beams we use are thousands of times less concentrated than a real laser beam and are little more dangerous than a TV remote controller at a distance.

I believe that in some states in the USA, home of litigation, there are some games where they are only allowed a fixed number of "laser" shots per game - 150 shots I think, just in case there might be an effect from cumulative hits. Once you run out, the gun still fires but only the IR beam comes out, making targeting a little tricky!

Guns

Anatomy of a Tag gun

All laser tag guns consist of the same main ingredients in differing proportions:

- An infrared emitter diode (possibly fitted into a lens assembly of some sort).
- An electronic circuit to generate and control the tag pulses.
- An arrangement of switches to control the circuit.
- A power source, normally a battery or battery pack.
- Something to generate a 'bang' sound, often connected to an amplifier and loudspeaker.
- An ammo-counter with display or a cut-out timer to limit the fire rate.
- A mess of wires to connect it all together (it doesn’t have to be a mess, but in practice!).
- A body made of some rigid material to physically house all of the other components.
- Accessories to make it easy to use: telescopic sights, carry straps and the like.

Commercial Guns

There are many different types of compatible commercially available (but not very available) guns on the market. There are also an increasing number home-made gun circuits, some of the simpler ones are included in this document. What follows is a brief description of each of the commercial weapons, all of which were originally supplied in a set complete with a sensor.

Lazer Tag (Starlyte)

These are the guns that really started the hobby, although not made any more, they were produced by Worlds of Wonder and originally sold at very expensive prices. The project seems to have flopped, but Lazer Tag sets can still be found very cheaply on market traders stores in some parts of the country (expect to pay up to £30 for a set).

The gun is a black plastic futuristic pistol, that fires a single shot every second over a range of about 70 meters. Claims have been made of much greater distances but these should be taken with a bucket of salt. The addition of a small telescopic sight onto the top of the integral sight, greatly improves the guns accuracy.

Throughout the rest of this document, you will find these referred to as StarLyte pistols.

NOTE: The newer WOW equipment made by Tiger Toys is not compatible with this older technology.

G.I. Joe

These guns were also made by Worlds of Wonder, they are made of green plastic in the shape of a pistol. Again these fire a single shot every second but their unmodified range is only about 20 meters. Again these guns can be found on market stalls and in small shops, expect to pay between £5 and £20. These guns are very versatile and a bargain (if you can find one!).

Quickshot / Sureshot

These pistols are made of a black or grey plastic and come complete with a sight that slides into the top. They can still be found in a variety of places and have a range of about 20M unmodified. Expect to pay between £15 and £25 pounds for a set. Not a bad little gun, which emits a smear of light when it is fired, rather than a single shot.

Neutronic 7000

I have only ever seen one of these grey plastic pistols which cost about seven pounds. It is similar to the Quickshot but less well made. Unfortunately it has to be turned on before use and has a continuous flashing L.E.D. when it is on.

Infra-red Rays Gun

These quaintly titled guns are an eastern import and look like a machine gun. They have a very loud gunfire and repeat automatically when fired. Unfortunately they are not very robust and have a limited range of about 10-20 meters. However they can be purchased from Jon Blau of Dark Star for about £30.

Terminator 2000

A practical weapon, but has the disadvantage of not triggering hits on SmartSensors. There are several options to modify the gun so that it will though.

Common Non-commercial Gun circuits

If you are interest in these boards, please see the “Supplies, Sources and Contacts” section for how to get in touch with the people who make them.

SmartGun

A board commonly found in new guns is the SmartGun board by Dave Bodger.

This is an intelligent board, based on the PIC16C84, that includes an ammo counter and allow the use to select between server gun types (i.e. Machine gun, shotgun, pistol plus many others) at switch on time. It also offers the ability to be configured by a computer via a RS232 connection.

Priest Boards

Phil Higgins makes to general types of board, the Spartan Mini and the Spartan SFX. Both boards are intelligent and based on the PIC16F84. They offer multiple configurations selectable at power on and an ammo counter.

The larger Spartan SFX board also contains a chip of digitised sounds for a range of gun events including firing, reload, out of ammo and many more.

Hi-Ranger

The Hi-Ranger mark 1 was based on the 2240 chip that was capable of single shot or fully automatic fire. It had a 3 gun sound chip that could produce a rifle, phasor or machine gun sound effect.

The mark 2 is a PIC based board that has a 50 round or unlimited magazine capacity. Outputs for 2 separate IR emitters as well as muzzle flash. It could also be set for single shot or full auto fire, but only at power up.

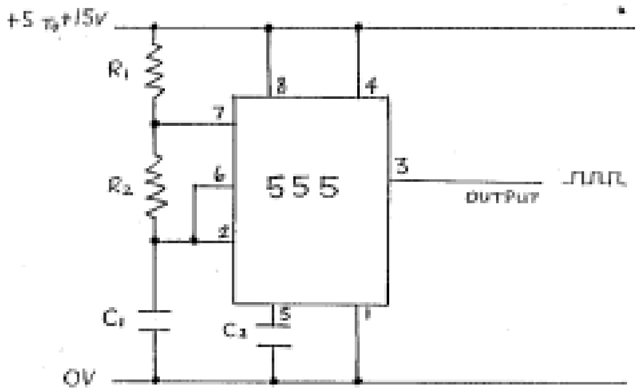
Others

There are many other good circuits out there, some of them one offs, and some of them discontinued. Just because it is not listed here does not mean it’s no good.

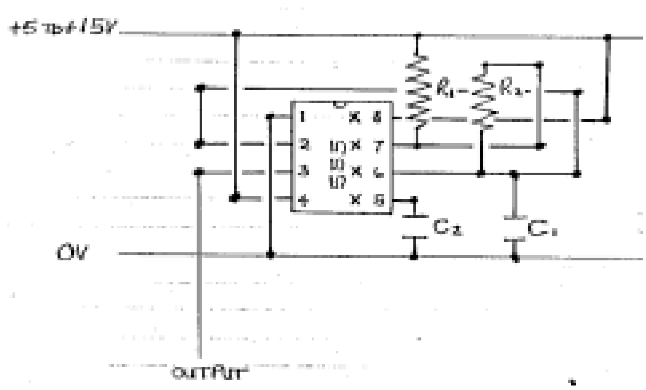
MACHINE GUNS

The first modification most people wish to make their shop bought weapon, is to convert if from a single shot weapon into a machine gun. At the heart of such a modification is an electronic circuit built around something called a 555 timer integrated circuit (I.C. or chip). This I.C. is a very versatile and common one and can be found in any electronics shop at a variety of prices (50p - £1.00). Now the same I.C. can come in a variety of different logic types e.g. T.T.L. and C.M.O.S., you don't have to know what this means, but I suggest that you ask for a T.T.L. 555 unless you know what you are doing with electronic components, as C.M.O.S. ones be damaged very easily.

This is a circuit diagram showing you how to build the circuit you require, you can see you will need a few other electronic components. When you come to build this you will do so on something called stripboard, this is a piece of non-conductive board with holes in it and strips of copper on one side. The components are soldered to the copper strips to make connections between them. The strips also have to be cut in some places to break connections. The diagram below has to be rearranged to fit it on stripboard and this has been done for you in the next diagram, the crosses indicate where the strips have to be cut. The rearrangement is not difficult so long as you are logical. You will have to do it for yourself in subsequent circuits.



Now this circuit is a very useful one, when a battery is placed across the two power rails (0V and +5V to +15V), the circuit produces a square wave output from its pin number 3. In other words it turns on and off repetitively. The speed of its on/off cycle depends upon the values of the other components in the circuit. Increasing the values of C_1, R_1 and R_2 will cause the oscillation to slow and vice versa.



For a nice fast machine gun rate try the following values:

R_1 1 Meg Ohm
R_2 47 kilo Ohm
C_1 0.1 micro Farad
C_2 0.1 micro Farad

Remember in construction that some capacitors have a polarity and you must place them in the circuit the right way around. To check the operation of the circuit, try placing a light emitting diode across pin 3 and 0V. If it does not flash then try it with the L.E.D. the other way around. If it still does not flash then check your circuit.

Now depending on what type of gun you are using, the method of connecting this circuit will vary.

StarLyte

With the gun open, disconnect the wire that is attached to the bottom trigger contact and reconnect it to the output from pin 3. Connect the positive power rail of the circuit to this bottom contact and the negative power rail to any handy negative source e.g. the negative side of the battery, or the negative side of the big capacitor in the gun handle.

All that remains to do is CAREFULLY de-solder the 1 micro Farad capacitor on the lazer tag board (labelled C8) and replace it with a 0.1 micro Farad capacitor. It may be better to cut the original capacitors legs and then re-solder to those rather than de-soldering it. With any luck it should now work.

G.I. JOE

The method of doing this is very similar to that above. One side of the trigger is positive, the other side becomes positive when the trigger is pressed. Disconnect the wire from this side (labelled E4) and reattach it to the output from pin 3. Connect the positive power rail of the circuit to the vacated trigger contact. Again find a convenient negative source to attach the negative power rail to.

Find the capacitor labelled C1 (47 micro Farad) on the G.I. JOE board and replace it with a 0.1 micro Farad capacitor.

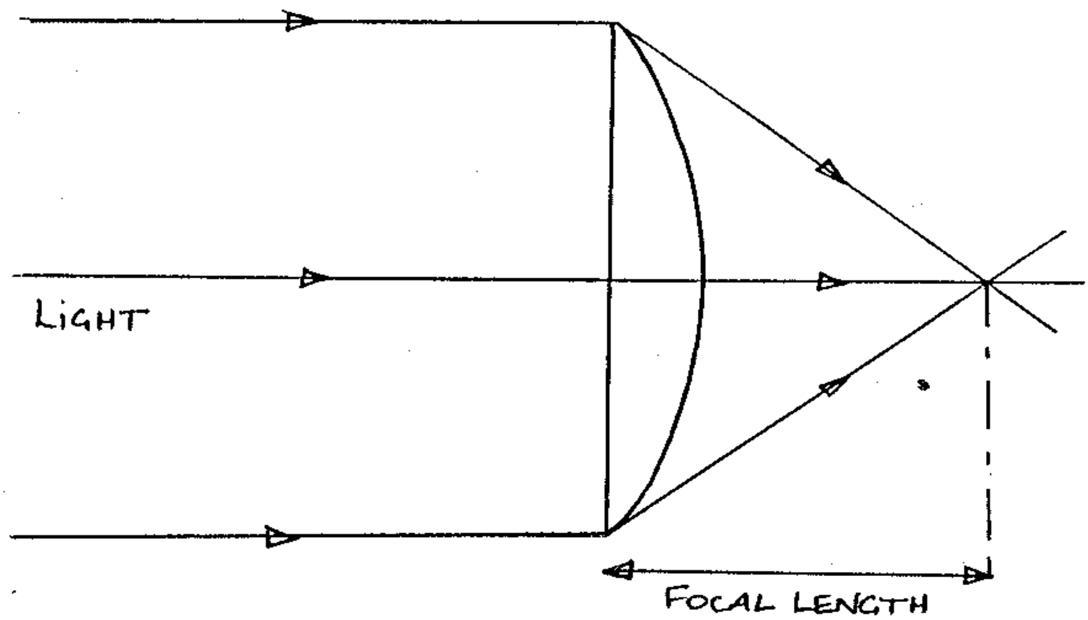
INCREASING RANGE

Lens System

The right type of lens can improve the range of any shop bought gun dramatically. The correct lens to use is a convergent or convex one, which can be obtained very cheaply by buying a magnifying glass and using its lens.

The effect of these lenses is to bend light towards a point. If the input light is diverging (as in the case of an LED) then the output light can be made parallel and this is the arrangement required to obtain long ranges.

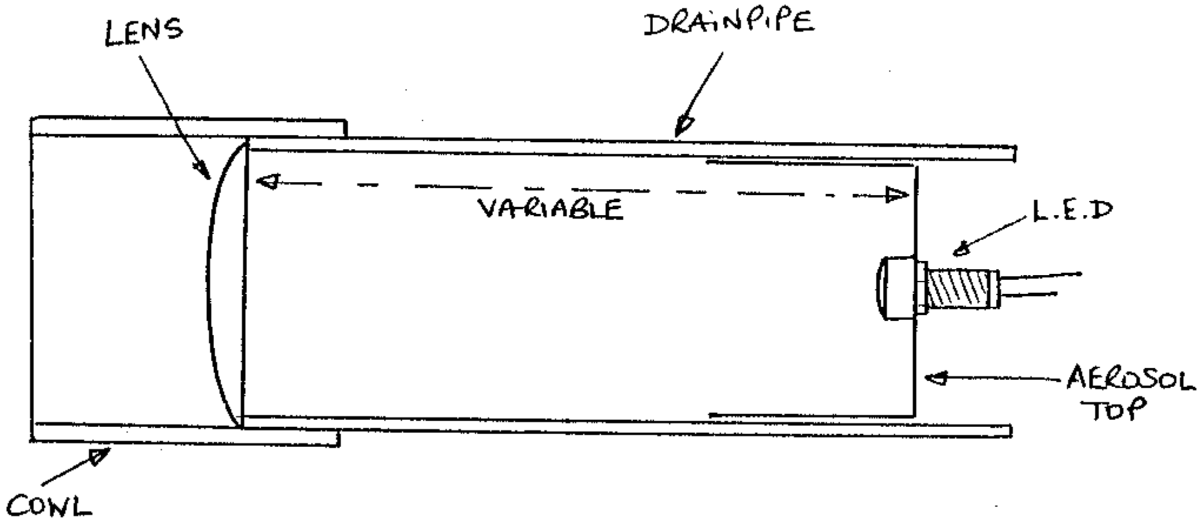
Lenses have a distance associated with them called the focal length, this is the distance from the lens at which parallel light entering its focused to a point, see the illustration below.



The approximate focal length of a lens can be found by holding it in front of a window with a piece of paper behind it. Move the paper closer and further from the lens until a sharp image of the outside world is obtained on the paper. The distance between the paper and the lens is the focal length.

The lens to use for your weapon should have a focal length of about 10 and 20cm. It is not possible to be precise about this, as it will vary with the type of infrared LED you are using.

When setting up the lens and LED, make sure that both are straight and that the LED is mounted at the centre of the lens a distance equal to the focal length from it. To get the best results it is necessary to field test the unit, trying different focal lengths until the best results are obtained. A popular way of mounting the lens and the LED is with a piece of drainpipe and a suitable aerosol lid used to mount the LED to slide it back and forth inside the drainpipe to alter the focal length (see diagram below).



The Farnell's CQW13L LED in a panel mount was recommended in the original edition. Now a popular choice is the SFH484-2 'lilac' also available from Farnell, in an appropriate bezel mount. These give a good range for a reasonable price.

The lens can be of any size diameter but between 5 and 10cm would seem to be the maximum sensible to fit on the front of a weapon. Theoretically the larger the diameter the better.

Ranges of well in excess of 200 meters are achievable using this method. It is probably better to cowl the lens as shown above, this protects it from damage and also stops the beam from spreading sideways too much, which will make you unpopular with the people you play with.

StarLyte

A short note about StarLyte pistols is appropriate here. The emitters used in these guns do not work well with glass lenses with a high iron content which tends to give the glass a blue tinge). The high iron content adversely affects the IR from these emitters, and possibly others. Many types of glass lenses are fine, and have advantages over other types, old military spec ones being preferred by some people.

Louder Gunfire / Sound Systems

It is only fair that the person you are firing at should be able to hear you at the same time as he hears his sensor go off. With the increased ranges now available this requires separate circuits to produce and amplify gunfire.

Louder is the general aim, but many people want their weapon to sound right. If your really want your weapon to sound like you think it should, you should look at the Spartan SFX gun board (set the section on non-commercial guns).

Don't forget that the sound system will put an extra load on your power supply. Big loud guns don't run for long on a PP3!

UM3562

IMPORTANT: The UM3562 is no longer available to buy, so unless you have one lying around you are not going to get far with this circuit!

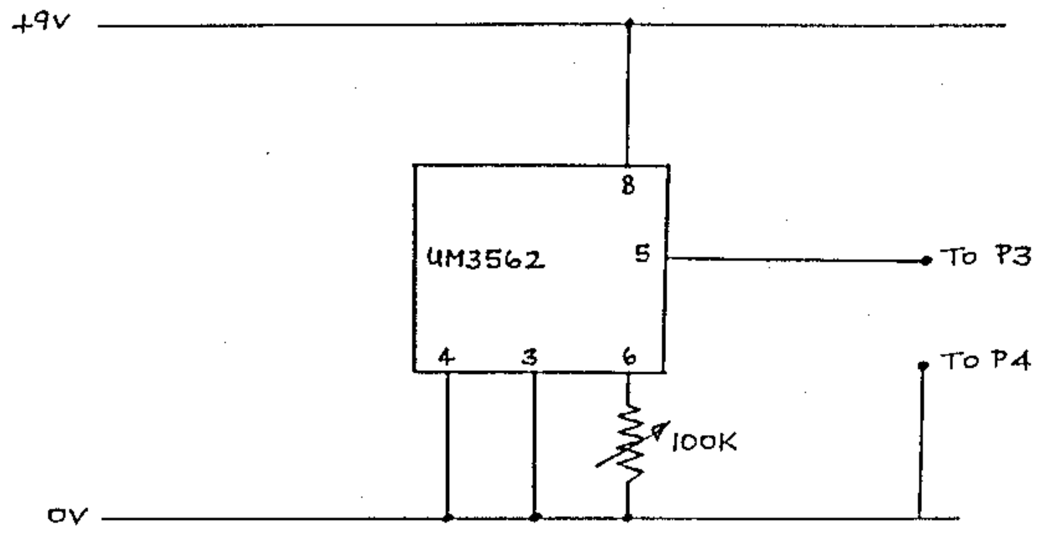
This system is built around a sound generator I.C. and project amplifier kit that can both be bought from Maplins. The total cost should be under £15. The noise made is that of a machine gun although 2 different sounds can be produced by altering where pin 2 on the sound generator chip is connected. A single rifle shot is produced if it is take to the +9V rail and a single phasor blast if connected to the 0V rail.

The parts list:

Part	Maplin Order No
Three gun sound generator	UL24B
1W Power amplifier module	LP16S
100K variable resistor	
1.5W 3.5" speaker 8 Ohm	YT25
Strip board	
Wire	
9V Battery pack	

Construction

Complete the power amplifier kit as per the instructions given with it. Construct the simple circuit show below using the three gun sound generator and the variable resistor.



Connect the wires shown in the circuit to the connections on the power amplifier kit labelled P3 and P4. Connect the speaker to the connections P8 and P9. Now take two wires from the positive side of the battery pack and connect one to the positive rail of the circuit above, and the other to connection P1 on the amplifier. Similarly take two wires from the negative side of the battery pack and connect them to the 0V rail and P2 respectively.

To switch the gun on and off, the power is connected and disconnected. The loudness of the gun can be varied using the variable resistor in the sound generator circuit.

HT2883

The HT2883F/HT2883E chips are suitable for a machine gun and are both available from Maplins.

*** Insert circuit info from PH here! ***

Simple Amlifier Circuit

*** Add circuit info here ***

Ammo Counter

A very nice addition to make to a machine gun type weapon is to add an ammo counter. This circuit will count the number of shots fired then disable the gun for a variable amount of time when all of the shots in a "magazine" have been fired. The time of disable is dependent upon the size of the magazine, a delay of ¾'s of a second for each 10 shots is the generally used standard. This gives a delay of 7.5 seconds for a 100 round magazine.

The use of ammo counters greatly increases the fun of a game, nothing is so frustrating as running out of ammo at a critical time, it also allows scenarios with limited amounts of ammunition (al a Aliens) to be run. Thirdly, it gives players who have not modified their basic weapons, a chance in games against others who have.

Example Circuit

The counter described below is the bog standard minimalist one, it has no display except a flashing LED to denote that the gun is disabled. It is set to count to a magazine of 90 although this can be made less by moving one of the wires as described later.

The counter may be given a simple LED display be connecting one or two bar graph displays to the outputs of I.C.s 3 and 4. To do this is simple but will require further information about the 4017 I.C.s. A digital display can also be connected to this circuit but this is more complicated and requires the removal of I.C.s 3 and 4 and their replacement with several other chips.

To understand what is happening in the circuit read the following:

1] IC1 is a 555 chip set to give a short "on" period when the trigger is pressed. Its purpose is to stop trigger bounce which would cause false shot counts. The 100K variable resistor may be altered to change the length of time of the "on" period, the practical effect of this is to change the amount of shots fired when the trigger is pressed momentarily. This burst fire mode is quite useful, I recommend that it is adjusted to give a burst of 1 to 3 shots.

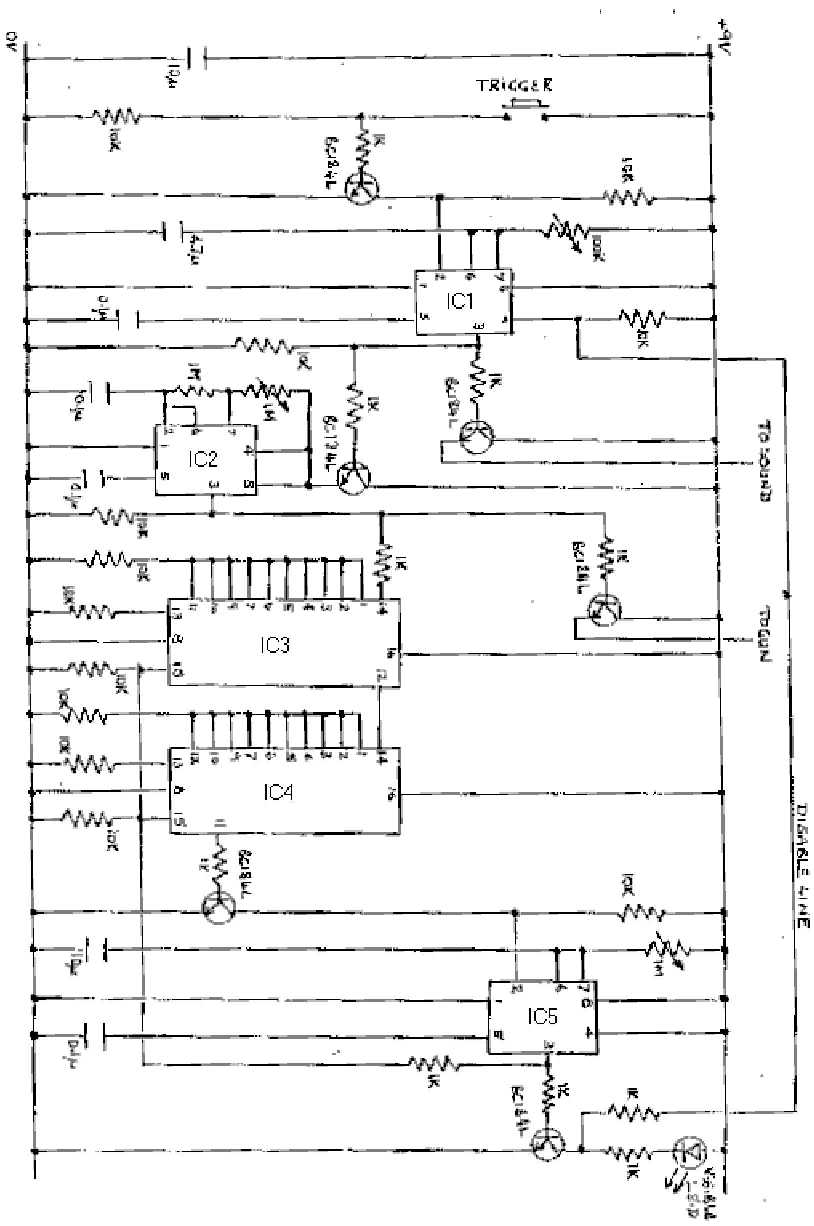
The other purpose of this circuit is to operate a sound system, the "to sound" output becomes positive in time with the chip and this can be used for this purpose.

2] IC2 is another 555 chip that is set up to turn on and off continually. However it only does this when IC1 is on, so you can see now how the burst mode works. These on and off cycles can be used to fire the gun. The "to gun" output becomes positive and negative in time with the chip and this can be used to activate the gun as described in the 'MACHINE GUNS' article earlier.

3] IC3 and IC4 are the 4017 counter chips, one of them counts to ten and then carries one to the next chip. The original chip then counts to ten again and carries again. This continues until the second chip has counted to nine, 9 x 10 is 90, the number of shots in the magazine. When this number is reached IC5 is then activated.

4] IC5 is another 555 chip again set to give a single "on" period. The period of this one is the length of the gun disable and it can be altered by adjusting the 1M variable resistor. Set it to about 7 seconds for this magazine size. Its output also powers the flashing LED to indicate that the magazine is empty.

Once the disable period finishes, the LED stops flashing and the gun is ready to file a new magazine.



Component List

Component	Maplin Code
3 x 555 Timer IC	YH63T
2 x 4017 Decade Counter IC	UB99H
5 x BC184L Transistors	QB57M
1 x Flashing L.E.D.	UK30H
1 x Microswitch (trigger)	FP43W
1 x 100K Variable Resistor	

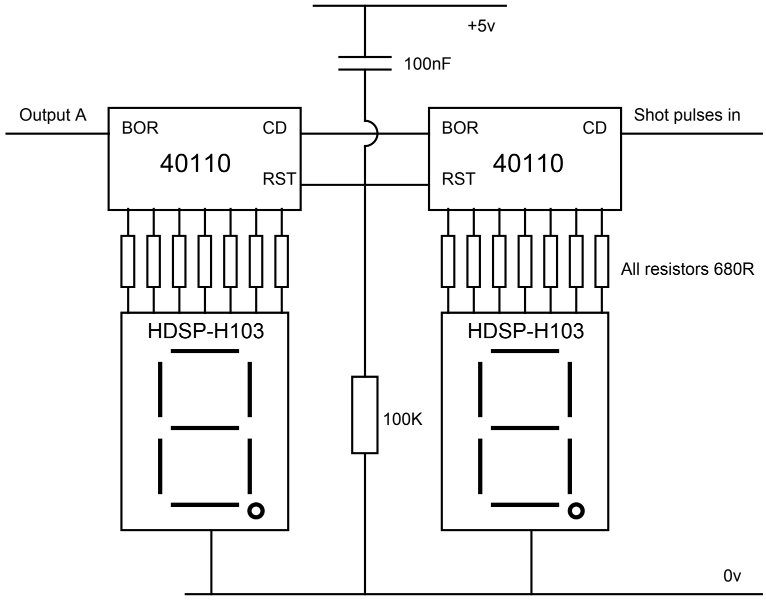
2 x 1M Variable Resistor
13 x 10K resistors
9 x 1K resistors
2 x 10 µF capacitors
1 x 4.7 µF capacitor
4 x 0.1 µF capacitor

Changing the Magazine Size

This can be achieved by changing the pin of IC4 that supplies the transistor. This is currently pin 11, by changing the connections between pin 11 and one of the other pins below, different magazine sizes can be produced. It is important that pin 11 is connected to 0V in the same way as the pin was that it is being exchanged for.

Pin Number	Magazine Size
1	50
2	10
4	20
5	60
6	70
7	30
9	80
10	40

Ammo Counter Display (SmartGun).



Muzzle Flash

The muzzle flash on most commercial guns is either inadequate or non-existent especially so if the range of the weapon is to be increased. High brightness visible LEDs of 1 to 3 candela output are the easiest way to produce a bright flash when the gun is fired, without drawing a lot of current.

Using one of these LEDs in the one of the Farnell panel mountings (see "Increasing Range") gives an excellent muzzle flash visible even in daylight.

Alternatively using a torch bulb gives a bright white flash that looks authentic. The disadvantage of a torch bulb muzzle flash is that the pulse draws a significant current, in the order of several amps, and this must be taken into account when deciding upon which batteries you are going to use. PP3 batteries would be unsuitable, C cells a minimum, and D cells preferable. It may also be necessary to "stiffen" the power supply by fitting a few 1000µF 16v electrolytic capacitors (high frequency versions preferred - Maplins Order Code JL56L) across the supply so as to accommodate the high-current surges generated by the torch bulb, sound amplifier and emitter all demanding current simultaneously. Connecting wire capable of passing 6 amps or more is recommended.

StarLyte

Dismantle the gun and cut the two wires that connect the board to the light bulb. Extend the wires from the board and connect them to the new LED via a 1K resistor. Make sure that the LED is connected the right way around and mount it on the front of the gun body you are using.

G.I. Joe

Dismantle the gun and cut off the small red LED that is mounted on the top of the gun. Reconnect the new LED with extending wires to the old LEDs remaining legs, ensuring that the LED is the correct way round. Mount the new LED on the front of the gun body.

Quickshots

Open the gun up and locate the microswitch next to the trigger. The wire connected to it at the top is always positive. The wire connected below it becomes positive when the trigger is closed. Connect a wire to this connection and run it to a hyper-bright LED via a 470 Ohm resistor. Then take the other leg of the diode back to the negative terminal of the battery connections.

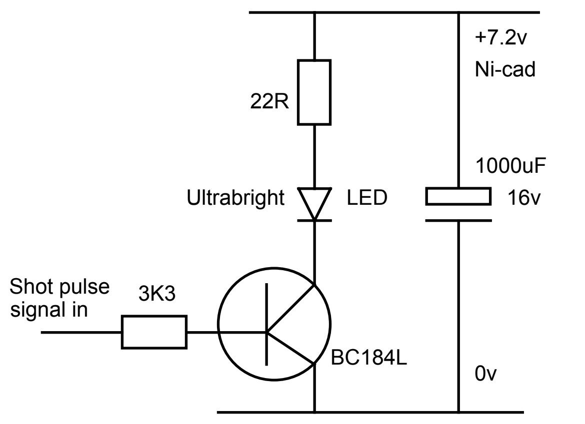
Drill a hole in the front plate of the gun below the barrel and poke the LED through and glue it. The LED should now light when the trigger is pulled.

Smart Gun

The SmartGun board was designed with ultra-bright high-power LEDs in mind however several people have asked if the SmartGun circuit will drive a torch bulb for use as a muzzle flash. In its standard form it will not, as the muzzle flash pulse is limited to 100mA by a 22 ohm resistor and to 200mA by the driver transistor. However Dave can supply boards specially configured with the more powerful ZTX689B transistor which is rated at 5 amps. Reducing the 22Ω resistor to 1.5Ω and using a 4.5 volt torch bulb on a 9 volt supply works well, giving a very intense flash. It is also possible to wire one on in parallel with the current muzzle flash circuit, should you wish to use both. It may also be necessary to "stiffen" the power supply by fitting electrolytic capacitors across the supply rails near to the battery connector and also where the supply wires connect into the main board.

Using ultra-bright 3 candella LEDs which are available in 5mm or 10 mm diameter is prefered by Dave for the SmartGun.

Smart Gun LED Muzzle Flash driver circuit



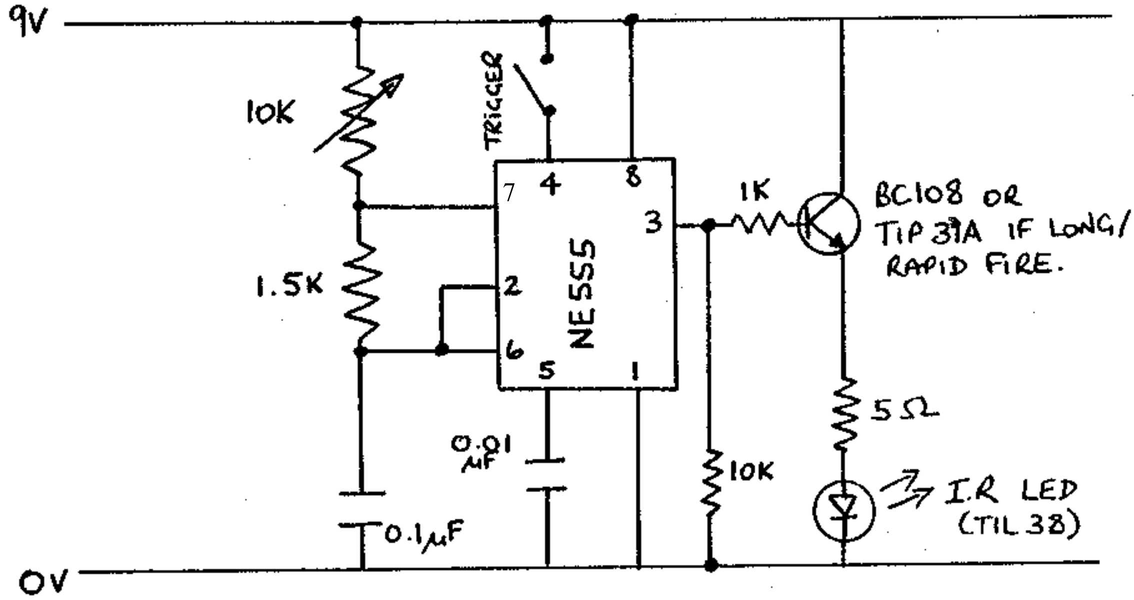
Choice of LEDs

Using one of the 3 candela (3000mcd) types available in 5mm or 10mm, which can be obtained from most suppliers for under £1, will give a very intense flash easily visible in direct sunlight. These are available in various sizes, the 10mm diameter ones look particularly good. Farnell Components and Electromail do some very high intensity types, up to 15 candela output with a narrow ±4° beam, but they are rather expensive at around £9 each. However they can produce a beam which is a reasonable looking safe simulation of a targeting laser at night.

Short Range Weapon

A very short range weapon suitable for mines, grenades and hand weapons can be made very simply by using a circuit similar to the one built in “Machine Guns”. The range depends to a certain extent on how well the circuit has been “tuned” to the correct frequency but will not exceed several meters without a lens system,

The circuit below produces a square wave which drives an infra-red L.E.D. via a transistor. The correct frequency to use is about 1.8 kHz and this can be accurately found by adjusting the variable resistor, with the circuit next to a live sensor. When the sensor is set off, gradually increase the distance between it and the circuit while fine tuning the resistor to get the maximum range.



Warning: Experience shows that this circuit tends to drift off frequency from time to time.

Long Range Weapon

This circuit gives a much greater range than the previous one, and it should be suitable for use in guns. Using a lens system it can obtain ranges of over 180 meters. Unfortunately many people have reported problems with this circuit. The crystal based circuit later should be much more stable.

When building the circuit use IC chip holders, and be careful not to touch the chip legs when installing them. The chips used are of CMOS logic technology and as such are very susceptible to damage from static electricity. It is best to follow accepted handling procedures when using these chips, which can be found in most electronics books.

Once built, the two variable resistors (VR1 and VR2), should be set to about their midpoints. VR1 should now be adjusted, sweep the resistor though its full range, with the circuit activated, noting when this sets off a sensor. Now move the resistor again and find the upper and lower limits of this range and position the resistor in the midpoint. If you own an oscilloscope or suitable frequency counter then the signal on pin 4 of IC1 should have a frequency of about 1.8 kHz.

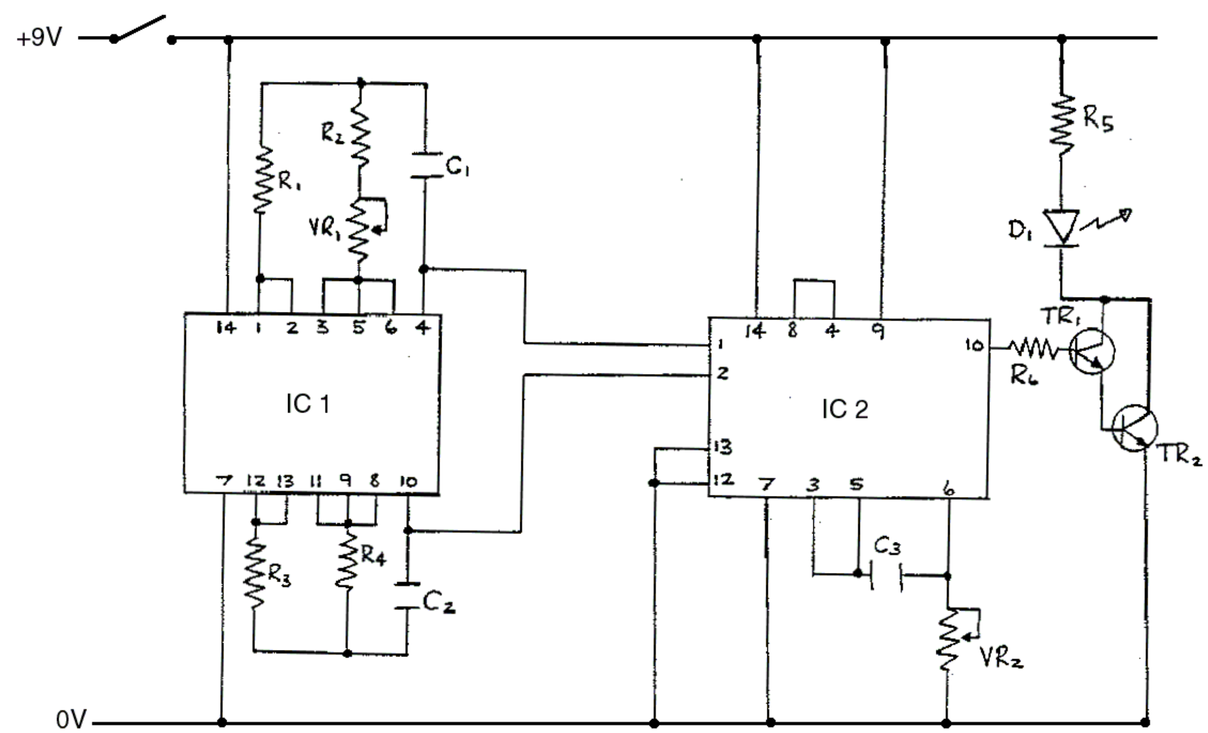
If the circuit does not hit no matter where VR1 is positioned, then first check that there is a signal on pin 4 of IC1 (this can be done by connecting a high impedance speaker between pin 4 and 0V).

If there is no tone then there is a fault in the circuit, or the chip has been damaged. If there is a signal then this tone can be matched (by varying VR1) to the tone produced when a loudspeaker is connected across the emitter in a tag gun (it may be necessary to change the value of R2 as well).

Now that the circuit hits a sensor, set VR2 to about ¼ of its maximum value and the circuit is now ready.

It may be necessary to re-tune VR1 when it is exposed to large temperature variations.

R1, R2, R3 =	22K Ohms	C1 =	22 n Farads
R4 =	10K Ohms	C2 =	1500 p Farads
R5 =	1.5 Ohms	C3 =	1000 p Farads
R6 =	47 Ohms	D1 =	TIL38 Infra-red LED (or equivalent)
VR1, VR2 =	10K Ohms variable		
TR1 =	BC 337	IC1 =	Quad Nand CMOS 4011 BE
TR2 =	TIP 122	IC2 =	Quad And CMOS 4081 BE



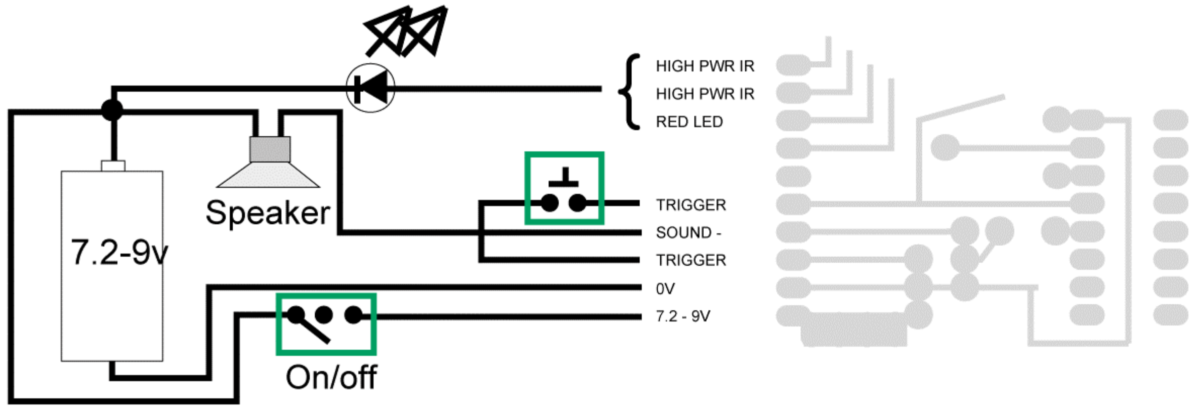
Long Range Crystal Gun

By Phil Higgins

Here is a circuit diagram for a complete long range tag gun that uses a crystal for maximum frequency stability.

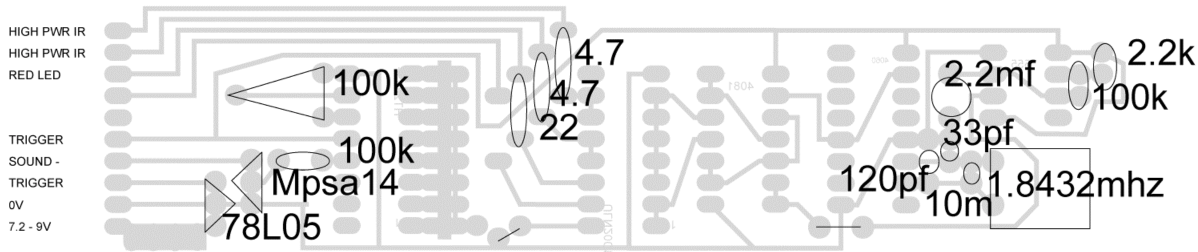
Wiring the circuit up is a relatively simple task requiring minimal tools, including a soldering iron, solder and a pair of wire cutters (or pliers).

The power supply should be a 7.2-9 volt DC supply (battery pack).

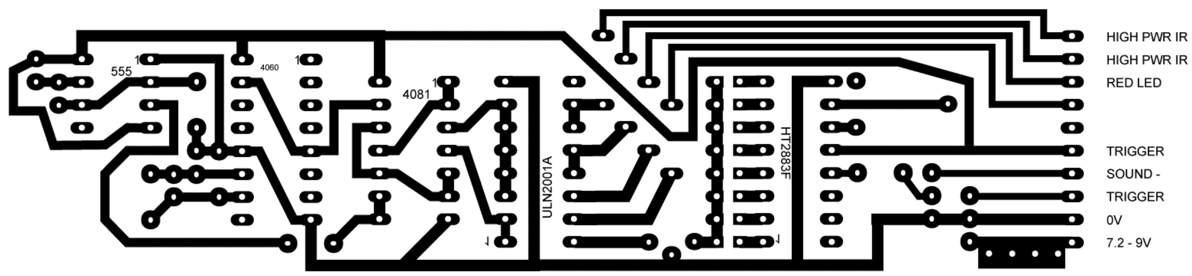


Make sure the connector side is at the left side of the board when viewed from above (the side the components are on). The LED outputs are connected Cathode to the board and Anode straight to the power supply. The speaker should be connected in a similar manner, one connection to the supply voltage and the other to the connector labelled sound on the diagram, it should be the 8 Ohm type. The circuit also requires two switches, one a single pole single throw, for on/off like a rocker or slide switch. The other is for the trigger of your gun, use either a simple momentary push switch or a micro switch connected to a trigger. If you want you can omit the power on/off switch by connecting your trigger where the on/off switch should be and connecting the two connects labelled trigger together. The circuit will then only use power (and work) when the trigger is pulled.

Component Layout



Track Layout



Component list

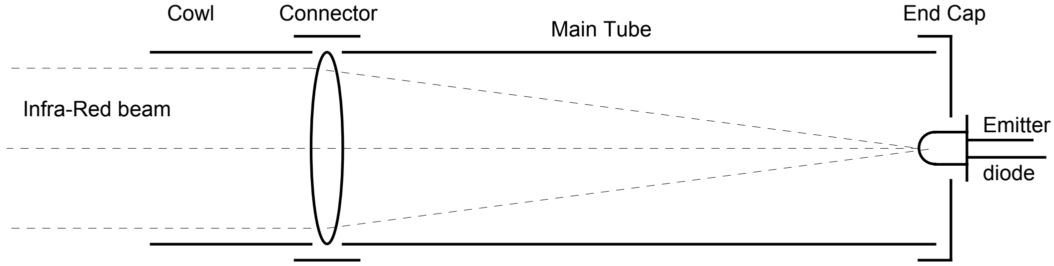
I.C.s	Capacitors	Resistors
1x 555	1x 2.2 mF	1x 10M
1x 4060	1x 120 pF	2x 100K
1x 4081	1x 33pF	1x 22K
1x ULN2003A		1x 22
1x HT2883F		2x 4.7
1x 78L05		1x 100K variable
1x Mpsa 14		
1x 1.8432MHz Xtal		

If you have any queries you can e-mail Phil Higgins (see contacts section at the end of this document).

Lenses and emitters (theory).

By Dave Bodger

Lens assembly

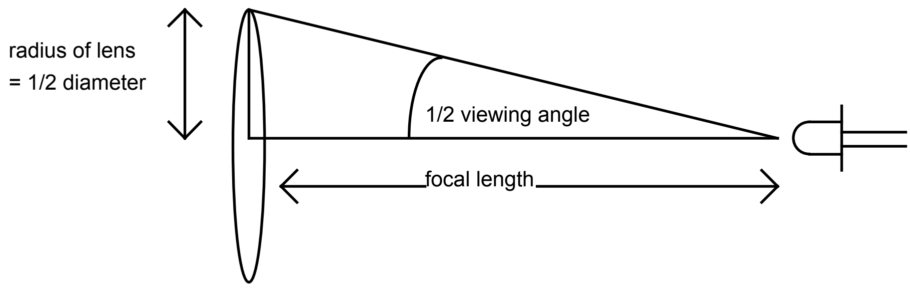


On its own an emitter diode produces a beam of infra-red light which spreads out by anything from 10 to 60 degrees or more as it moves away from the source. This is normally only enough for a range of about 20 to 30 meters. To get a reasonable range you need to concentrate the beam before it becomes too dispersed. This is commonly done with a convex (magnifying) lens, as shown in the diagram above, in conjunction with some 50mm diameter plastic drain pipe and fittings. The difficult part is finding the correct distance between the emitter and the lens such that the maximum amount of IR light is captured and made to travel forwards in a concentrated beam. Much has been said about focal lengths of lenses, and how to calculate them exactly, but in my experience there are too many variables involved to get a good result purely by calculation. The best method I have devised is to view the beam when it has been projected onto a wall in a darkened room by using an IR sensitive CCD security camera (I got mine from Maplins). This allows you to move the emitter backwards and forwards and see the resultant beam spread on the wall. Using this method I have obtained ranges in excess of 400 meters from a high-powered emitter assembly (6.5 amps through an OD50L emitter and a 3" 1.75x magnification lens).

There is a trade-off involved here however. A tightly focused beam will be more difficult to aim accurately. Sometimes it is better to have a softer focus and allow the beam to spread a little to make aiming easier. This is at the expense of range, however I think ranges in excess of 200 meters are of little practical use except on the very odd occasion when you are playing on an airfield runway. The sort of terrain tag games are played over precludes contact distances of more than 100 meters in most cases. Many people fit their guns with a secondary lens unit with a wider spread of 20 to 40 degrees for close quarters combat. These units often only have a range of 30 meters or so.

Lenses of diameters varying from 12mm up to 100mm and more have all been used successfully in the construction of tag guns. Designing your own lens assembly requires you to make some decisions about several elements, all of which interact. A "good" lens assembly is one which collects the maximum available IR and sends it out in a beam of the right shape to give you the coverage you want. Here are the design steps as I see them.

1. Decide what sort of gun you are constructing and hence what range and spread you require.
2. Pick your emitter diode and find out what its "half-intensity angle" or "viewing angle" is.
3. If you are going for maximum range pick a lens of about 2x magnification or less. If you want a good spread but less range, pick a lens of 4x magnification or greater.
4. The lens diameter required will depend on both the viewing angle of the emitter diode and the magnification of the lens. To best match the emitter to lens, you want to make sure the diameter of the lens is at least big enough to catch the beam from the emitter all the way out to the limit of its viewing angle. Some simple mathematics is required here.



The focal length of the lens is related to the magnification by the formula:-

Focal Length *in mm* = 250 / (Magnification - 1)

and/or

Magnification = (250 / Focal Length *in mm*) + 1

The other way of describing a lens which you may encounter is in Diopters, which is a measure of the power of a lens. This is related to focal length by the formula:-

Focal Length *in mm* = 1000 / Diopters.

Therefore by substitution:-

Diopters = 4 x (Magnification - 1) and/or Magnification = (Diopters / 4) + 1

From all this you should be able to calculate the radius of the lens by the following formula:-

Lens diameter ≅ Focal Length x (TANGENT of the viewing angle)

Example 1. Take an emitter with a viewing angle of 16 degrees which is about the best you can get in cheap high power emitter diodes. Decide to go for long range (2x magnification).

Focal Length = 250 / (2 - 1) = 250 mm.

Lens Diameter = 250 x TAN(16º) = 71.69mm

Therefore Lens Diameter should be at least 72mm. The nearest readily available lenses are 75mm.

Example 2. Using the same emitter as example 1, decide to make a close range "Blaster" (8x magnification).

Focal Length = 250 / (8 - 1) = 35.71 mm.

Lens Diameter = 35.71 x TAN(16º) = 10.24 mm

Therefore Lens Diameter should be at least 10mm. Anything from 12mm to 25mm would be a good choice.

Example 3. You already have a lens 50mm in diameter and have measured its focal length as being 110mm as close as you can estimate.

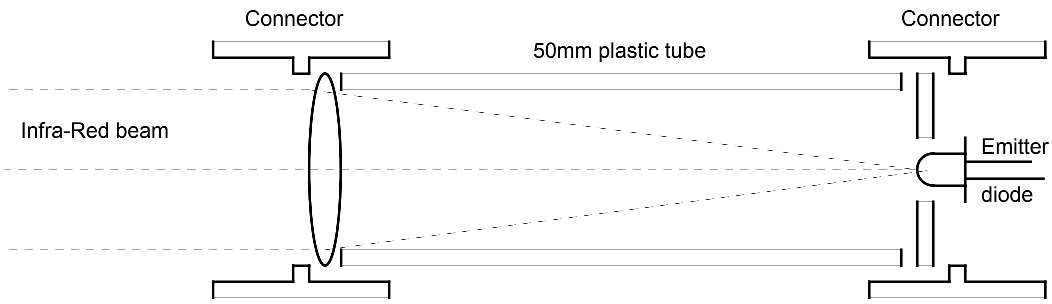
Magnification = (250 / 110) + 1 = 3.27 (Power in Diopters = 1000 / 110 = 9.09)

Viewing angle = the angle whose TANGENT is 50 / 110 = 24.44º

Therefore an emitter with a viewing angle of 24º or less would be the best match. The magnification of just over 3x should give a reasonable range with moderate spread.

Note that there are still worthwhile amounts of IR produced outside of the viewing angle of the emitter, so if possible always use the largest diameter lens you can get which has the focal length you want and treat the calculations here as a minimum.

Practical lens assemblies.



To help beginners, I have designed a lens assembly which can be made from readily available materials at low cost. It will not deliver top of the range performance but should allow you to obtain ranges of around 200 meters, if used in conjunction with a telescopic sight, which should at least let you play on a more level footing.

To make one, find a supplier of "Hunter" plastic drainpipe in your area (I got mine from Homebase) and purchase the following 50mm grey drainpipe fittings :-

- 2 - straight pipe connectors.
- 1 - 200mm length offcut of 50mm diameter pipe. (or buy a 2 meter length and make 10 !)

Buy a '2 inch Pocket Magnifier' from Maplin Electronics, which costs £1.95. It has a magnification of approximately 3x. See table for other lens/tube/emitter combinations.

Buy a LED chrome bezel (Order Code FM38R) from Maplin Electronics to mount the emitter in. Costs 50p.

Buy a Siemens SFH484-2 emitter diode. (available from "Bodger's Bits" or Farnell Electronics - Order Code 212-672). Costs 60p.

Make a 50mm disc from 18 gauge aluminium or thick plasticard or thin plywood. Drill a 7.5mm hole in the middle, as central as you can make it. (or buy one from "Bodger's Bits", ready drilled and accurately cut from 18 gauge aluminium and available in two sizes, 25mm or 50mm, for £1.50 each.)

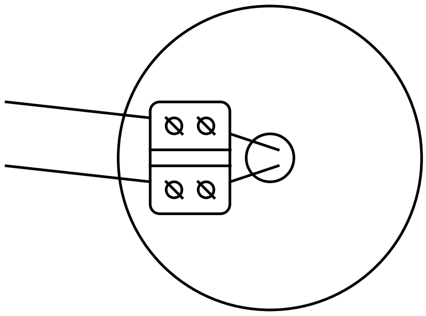
Fit the bezel in the hole and tighten the nut.

Fit the SFH484-2 emitter in to the black rubber grommet provided with the bezel and push this into the hole in the bezel until it's all the way home. If you prefer not to solder, connect a wiring block to the disc and use it to attach the wires to the main circuit board (see diagram).

Get the lens out of its housing by pushing it out carefully.

Fit the lens in one straight pipe connector and the disc with the emitter in it in the other one.

Cut the pipe to exactly 112mm long and plug the two connectors on to it so that the lens and emitter disc are sandwiched by the tube (see diagram).



Using a screw-connector block to attach wires to the emitter

Either drill and screw two small self-tapping screws through the connectors and pipe to hold them in place, or glue them using solvent-weld or some other suitable glue, to finish off. If the connectors are a nice tight fit, you may consider not fixing them as it will make it much easier to remove the lens for cleaning at a later date. If you do glue, use something like UHU which is easy to take apart later.

Paint the assembly to match your gun and affix with screws or clamps.

A variation on this is to recess the SmartGun LED display board into the end of the pipe connector, with the ribbon cable plug fitted through a slot cut into the connector. You will find that if you fit a ring of pipe 20mm long into the rear of the pipe connector which houses the emitter and cut the corners of the display board at 45 degrees so you cut into the mounting holes and cut a slot 10mm deep and the width of the ribbon connector, it should all fit quite snugly. To finish it off, and keep the weather out, you can fit a 50mm diameter circle of perspex over the display board. See diagram for details. The whole assembly can then be mounted on top of your gun, or along the left or right sides, where the display will be visible to you but not to anyone in front of you or to either flank.

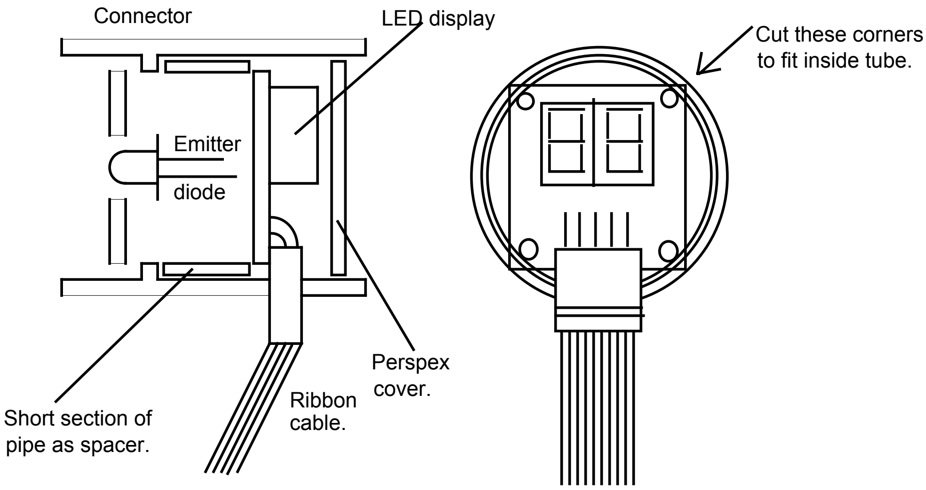


Table of lens/tube assembly measurements.

Type of lens	*Type of emitter*	*Pipe length in mm.*
50mm Draper	SFH484-2	120
2" Maplin pocket magnifier	OD8810	110
2" Maplin pocket magnifier	SFH484-2	112
2" Maplin pocket magnifier	OD50L	125
50mm HiRanger	SFH484-2	160
50mm HiRanger	SFH484-2 in Farnell lens housing	150
25mm Maplin Eye Glass fitted in 25mm plastic conduit pipe.	SFH484-2	91 May need to adjust, as I have found a large variation in the focal length of these lenses.

An example toy gun conversion.

By Dave Bodger

Using the above method of constructing a lens assembly and display housing I have converted a "Combat Series MP50A by Larami" bought from "Toys-R-Us". I used the flexibility of the SmartGun system to allow me to retain the gun's own sound generator (which I quite liked) for the shot and magazine change sounds. I did not use the sound board provided with the SmartGun circuit, which saved a little space. I added a 10mm ultra-bright (14 candela) LED from Electromail, fitted in the hole in the middle of the "barrel", to provide a serious muzzle flash. I fitted a small push-to-make switch on the left side of the casing near the front above the front hand grip where it can be easily operated by thumb; this was connected to the "grenade launcher function". A small cluster of three more push-to-make switches was fitted on the left side just above the trigger, for the up/down brightness controls and the display off function. One final push button switch on the left just above the handle grip (where the dummy plastic fire selector switch is) was fitted to activate the fire selector function.

Internally, the SmartGun main board fits nicely in front of the unused battery compartment. This compartment shows the history of this plastic casing - it is the same moulding Larami used to use for their motorised water pistols! The yellow wire from the front trigger post is disconnected and inserted into socket hole number 5 on the SmartGun sound connector. The rear yellow wire is removed and discarded. The two trigger post connections are now available for the trigger function. The original magazine change sound switch is left in place and a small micro-switch is screwed to the plastic next to it, bearing on the magazine in such a way that the switch is made when the magazine is withdrawn and broken when it is re-inserted, to provide the magazine change function.

I got 6 AA sized NiMH batteries (Farnell Order Code 507-040), the type with solder tags fitted, and made up a 7.2 volt battery pack to fit in the "unused" battery compartment to power the SmartGun board, emitter and muzzle flash. A small power connector was fitted, accessible through a 6mm hole in the gun body, so the batteries could be recharged in situ. As I was retaining the original sound system and triggering it from the SmartGun board, it was necessary to connect the negative of my new battery pack to the negative of the original batteries (hidden inside the magazine) at the point where they plugged in.

The lens assembly was screwed to the right hand side of the gun, in line with the "real" barrel. The cable for the display was fed through the slight gap between the internal battery compartment cover and the gun body. Two wires for the emitter were soldered to two thick pieces of stiff copper wire which were poked through holes drilled in the gun body to mate up with the screw connector block in the lens assembly.

A good coat of matte black spray paint finished it off nicely. The resultant gun is compact and well balanced, with enough weight to make it feel "right" without making me feel my arm is about to drop off at the end of the day.

Electronic Circuits.

By Dave Bodger

The "Worlds of Wonder" StarSensor is most sensitive to an approximately 1800Hz signal ±100Hz modulated over a 58KHz carrier. Therefore a circuit which generates a clean signal of this form is to be recommended. The SmartGun circuit uses a 57600Hz signal to carry a precise 1800Hz tone.

If you are thinking of designing your own circuit, have a look at the example circuit I designed for my first tag gun (later on in this document).

Switches.

By Dave Bodger

These should all be of the push-to-make variety. You can use some fairly crude switches, such as bent pieces of wire, but you will find that they tend to give multiple connections from one push (known as "switch bounce") which may cause erratic operation of some of the circuits functions. It is best to use proper switches which are obtainable from suppliers such as Maplins.

I personally prefer to use micro-switches for the trigger and magazine change functions. They are very reliable and give a positive "click" when operated. They can also be bought with various types of operating lever fitted which can be bent to shape, which makes them more flexible in placement. Because they are always of the "momentary action change-over" type, they can be used in both push-to-make and release-to-make roles.

Note that the switch for the magazine change function needs to be "made" and "broken" to invoke a change of magazine clip. It may be necessary to use a release-to-make switch if you are fitting a physical representation of a magazine, arranged so that it makes a connection when the magazine is ejected and breaks the connection when the magazine is reinserted.

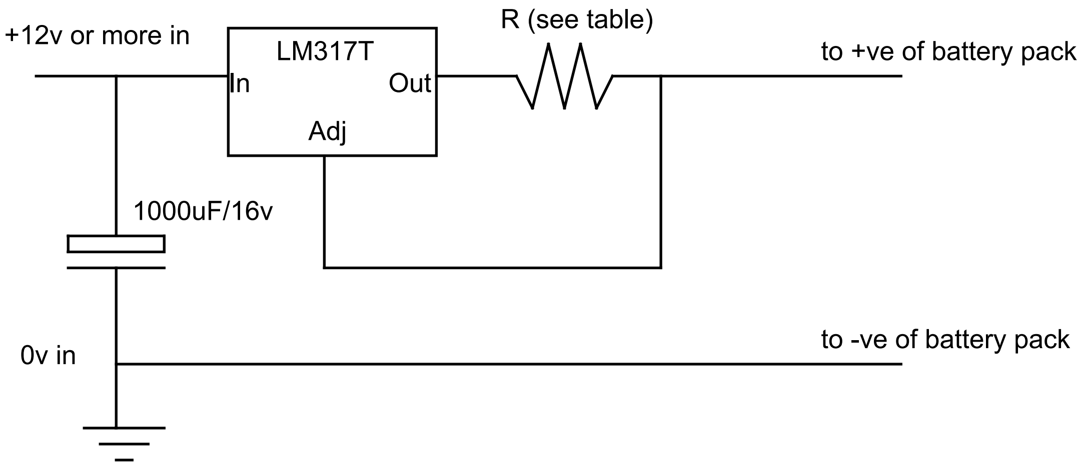
Also note that only one switch should be pressed at any one time. For example, if you press and hold down the brightness switch then try to press the trigger, the gun will not fire until both switches have been released. If your gun seems to stop working during a game but the display is still illuminated, check you have not accidentally jammed a switch down (by running into a tree for example).

Because the SmartGun circuit was designed to be used in a variety of roles (it will form the heart of the armourer and medic boxes for example) it was designed with a keypad in mind for use as a data entry device. The keypad is not necessary in its role as a gun board; however if you do decide to use one (possible because you think it looks good!) you will find that the 12 way telephone style keypad from Maplins (Order Code JM09K) which costs £2.59 will connect up directly and matches the switch matrix layout in the installation guide. Keys which do not have an associated function in the gun mode will simply be ignored except that pressing them will illuminate the display. Even with a keypad fitted you still need to have separate switches for trigger and magazine change.

The new NiMH (Nickel Metal Hydride) batteries look good, and do not suffer from memory effect, but in practice you have to recharge them the night before use as they have a high self-discharge rate compared with NiCads. Leave them for 3 or 4 weeks without use and they will be virtually flat! They are a fairly new technology however, so expect capacities to go up and self-discharge rates to improve in the future. As long as you are happy to pay attention to preparation they can be a good choice. They are often called "Green" batteries as they are "Eco-Friendly" and use no heavy metals in their construction.

Farnell Electronic Components now sell a good range of improved high capacity NiCad batteries at reasonable prices. In particular they do a PP3 with 150mAH capacity (Order Code 451-472), and an AA with 850mAH capacity (Order Code 451-411 not tagged, 451-423 tagged). They also do the AA sized NiMH 1200mAH capacity batteries (Order Code 507-039 not tagged, 507-040 tagged). The tags allow you to solder the batteries together to make up your own packs.

A simple constant current charger can be assembled from a few cheap components for those people who are trying to save money. For a few pence more this can be made to produce several different charging rates by the addition of a switch and a few resistors. For battery packs of up to 6 cells (7.2v race pack) the power can come from a car battery or 12v mains adapter. For higher pack voltages you need to provide an input of at least 3 volts above the peak charged voltage of the pack (i.e. 7 cells needs 13.5v, 8 cells needs 15v, 10 cells needs 17.5v). Maplin Electronics sell all the parts required.



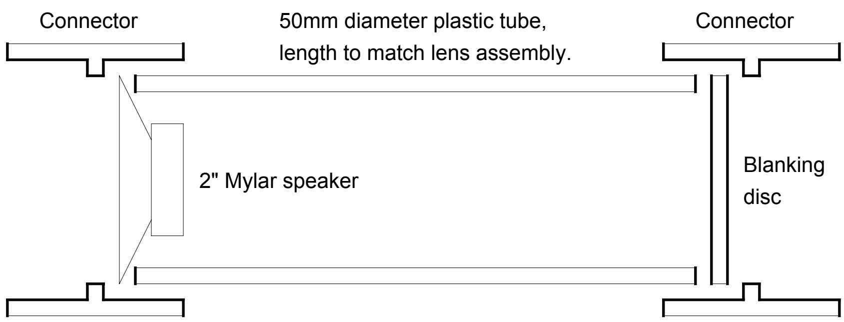
Value of R	Charge current	Charge rate for 1200mAH battery.	Time to recharge
20Ω	63mA	½ standard rate	28h
10Ω	125mA	Standard rate	14h
4.7Ω	266mA	Double standard rate	7h
3.3Ω	379mA	Triple standard rate	4h 40m
110Ω	11mA	for ordinary 110mAH PP3	14h
82Ω	15mA	for hi-capacity 150mAH PP3	14h

Resistor "R" can be calculated from V=IR if you know that the LM317T works by imposing a voltage of 1.25v between its output terminal and its adjustment terminal. I have provided a table of pre-calculated values. These are suitable for various types of battery pack. You have to decide how fast you want to recharge your batteries. For example if you recharge a 1200mAH battery pack at 120mA it would take 14 hours to recharge. 'C' is often used to describe the capacity of a battery pack. 'Standard Charge' is normally $^{1}/_{10}$ C applied for 14 hours (1.4 times the '10 hour rate'), in this case 1200/10=120mA. Therefore 60mA for 28 hours, 240mA for 7 hours, etc., will all recharge the battery fully. If you were charging 600mAH AA cells then you would simply scale the values by halving the current. In practice you must be careful if charging above double the standard charge rate in case the batteries get too hot through over-charging. It is normal for batteries to get warm while being charged, but more than 40°C can destroy them. You can use an alarm clock as a timer. You could use a switch to switch in various resistors to make a more flexible device. I have included resistor values for PP3 NiCad batteries as well, but remember these must always be charged for 14 hours and never charged any faster or at higher currents (they can get very hot and explode!)

Loudspeakers and enclosures.

By DaveBodger

I have found that the Maplins Mylar speaker range is ideally suited to use with the SmartGun circuit, they have plastic cones which are suited to outdoor applications. The 2" speaker (Order Code YM97F) is actually 50mm in diameter and can be used in conjunction with a plastic drainpipe enclosure in much the same way as the lens assembly mentioned previously. The square 3" speaker (Order Code YN01B) is the most robust unit and gives some powerful bass resonance's when fitted to an air-tight enclosure. Remember that any speaker you decide to use should be 8Ω.



Infra Red Emitters and their driver circuitry.

By Dave Bodger

The emitter driver resistor, the one in line with the emitter diode, may need to be recalculated for other diodes or supply voltages. It can be worthwhile doing this even within the normal supply range of 7.2v - 9v when you are trying to achieve maximum range by running the emitter at the extremes of it performance envelope. In particular note that if you are trying to put 10 amps through an OD50L diode you must use a different output transistor because the ZTX689B transistor on the SmartGun board cannot sustain more than 5 amps. Power MosFets are the best thing to use but it can be difficult arranging a sufficiently high base drive voltage. New devices are now available and I recommend the IRLZ24 for all new designs. It can handle 16 amps and requires minimal drive current. It is ideally matched to the output from the PIC16C84 chip. It must not be driven by more than 5 volts though, so you cannot retrofit it to old CMOS designs running at full battery voltage. The IRFZ24 would be a better device in that case, but it needs 6 or more volts at its gate to turn on fully. Careful study of data books is required to select suitable mosfets, and they must be protected from static during construction.

The resistor calculation is (battery voltage minus 0.5 volts for the transistor {or 0.1 times the current for an IRLZ24} minus something between 3 to 4 volts depending on the diode and the amount of current you want to drive through it) divided by the current you want to put through the diode.

ExampleDrive 1.5 amps through an SFH484-2 diode (3.5v drop at 1.5Amps) from a 7.2v Ni-Cad racing battery pack using a ZTX689B transistor (0.5v drop).

$$\frac{7.2 - 0.5 - 3.5}{1.5} = 2.1333 \text{ ohms; i.e. nearest value = 2R2.}$$

Power dissipation will be around current squared times resistance, i.e. for this example :-

$$1.5 * 1.5 * 2.1333 = 4.8 \text{ Watts}$$

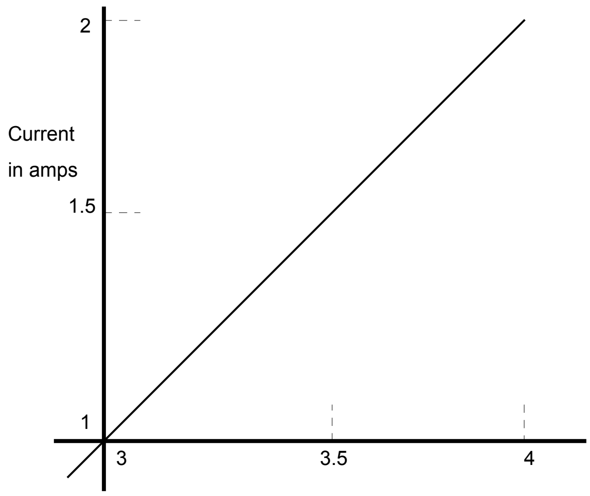
This is reduced by the duty cycle of the signal - for example a standard tag shot of 50mS fired 5 times per second has a duty cycle of 6.25%. 6.25% of 4.8 watts is 300 mW, which is well within the capability of Maplins 0.6w resistors.

The duty cycle can be calculated by examining the structure of the tag pulse. The 57600Hz carrier frequency is a square wave with a duty cycle of 50%. This is modulated buy an 1800Hz signal which also has its own 50% duty cycle, therefore the overall duty cycle is 50% of 50% = 25% for a continuous stream of tag. We reduce this again by only firing short "shot" pulses. If you fire 5 shots per second, the shots will repeat every 200mS. The shot pulse itself is only 50 mS long, therefore the duty cycle of this is 50/200=25%. This is in addition to the previous calculations, therefore the overall duty cycle for 5rpm with 50mS shots is 25% of 25% = 6.25%. The shortest shot pulse produced by the SmartGun circuit is 50mS (Assault rifle) at 10rpm = 12.5% duty cycle; the longest is 140mS at 1 rpm = 3.5% duty cycle. Other duty cycles may be calculated in a similar fashion.

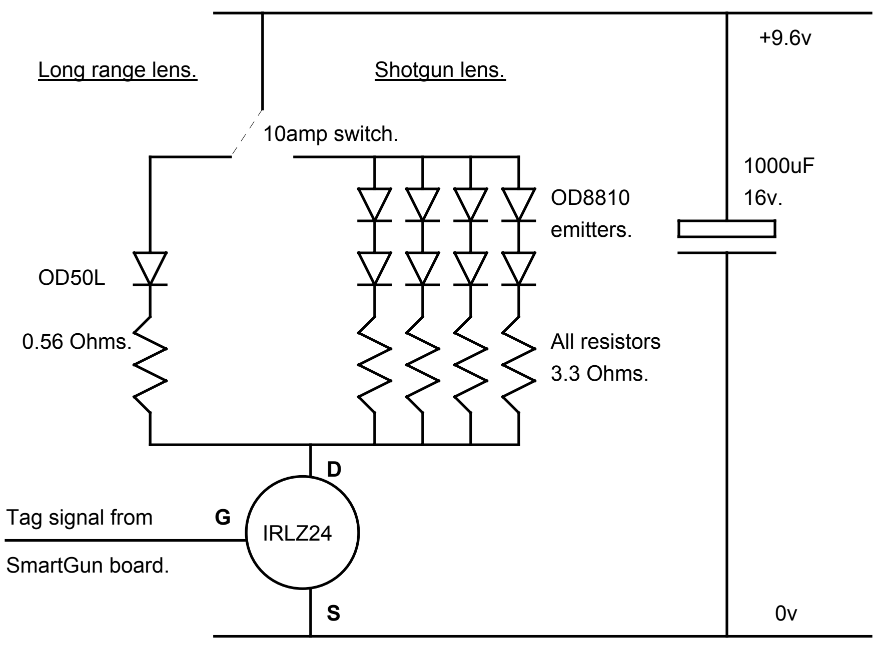
Here is a table of resistor values already calculated for you. You can use these as a starting point. Try performing the calculations and see how your values compare to mine. I have tried to choose the nearest available real component values.

	Battery Voltage ==>	6v	7.2v	8.4v	9v	9.6v	12v
IR Diode	Power Switch Device						
SFH484-2 x 1.5A	ZTX689B	1R5	2R2	2R7	3R3	3R9	5R6
OD8810A x 1.5A	IRLZ24	1R5	2R2	3R	3R6	3R9	5R6
OD50L x 8A	IRLZ24	0R1	0R27	0R47	0R47	0R56	0R82

The OD8810A and the SFH484-2 (or "lilac") diodes have virtually the same performance characteristics. The SFH484-2 produces a slightly tighter beam of 16° versus 20° for the OD8810A and costs half the price, thereby making it the diode of choice for long range guns. Both have a fairly linear relationship between voltage drop versus current in the area we operate them; see graph.



Here is a real-life example circuit I designed to give someone a high power rifle with switchable "shotgun" effect. The OD8810 emitters were arranged in a 4 by 2 array to cover an area ±10° vertical and ±30° horizontal. The drive signal is picked up from the PIC side of the resistor driving the emitter transistor; not from the cage-clamp connector ! (see diagram in installation guide)



At a current of 1.5 amps both the OD8810A and the SFH484-2 emit a total of approximately 300mW of IR. The data sheet for the SFH484-2 indicates that there can be a variation of ±50% in output power between minimum, typical and maximum; the data sheet for the OD8810A does not mention this parameter so it could be anything! This may account for reports of varying success with these devices. It may just depend on how good the batch was that your diode came from. One of the more common "high-power" TV remote controller diodes with a 40° beam coupled to a high magnification lens might be a better choice for a short range wide beam blaster.

At the present time there is only one real choice for serious output power - the OD50L from Opto-Diode Corp. This device can emit a total of 600mW of IR at 10 amps with a half intensity angle of only ±5°, producing the most powerful beam currently available. It is available from Electromail for £18.28 including VAT.

Output power is often quoted in mW/steradian. The number of mW per steradian is a measure of radiant intensity. This is a way of measuring the output power per unit area. The formula to find out how many steradians your beam is covering is $2\pi(1-\cos.\frac{1}{2}\theta)$. See the table below for some ready calculated values. By understanding this value, which is often quoted by the manufacturers, you can easily compare the effective output of different emitters. Remember to check any tolerance figures; ±50% seems to be common and could seriously affect your calculations!

Also remember that they often quote "total" output power. This includes the portion of power emitted outside of the half-intensity angle, which can be substantial. If all the information you have about a particular emitter is its total power output and viewing angle it is sensible to divide the total power output by 2 to give a more realistic value per viewing angle. This will not give you an exact value but is the best you can do without careful examination of a graph of output power verses emission angle, which can be hard to obtain.

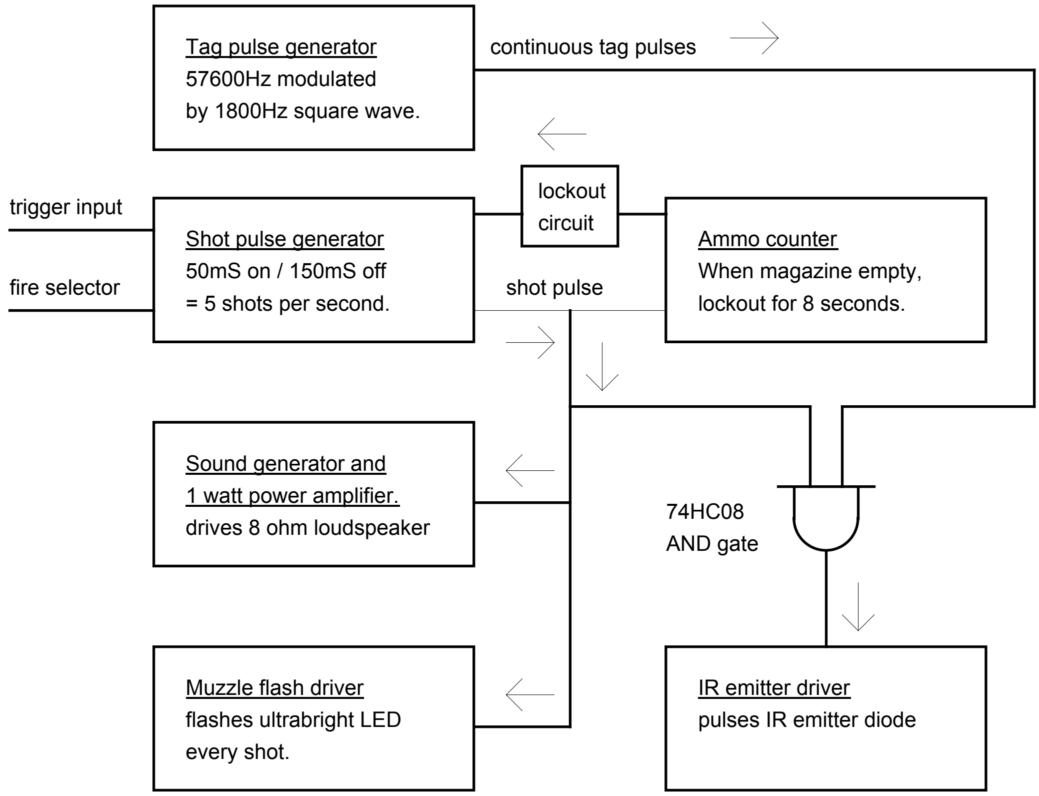
Half Intensity Angle or Viewing Angle	½ of H.I.Angle or Viewing Angle	Number of steradians this represents	Ratio relative to 1 steradian.	½ total output in mW.	mW/steradian for (x) device
10° (OD50L)	5°	0.02391	41.82	300	12547
16° (SFH484-2)	8°	0.06115	16.35	150	2452
20° (OD8810A)	10°	0.09546	10.48	150	1571
30° (???)	15°	0.21409	4.67	150	700
40° (???)	20°	0.37892	2.64	150	396

Note that at high currents (more than 2 amps) high frequency impedance along with actual wire resistance's come strongly to the fore, making it likely that you will find the actual current passed is less than that calculated and therefore output power is reduced. OD50L diodes require heavy duty wiring and high capacity batteries !
If you want to check the actual peak current, place the probe of an oscilloscope across the emitter resistance and record the result. Once you know the voltage dropped and the resistance it's across, it's easy to calculate the peak current using V=IR.

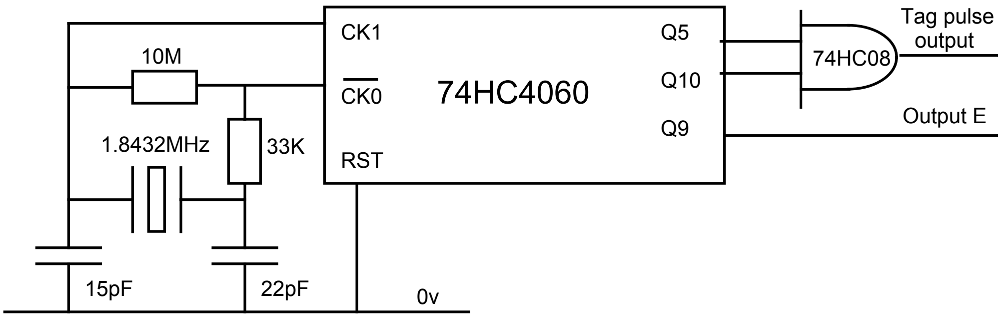
Example tag generating (i.e. gun) circuit.

These diagrams describe the tag gun circuit I designed from scratch, which powers my 'Big Green Gun' which has a range in excess of 400 meters using an OD50L emitter and home-brewed lens assembly.

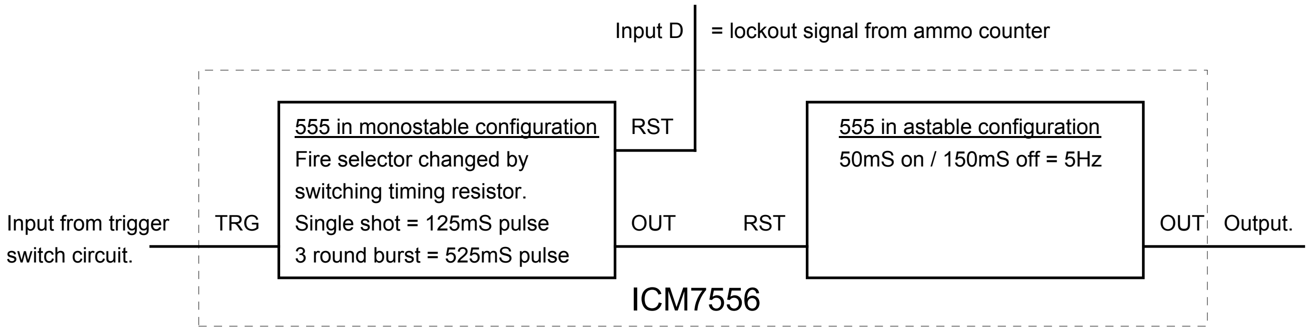
Tag gun functional block diagram.



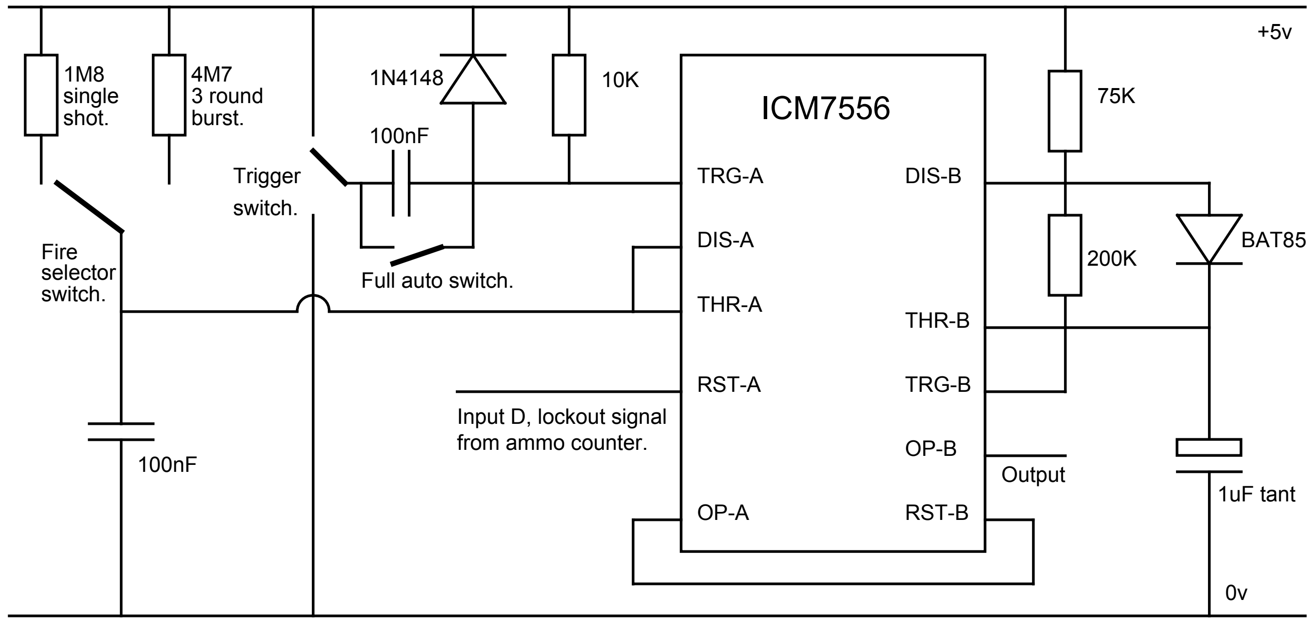
Tag pulse generator.



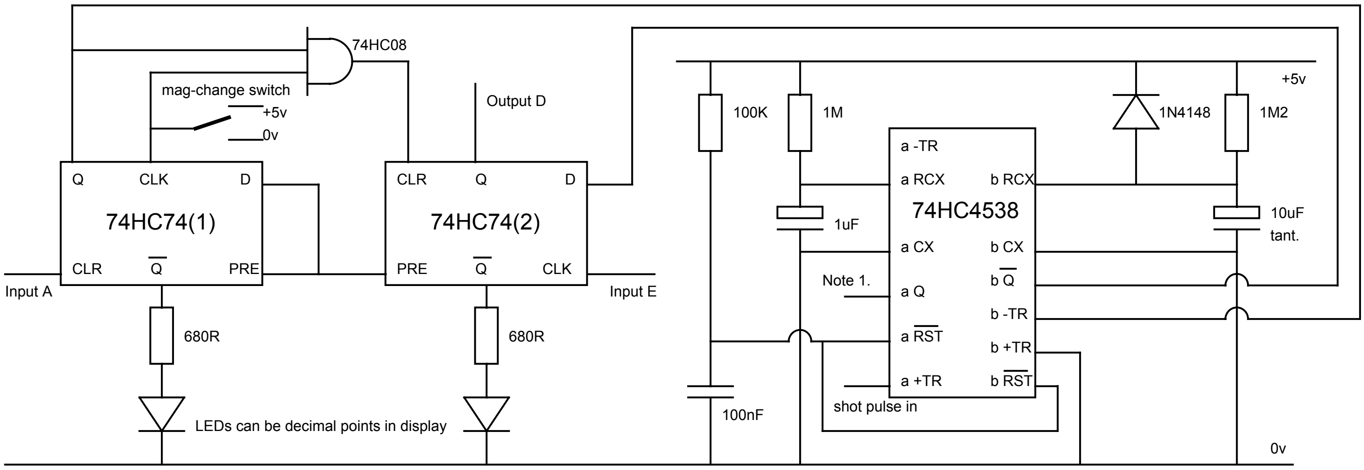
Shot pulse generator functional block diagram.



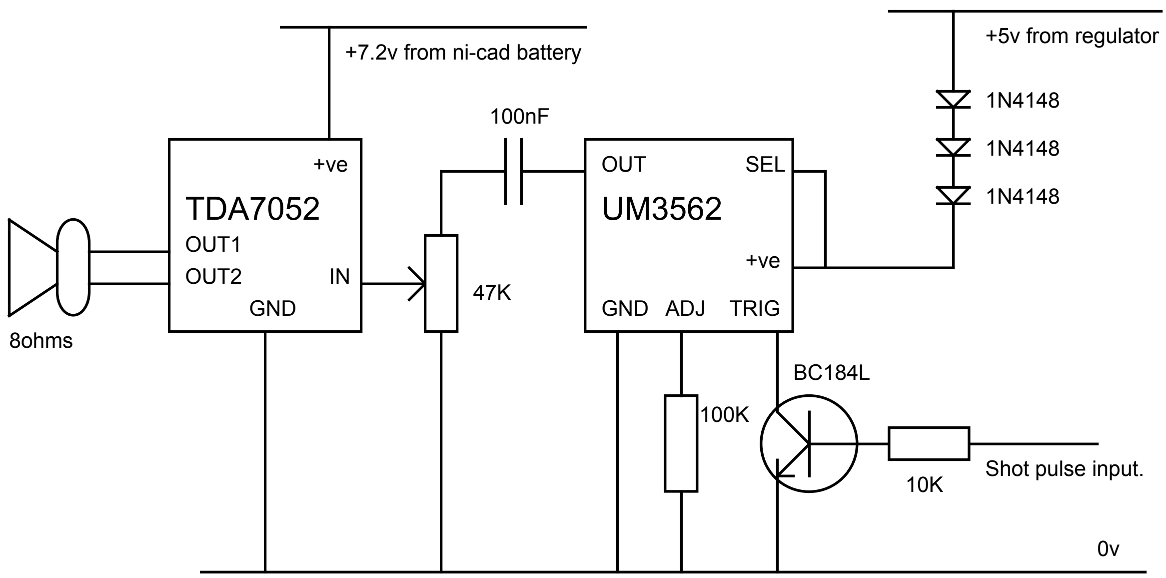
Shot pulse generator detailed diagram.



Magazine Change Lockout Circuit.

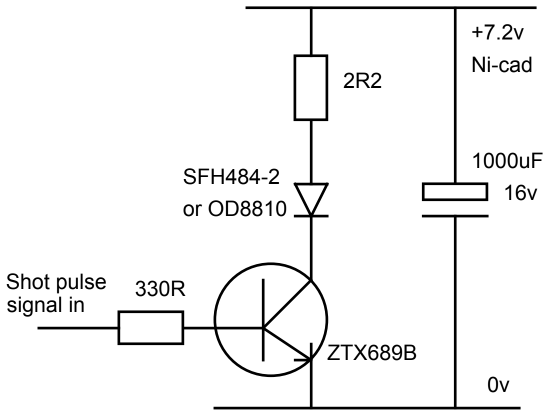


Sound generator and power amp.

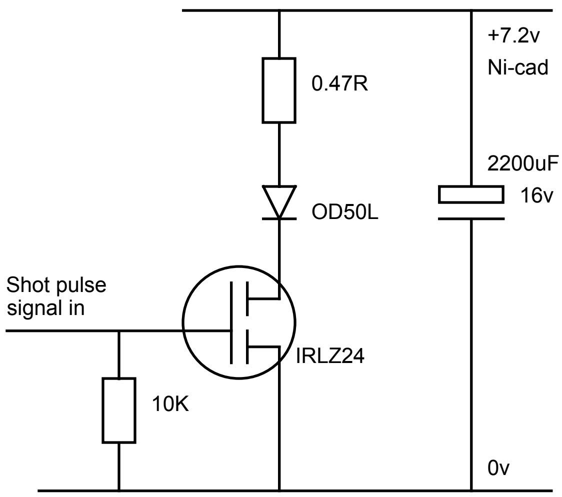


Emitter driver circuits.

Standard power driver circuit



Hi-power driver circuit.

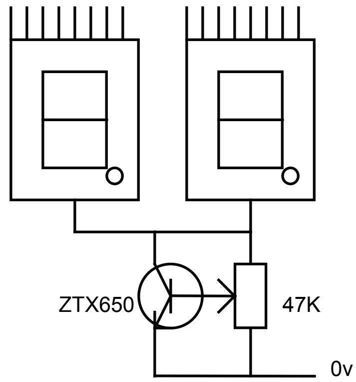


Note 1.

This output was used to drive a xenon strobe beacon via a BUZ10 MOSFET transistor switch, to provide a high-intensity 'tracer' style muzzel flash. It is on for .75 seconds, retriggered by each subsequent shot. This guarantees 1 flash for single shot, 1 or 2 flashes for 3 round burst and 2 flashes per second on full auto.

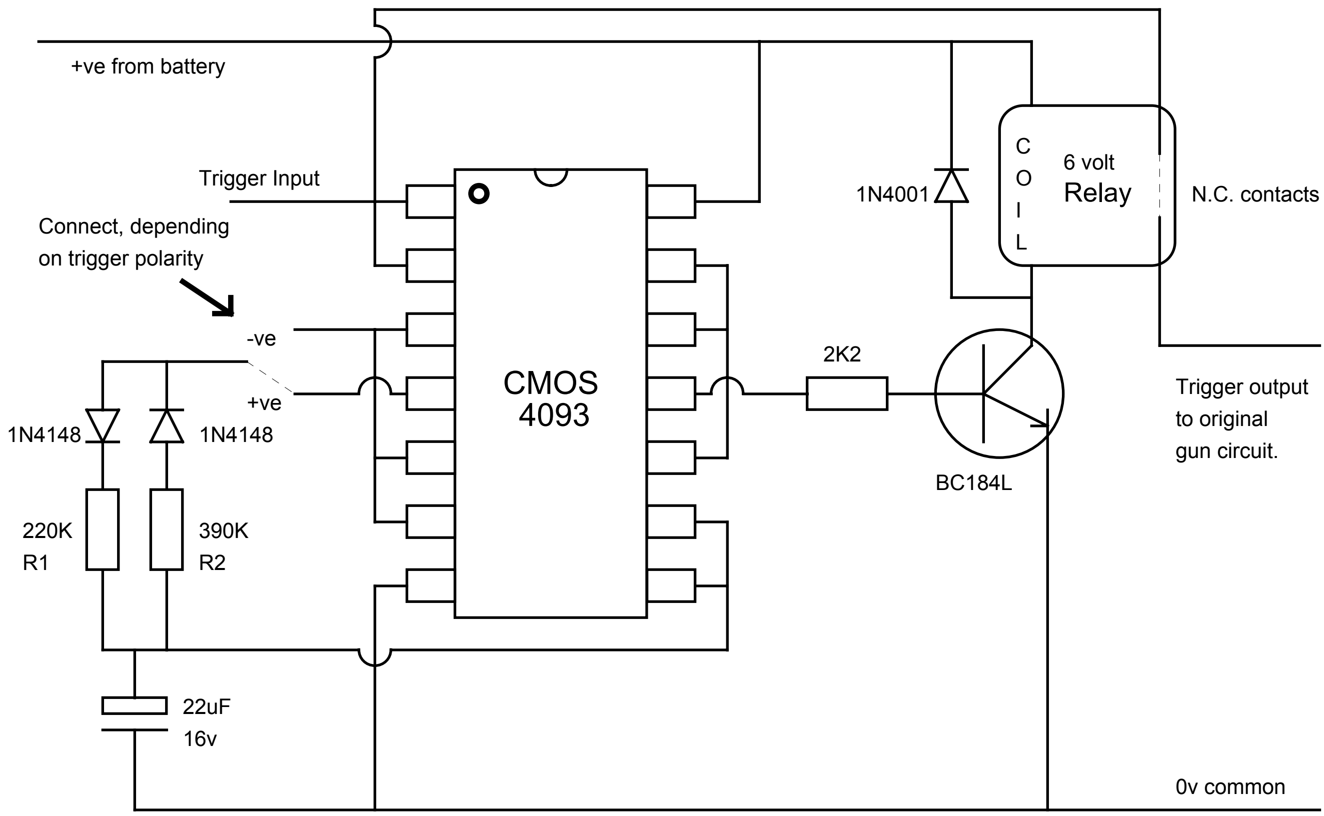
- All the logic chips require +5v from a regulated power supply to pin 16 (or 14 if they've only got 14 pins). All require 0v to pin 8 or 7 respectively. Check the datasheets to be sure. Using a 78L05 (100mA) voltage regulator should suffice for the +5v power supply.
- Note that the TDA7052 takes its power directly from the main batteries, not from the regulator. If you get a buzzing or humming from the speaker when it's not firing, you may need to add more smooting capacitance to the power rail. Try 4700µF or more. You may also need to use screened cable to its input if the distance is great or the wire is running next to other wires carrying high currents.
- Any unused chip inputs should be tied to +5v or 0v, not left floating.
- The 4060 chip should have pin 12 (reset) connected to 0v.
- On the 74HC74 chip the CLR pins are sometimes referred to as the RESET pins, they are one and the same thing.
- On the 74HC4538 the RST pins are sometimes referred to as the CLEAR pins, they are one and the same thing.

- A 74HC08 should be used as the source of the 2 input AND gates and should have all unused inputs connected to 0v or +5v, as stated previously.
- The 40110 chips require pins 4, 5 and 6 to be connected to 0v for correct operation. Also the unused count inputs should be connected to 0v.
- In my original gun design I fitted a transistor between the common cathode connections and earth which was controlled by a variable potentiometer to control the brightness. This allows the display to be dimmed for night time use or turned down completely to preserve battery power. For simplicity you could just connect the common connections to earth via a push to make switch which would then only illuminate the display when the button was pushed.



- The Emitter driver resistor, the one in line with the emitter diode, will need to be recalculated for other diodes and battery voltages; see relevant section in construction notes.
- I recommend the IRLZ24 mosfet power switch for all new designs attempting to drive an OD50L. It can handle 16 amps and requires minimal drive current. It is ideally matched to the output from the 74HC series chips. It must not be driven by more than 5 volts though, so you cannot retrofit it to old CMOS designs running at full battery voltage. The IRFZ24 would be a better device in that case, but it needs 6 or more volts at its gate to turn on fully. Careful study of data books is required to select suitable mosfets, and they must be protected from static during construction.

Ammo timer / lockout circuit.



This circuit is in response to the latest inter-club rules which require that :-

'*Weapons with a rate of fire greater than one shot per second and a range greater than 100 meters should not have a sight fitted unless they have a fire limiting device (times lock-out, ammo counter, etc.) also fitted.*'

With the values shown, and running off of a 9 volt supply, it allows fire for 10 seconds and then cuts out for about 4 seconds (the 4 seconds does not start until the trigger is released). The 'on' time is controlled by the value of R1, the 'off' time is controlled by the value of R2. These values may be changed to 'tweak' the timings if you run a different battery voltage, or to change the ratio of on/off.

If short controlled bursts are used it is possible to fire without the lockout activating.

You must determine the polarity of your trigger to successfully utilise this circuit. See what voltage polarity you have on the trigger when it is pulled and set the connection to the two diodes to match.

This circuit is unlikely to work on microprocessor controlled guns which scan a matrix of function keys, but then that type of circuit will probably have some kind of fire limiting device programmed in anyway.

Laser Challenge Info

The new *Laser Challenge* (LC) equipment is cheap, plentiful, and not Worlds of Wonder (WoW) compatible.

It uses a 38KHz-carrier frequency modulated by a 250Hz signal of 150 milliseconds duration to signify a hit, and a 185Hz signal of 500 milliseconds duration to reset the sensor.

If you fire a WoW gun at a LC sensor it will register hits most of the time (albeit at much reduced range compared to a WoW sensor) but occasionally it will reset the sensor. This 'side-effect' gets worse as the range increases, making it pointless to try using the LC sensors within a game with primarily WoW guns.

LC guns have no effect on WoW sensors.

The LC equipment is not alterable (other than the normal fitting of a lens assembly to increase range and extra amplification for sound) because it's circuitry is almost all contained within a custom chip which is not re-programmable.

The SmartGun circuit can fire a Laser Challenge tag pulse from version 1.6 onwards, at the request of a small number of people. This is in place of the normal WoW shot, you cannot fire both simultaneously, but it is relatively easy to switch back and forth from WoW to LC and vice-versa via the power-on configuration menu. The SmartGun LC compatible pulse uses a 248Hz modulation over the normal 57.6KHz carrier, fired for 185mS. This appears to be accepted by LC sensors without any problem. The SmartGun circuit can not generate a LC reset shot, but as the LC sensors are easily reset by powering off/on I don’t see this being a big problem.

Laser Challenge Pro is now available in the shops (Late 1998 I’ve only seen it in Toys-R-Us in London, but outside London keep your eyes open). Unfortunately it is no great advance on the original LC gear (unless you are an arena player for whom a slew of features has been added) as the gun is tied to the vest via an umbilical cord and cannot be separated.

The vests themselves would make a passable stand-in for (expensive) sci-fi body armour in a suitable game, and I think that is about all the set I bought is going to get used for.

I have also heard bad reports about its usefulness outdoors, with some people saying its sensitivity in direct sunlight is such as to make it a waste of time trying to play a game on a sunny day.

I have had virtually no playing experience with LC equipment so cannot comment on this myself.

But, given the type of electronics they use in the sensor, I would not be surprised in the slightest.

Laser Challenge V2 has yet to reach the shores of the UK yet (Feb 1999) but as I understand the sensor system has not been improved it seems unlikely it will supply the panacea we seek.

Sensors

Each different type of commercial gun has its own sensor supplied with it. Lazer Tags have three different types of sensor. All seem to be compatible to a greater or lesser extent.

StarLyte: Star Sensor / Star Cap / Star Helmet

The sensor supplied with the gun is a Star Sensor. It will receive hits from about the forward 170^0. Another type of sensor that can be purchased is the Star Cap this receives hits from the full 360^0 as does the last type, the Star Helmet. The Star Cap is a little small for adults and requires some cutting and alteration to fit. The Start Helmet fits adults but restricts hearing a lot and is also hot to wear.

For some reason the Start Sensors are the most sensitive, Star Caps next and Star Helmets least sensitive. All three types count up to six hits.

G.I. Joes, Quickshots, and Infra-red Rays Guns

The sensors supplied with all of the above only receive hits from the forward 90^0 and so are not suitable to wear in games (unless special rules apply). They also only count 1 hit at a time.

The G.I. Joe sensor is not able to detect more than the first hit from a rapid-fire weapon until the fire is stopped and then started again. The Infra-red Rays gun sensor has to be adjusted by a small variable resistor inside before it will register hits from Lazer Tags, however doing so makes it insensitive to hits from its own gun (not ideal).

Smart Sensor

The Smart Sensor is one of the new generation of enthusiast developed / built sensors. Compatible with the original Star Sensors but with a lot of extra features.

One down side of these sensors is that they don’t take hits from Terminator guns.

Heart Beat Blip Cure

The continual bleeping of the Lazer Tag sensors will give your position away and drive you crazy if you wear them long enough.

You may also find you are positioned well away from everyone else if you do have your blip still active!

Many is the time I have sat in the bath after a days tagging, swearing that I can hear a sensor switched on.

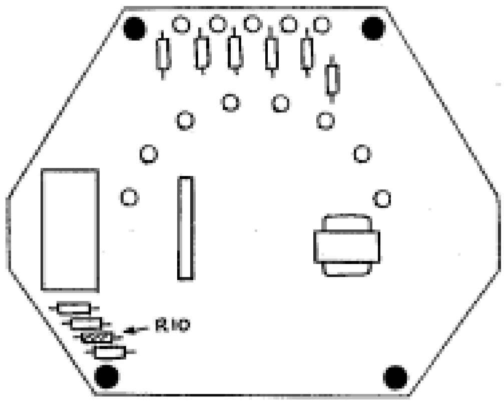
The cure for this condition is to remove the bleeps before they remove your sanity, and to do this is a simple matter of cutting out a resistor.

This is probably one of the first modifications you will want to make if you still have the bleep, and one of the simplest requiring just one or two snips with a pair of wire cutters.

If you wish, you can just cut one leg and bend it out of the way to allow reattachment though I don't know of anyone who, having got rid of the noise wanted it back again!

Star Sensor

Remove the back of the sensor and gently pull out the circuit board. On the left hand side of the board from the front is a large chip with 4 resistors below it. Using wire cutters, remove the resistor labelled R10 (2K7). This is the second one from the bottom. Now rebuild the sensor.



Star Cap

Disassemble the front of the Star Cap by removing the screws on its inside. Find the resistor labelled R7, which is on the opposite side of the board to the on/off switch, and remove it. Reassemble.

Star Helmet

Disassemble the Star Helmet and find the resistor labelled R10. Remove it and reassemble.

NOTE: By removing the bleeps you make it less obvious when your battery is running out. Therefore regularly check your battery charge and use only new batteries.

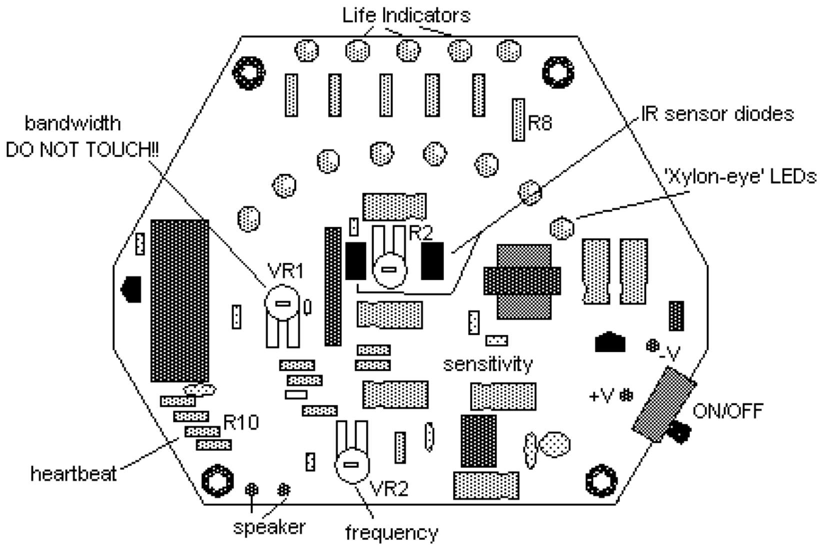
Removing Sensor Lights

The bouncing ball LEDs (Xylon-eye) on the Star Sensor can be a bit of an annoyance during night game, as they are difficult to obscure from the outside without covering the receptor of the sensor at the same time. There is a similar modification to the "Bleeps Cure" that can be performed to stop these lights, but since not all clubs allow this it is wise to use a switch rather then to permanently break the connection.

The lights on the Start Cap and Star Helmet are easily obscured with black tape and so similar modifications are probably not worthwhile.

Star Sensors

Disassemble the sensor to expose the circuit board and locate the resistor labelled R8 on the far right side of the top. Cut one of its ends and solder two pieces of wire, one to each side of the cut metal. The two free ends of the wires can then be soldered to a switch which can be placed in a convenient place on the body.



Star Caps

The resistor required is R5.

Star Helmets

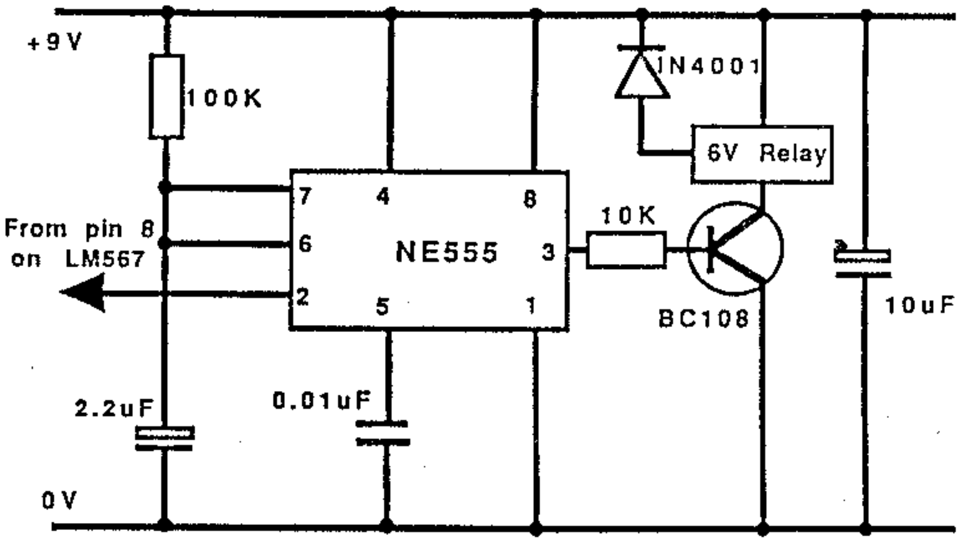
The resistor required is R6 in the compartment behind the LEDs.

G.I. Joe Sensor Modification

The one shot sensor supplied with the G.I. Joe gun can be put to good use by converting it to activate a relay when it is hit. This can then be used to set off all manner of other circuits including guns and flash cubes etc.

Open the sensor and locate the LM567 IC. The circuit below should be built and connected to pin 8 (top right when chip viewed with spot/notch at the top) on this chip.

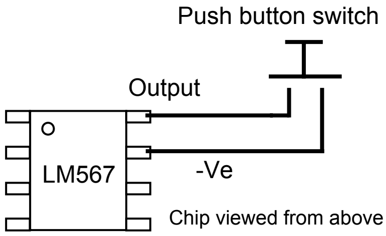
Changing the 2.2 micro Farad capacitor in the circuit alters the length of time that the relay closes for. With the values given the time will be about 0.5 of a second, longer times are produced with bigger capacitor values.



Hit countdown button.

By Dave Bodger

To make a sensor take a hit each time a button is pressed, connect a 'push-to-make' switch between TP8 which connects to pin 8 of the LM567 chip and TP4 which connects to pin 7. It will allow the sensor to be quickly and simply set to less than 6 hits at the start of a game.



Sensor 'blip' cure.

By Dave Bodger

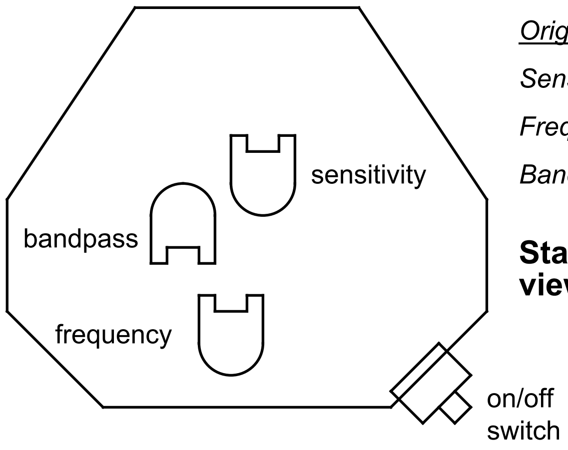
To stop the heartbeat blip driving you mad and stopping you hearing that alien creeping up on you, simply cut one of the wires on Resistor R10 on a StarSensor, R7 on a StarCap or R10 on a StarHelmet.

Turning off sensor lights

By Dave Bodger

To disable the 'cylon' or 'bouncing ball' lights so they do not give your position away during a night game, cut R8 on a Starsensor, R5 on a star cap, R6 on a Star helmet (in the compartment behind the LEDs). It is wise to actually put a switch here so you can turn the function on and off - some club rules forbid the concealment of these lights. The other alternative is to cover the lights with black insulating tape which can be removed later.

Sensor adjustment points



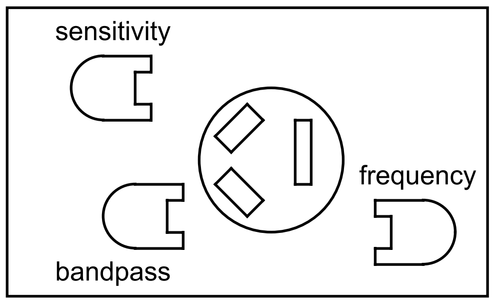
Original Component Values

Sensitivity = 200 R

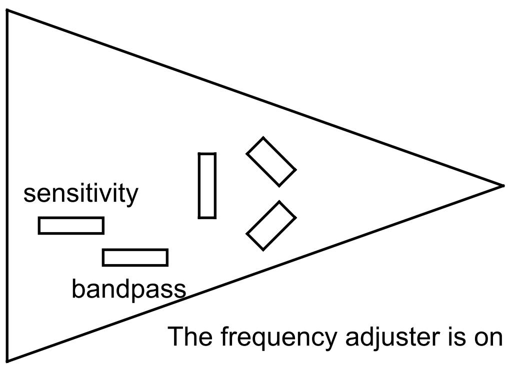
Frequency = 20 K

Bandpass = 200 K

Starsensor circuit board viewed from component side.



Starhelmet



Starcap

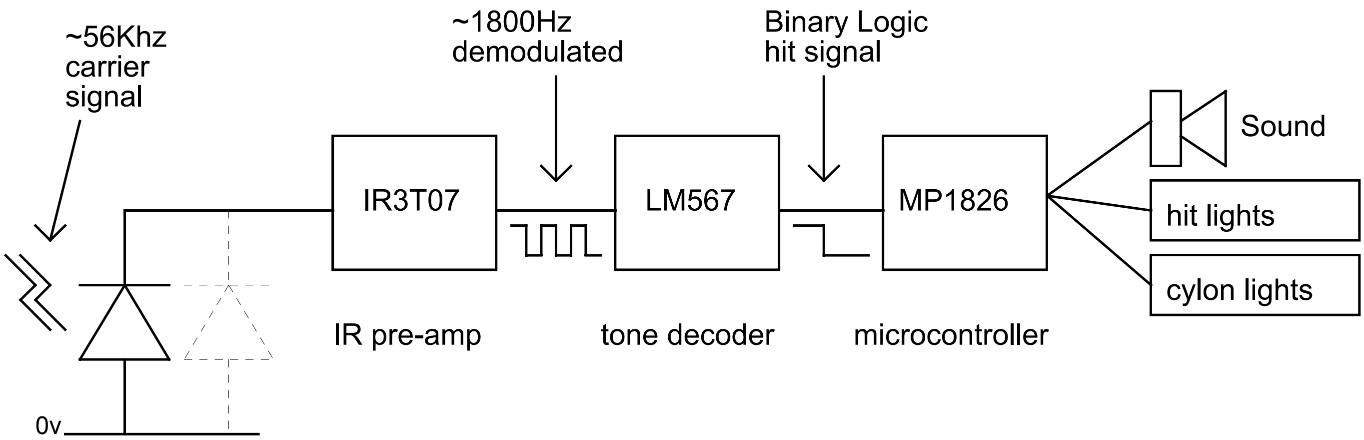
The frequency adjuster is on the other circuit board.

Attach frequency meter to pin 5 of the LM567 chip and turn frequency adjuster to set 1800Hz.

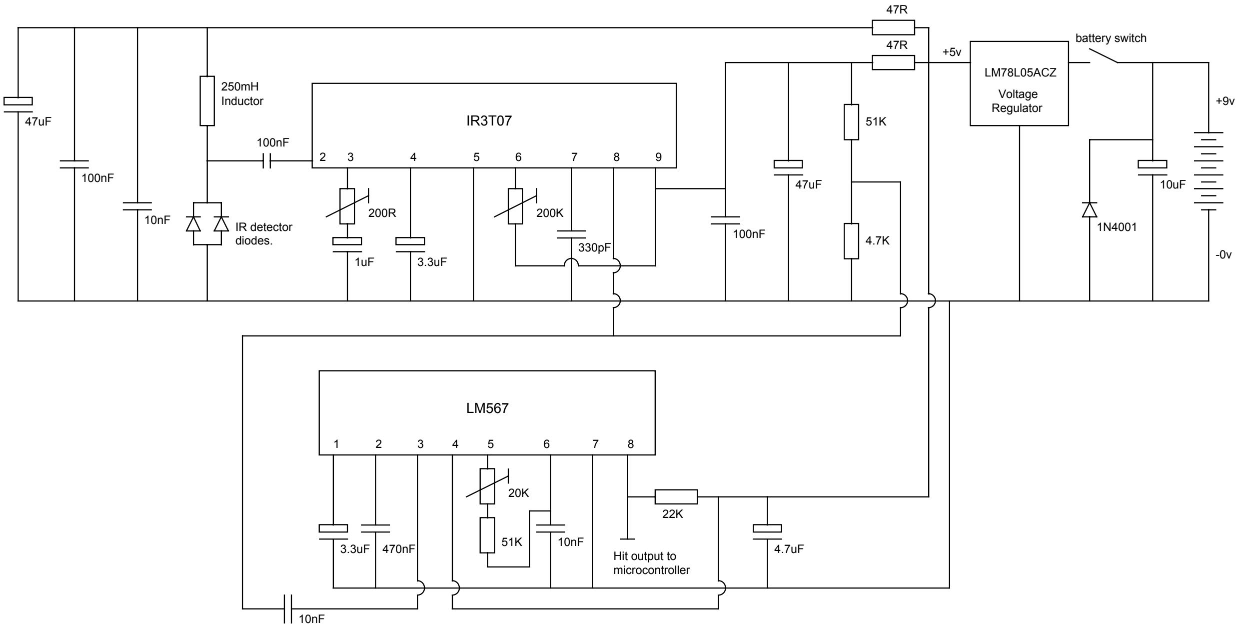
Adjust sensitivity until sensor takes hits from a Starlyte pistol, with lens removed, at 4 meters or greater. Try starting at 47 Ω.

Bandpass should not normally need adjusting. If you have to replace it because it has broken, set the new one to about 90KΩ by measuring it with an ohm meter before soldering it into place.

Simplified operational overview of WoW sensors.



Input circuit of original 'WoW' Starsensor and Starcap.



StarSensor modifications to extend battery life

Replacing the following components in your StarSensor will reduce the current consumption, and hence improve the life of the battery. The original article came from Dave Bodgers DIY construction guide which included prices, however these have been removed because of changes over the life of this document.

Component ID	*Description*	*Standard type or value*	*Replace with*	*mA saved*
VR1	Voltage regulator	UA78L05AWC	LM2936Z-5	3
CR12 & 13	LED	Green 3mm	Low current LED	
CR14 & 15	LED	Yellow 3mm	Low current LED	
CR16	LED	Red 3mm	Low current LED	
R11,12,13,14,15	Resistors	1K2	4K7	3
R8 (Cylon light)	Resistor	1K2	2K4	2
R17	Resistor	51K	33K	
C11	Capacitor	470nF disc.	47nF disc.	
C12	Capacitor	3.3µF electro.	reuse 470nF disc.	
C13	Capacitor	10nF	4.7nF ±1% poly.	
U2	Tone detector	LM567	LMC567CN	7
R10	Heartbeat 'blip'	2K7	Cut resistor	0.2

Total upgrade price approx £4.64

'Icing on the cake' mod.

CR4, 5, 6, 7, 8, 9, 10, 11.	8 x Cylon LEDs	Red 3mm	Low current LED	
R8	Resistor	2K4 (modified)	4K7	1

A standard StarSensor with no modifications and a fresh battery consumes approximately 25mA with one hit light lit up, 21mA with no hit lights on. The above modifications reduce this to 11mA with one hit light on, 10mA without.

Also read the comments on the next page, which are applicable to both the Starsensor and Star Cap.

StarCap modifications to extend battery life

Component ID	*Description*	*Standard type or value*	*Replace with*	*mA saved*
VR1	Voltage regulator	MC78L05AC	LM2936Z-5	3
CR1 & 2	LED	Green 3mm	Low current LED	
CR3 & 4	LED	Yellow 3mm	Low current LED	
CR5 & 6	LED	Red 3mm	Low current LED	
R8, 9, 10, 11,12	Resistors	1K2	4K7	2
R5 (flashing led)	Resistor	1K2	4K7	2
R13	Resistor	39K	22K	
C3	Capacitor	0.47µF electro.	47nF disc.	
C4	Capacitor	3.3µF electro.	reuse 0.47µF elec.	
C5	Capacitor	10nF	4.7nF ±1% poly.	
U1	Tone detector	LM567	LMC567CN	6
R7	Heartbeat 'blip'	2K7	Cut resistor	0.2

Total upgrade price approx £4.91

□

□

A standard StarCap with no modifications and a fresh battery consumes approximately 21mA with one hit light lit up, 17mA with no hit lights on. The above modifications reduce this to approximately 9mA with one hit light on, 7mA without. The savings vary by a milli-amp or two from one circuit to another.

These modifications should in total more than double the battery life.

The original voltage regulator stopped regulating when the battery voltage dropped to 7 volts. The new one will keep on regulating down to 5.2 volts. This allows you to milk an extra 5% to 15%'ish out of an alkaline battery.

The LMC567 needs to be tuned to 3600Hz at pin 5 by adjusting R1. Or just turn the variable resistor left and right, noting when the sensor stops taking hits, then set it halfway between the two points. I will carry a frequency meter with me to games in the future so sensors can be accurately set.

I can provide small quantities of the LM2936 voltage regulator for £1 each and the LMC567 tone detector for £1.20 each. Add 30p postage & packing per order if you need me to post it to you; or catch me at a tag game to save a few coppers. Most of these bits can be obtained from Farnell Electronics, who you should contact if you want hundreds.

With the high cost of new alkaline batteries nowadays you should find yourself recouping the outlay for the upgrade within a few games. The savings could be even greater if it allowed you to switch over to rechargeables and you play more than a couple of games a year. (just remember to recharge them the day before the event!).

U.S.C.M. STATUTORY SENSOR HEALTH WARNING NOTICE: These notes are only for use by highly skilled ‘techs’ and should not be attempted by 'grunts'. All 'grunts' should contact their local 'tech' representative for assistance. (in other words - I deny liability for any damage you may do to your sensor while trying to perform the above modifications).

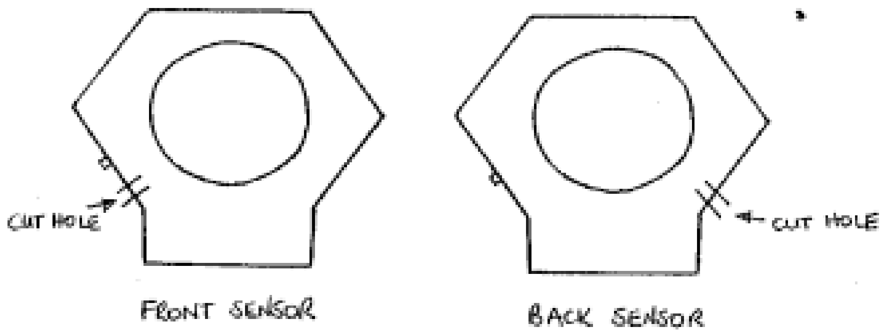
Slaving Lazer Tag Star Sensors

Since Star Sensors can only receive hits from the front, one possibility to connect or slave two sensors together to obtain a 360^0 arc of sensitivity that all groups currently use with Star Caps, Helmets and Y-Rigs.

This method has now fallen out of popularity, people favouring building Y-Rigs instead now as it requires only one Star Sensor, and looks neater.

If you do want to do it, here is how:

1. Open the sensors by removing the four screws on the back of each.
2. Cut some two core cable to the required length, that is the distance the two sensors are going to be apart plus about 15cm for the bit in the sensor cases.
3. Locate the points TP6 and TP10 on the back of the sensor circuit boards. Solder the ends of the wire to these points on each sensor ensuring the same wire is connected to the same point at each end. Two colour wire is useful to ensure this.
4. Cut two holes, one in each sensor body to enable the wire to exit. Remember to cut the holes in opposite sides so that the wire is on the same side when the sensors are warn back to back.



5. Bend the wire from the contacts down to the channel beside the battery compartment away from the hole that you have made. Then bend the wire back up the channel towards the hole, make a final 90^0 bend then pass the wire out. This arrangement secures the wire and prevents stress on the contact points.
6. Cut the wires to the speaker on the sensor that will become the rear one when worn.
7. Reassemble the sensors taking care not to trap the wires. On the sensor with the hole opposite the on/off switch. Some plastic will have to be removed from the back of the sensor to allow the wire to exit.

Using the Sensors

To use the sensors, perform the following routine:

1. Switch off both sensors.
2. Put batteries in both sensors
3. Switch on the rear sensor. Its lights will flash and then it will receive six hits automatically.
4. When the rear sensor has stopped flashing and 'died', turn on the front sensor.
5. You are now ready to play.

Y Rig Sensor

By Sarah Clark

This article was written in 1994 when Y-rigging sensors was a pretty revolutionary idea and it appeared (in a truncated form) in Firefight in 1995. Since then, with sensors becoming increasingly difficult to come by, Y-rigging has become the norm.

Most Taggers are familiar with the idea of 'pairing' or slaving sensor packs to give a 360º coverage of detection. Anyone who wears this rig also knows that it is cumbersome and expensive and, to be frank, looks pretty naff. I mean, what is the point of going to all the trouble and expense of getting yourself fully kitted out in your Colonial Marine's finest if you then have to top it all off with Xylon-eye flashing lights and two silver boxes?

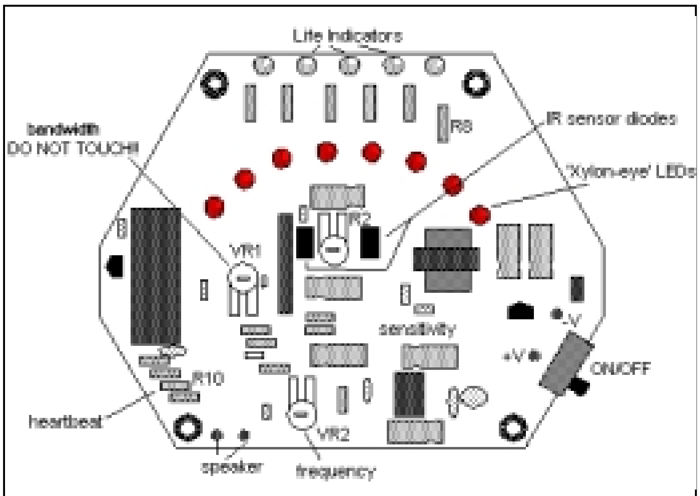
It was a simple matter to rig a couple of diodes in a clear plastic box connected in to the master set to get full cover from a single sensor pack

From there it was a small step to completely remove the master diodes from the casing (which could now be re-sited on the belt or shoulder) and fix the small diode "wanders" to any sort of hat or even an elasticated head-band. You can probably see the logical progression to the "Rebel-donut" helmets first seen at Dropzone '93:- the four single sensor diodes are mounted in sections of plastic tubing behind holes in the helmet and protected by Maplin IR lenses (which also help to gather the beam on to the diode). The leads from the diodes gather together at a jack-socket so the sensor pack can be detached and used with any other head-gear fitted up in the same way.

There *is* a loss of sensitivity but in most cases that can be overcome by tweaking the gain and frequency presets on the board (see below). This setup will never be quite as sensitive as a completely unmodified sensor straight from the box, but by careful tuning it can be brought within the various club's minimum requirements. I know of one person who has installed an amplifier to try to overcome the problem but I don't know how effective this is as there is a tendency to amplify the inevitable noise as well as the Tag signal.

Without further preamble, lets get your precious sensor opened so you can see what I'm talking about.

Obviously, the first step is to open the box by removing the four screws. If they are stiff, take some care as they are of a rather soft aluminium and it is easy to round out the cross head making them difficult to undo in the future. If the battery is still in, remove it - never, ever, ever work on a circuit when it's powered up as one short to the wrong component can knacker it beyond repair (there's one exception which I'll come to later).



Star sensor board viewed from the front.

The board rests on four posts and may need a little gentle persuasion to come free the first time you remove it. Don't pull too hard or you may loosen the speaker connections which are quite short. Hereafter the side of the board exposed when you open the box will be refered to as the 'back' and the side with the components on will be the 'front'. Unless otherwise specified, component numbers refer to those on a StarSensor board.

So now you have it open what can you do to your sensor by way of useful modifications?

Lights out

Next easiest is to get rid of the 'Bouncing ball' lights. This a little more controversial as some clubs, most noteably the Warlords, require a light to be shown at all times at night. I'm not about to argue the pros and cons here, but you will need to make provision for a 'nitelite' if you are playing in any of their games.

If you still intend to wear the sensor on your head you could leave one diode attached or with a switch installed between it and the board to make it optional. If you are going for detached sensors, it is quite easy to make a small 'torch' with a couple of AAAs in a holder running to an LED soldered to a 150Ω resistor. This will tuck up inside a hat or tape on to a helmet and seems to satisfy the requirement.

The diodes are arranged in an arc on the front of the board and are quite obvious when it's powered up. If you want to make a permanent job you can go for a complete LEDectomy - simply cut them off, being careful not to disturb the surrounding components or damage the tracks on the board. On some models they are braced with grey or black pillars. In this case you just have to be a bit brutal I'm afraid and haul them off by main force as desoldering tends to burn the pillar with the release of some really noxious fumes. Like for teeth, use a twist and pull action (sorry Bodger, but there's times when you have to forget the book!). If, on the other hand you think you may want to reverse the operation, you can disable the lights by cutting one leg of resistor R8 at the top right as seen from the front.

Y-Rigging

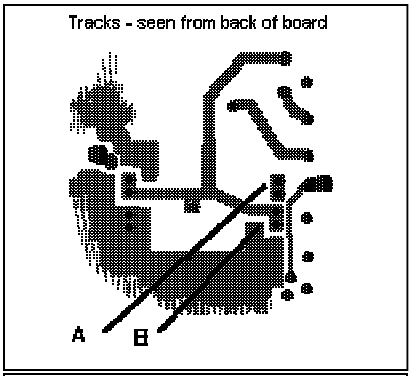
(To modify star sensors so that you can use just one for 360º cover)

Materials:

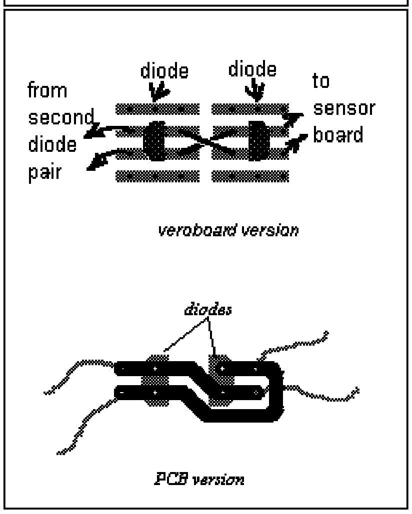
One StarSensor in working order
IR Sensor diodes, x4 - (Maplins, 99p each)
Veroboard - (Maplins or other supplier-prices vary)
Thick Plasticard or Perspex, ~3" x 9" - (model shops)
Mini flex wire - not too fine, ~ 4' - (any electrical store)
You will also need either a spare red dome (perhaps from the other sensor) or you should find or make a housing for the second sensor pair. In the 'Rebel commando' helmets we successfully used Maplins IR lenses glued over the end of a ¾" section of plastic tube!

Remove both sensor diodes from the board. This is best done by cutting through the sleeved legs from the front.

Cut 2 lengths of about 2½ft of flex and strip away the last inch or so of the outer sleeve and about ¼" of the insulation from the inner wires.



Solder the ends of the wires to the points on the back of the board that correspond to the legs of the right hand sensor diode - the ones nearest the long black bar (A & B). Be very careful that you do not foul the surrounding tracks as they are very difficult to clean afterwards without damaging the board. If you have not done much soldering before it is probably best to practice the technique on a piece of veroboard first - you'll find it easier if you 'tin' the ends of the wire with solder before trying to attach them to the board. Avoid swamping the board with solder and overheating it but make sure that the solder 'runs' well and doesn't just bead up on the surface.



The sensor diodes need to be connected together in pairs in parallel. This is where a lot of our earlier efforts lost sensitivity. The best way we have found to mount them is on a small piece of veroboard or, better yet, on a pcb etched as shown. The strips and diode legs must be scrupulously cleaned and I recommend using plated pins to fix the connecting wires to. Use a heat-shunt when soldering the diodes and resist the temptation to re-use old ones to save cost as they suffer from repeated heating - deteriorating quite markedly.

Before you go any further, test that the pair will respond to a "hit". If it doesn't, try reversing the connections, as some diodes are biased in the opposite way to the Maplins type.

When you are happy that the connections are OK, bend the heads of the diodes back so that they are at about 45º to the vertical as in the original.

Repeat for a second pair, connecting this to the first as indicated in the diagram. Mount the pairs in their housings and attach velcro to the back for fixing to headgear.

Most people the box the new sensor assembly to protect the diodes against damage. This is usually done by finding a suitable clear plastic dome (I have seen boxes used, but domes look better) and sealing onto the diode board with something like silicon or clear bathroom sealant. An alternative idea being tried out buy Black Watch is to encapsulate the diodes into resin, using an appropriately shape/sized smooth ice cube tray as a mould.

Optionally remove the red dome from the sensor box, cut the lugs from the back and twist to remove from case. Cover the front of the box with a disk of plasticard to seal the unit.

Make a notch in the edge of the case to take the wires through when it is closed up (about 5mm). Before closing up it is a good idea to lacquer the board with conformal coating to protect against moisture - the cause of most sensor breakdowns.

Replace board in case and close up, sealing exit hole with a grommet, silicon bathroom sealant or Araldite.

We did experiment for a while with a rig which could detach from the diode pairs so that these could be permanently mounted in helmets. Unfortunately we could not find a connector which was robust enough to stand up to Tagging and remain clean enough for the very tiny signals involved. However, with the use of pressed Perspex domes the head rig has become so compact that it can be fixed to any helmet without looking too daft so this is probably the form in which it will remain.

Tuning

The tuning of sensors to achieve the correct level can be quite tricky, but here are a few basic pointers:

1. First step - adjusting frequency. With the sensor on, slowly turn variable resistor VR2 either way until the sensor stops responding to a Starlyte pulse (the hobby standard). You will need to do this in small steps, removing the screwdriver after each before firing as its proximity may trigger the sensor by inductance. Mark this position with a felt-tipped pen - not pencil as it conducts electricity - then turn back through the responsive band until you lose it again. Return to the centre position and you should have the best frequency response though it's best to check against non-Starlyte weapons as well such as the Terminator and Quick-shot as these can be slightly off the standard but should still trigger the sensor. Incidentally the width of the response band is a good indication of the health of the sensor: if the band occupies more than 90º on the resistor, the board is on it's way out and should be checked frequently to make sure that it hasn't died completely.

2. Now remove the lens from an **unmodified** Starlyte and with fresh batteries in both, test whether the sensor will take a hit at 4 metres distance (the Warlords standard and the most stringent we have come across in the hobby - pass this and your sensor should be acceptable by any club!). If not, turn resistor R2 (not VR) clockwise until it does. You may find that this only just occurs or that you cannot achieve this level of sensitivity. Well, I think most clubs would accept 3 metres - 10ft - with a snubbed Starlyte but check before leaving for an event and be prepared to hire or borrow an acceptable replacement if the organisers decide that your equipment isn't up to scratch. If you are just under, try remaking your connections as a dodgy join can seriously affect signal transmission.

3. don't ever touch the 'bandwidth' adjustment (VR1)

4. don't ever touch the 'bandwidth' adjustment - I know I've already mentioned it, but it's so important I thought I'd say it twice.

A last couple of points:

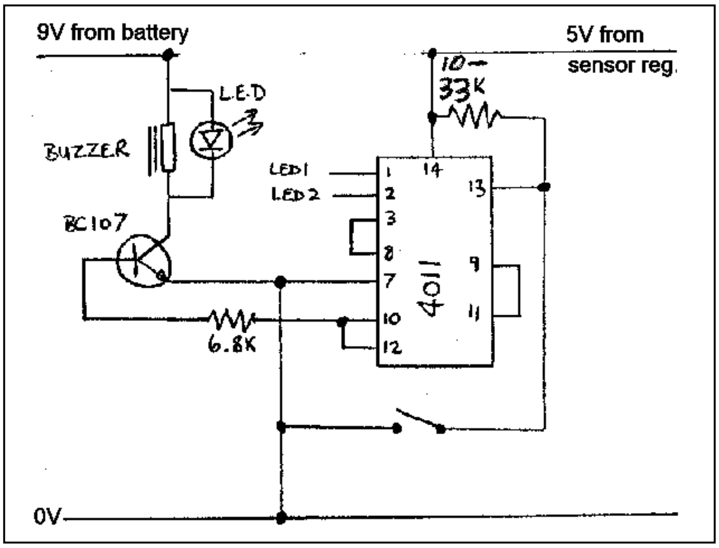
a) if your sensor keeps unexpectedly re-setting during play the most likely cause is a faulty battery connection. Pinch the flanges on the connector and the battery *slightly* to tighten them. If they are still loose tape the connection down during play.

b) rechargeable PP3's start at a lower voltage than non-rechargeables (8.4V vs 9V) and lose charge very quickly in damp conditions. See also the section on power supplies later on.

The most important thing to bear in mind is that the equipment we use is now about nine years old [1995]. As it was only intended for a toy with a life of perhaps two years it is only to be expected that units will begin to fail. Hopefully a replacement will be available in the near future - I know that several people are working on them - but until then, take care of what you have and test before each event to make sure that it is still up and running - saves arguments, embarassment and bad feelings all round.

Buzzer Board (Star Sensor)

It is sometimes difficult to hear your sensor 'die' when you are in the middle of a firefight. To ensure you notice this important fact you can add this little modification to sound a loud buzzer and additionally flash a bright LED in your face!



This circuit sounds a separate buzzer when all of your hits have been taken, which can be placed close to your ear. It also lights a bright LED that can be positioned so that it can been seen if you want.

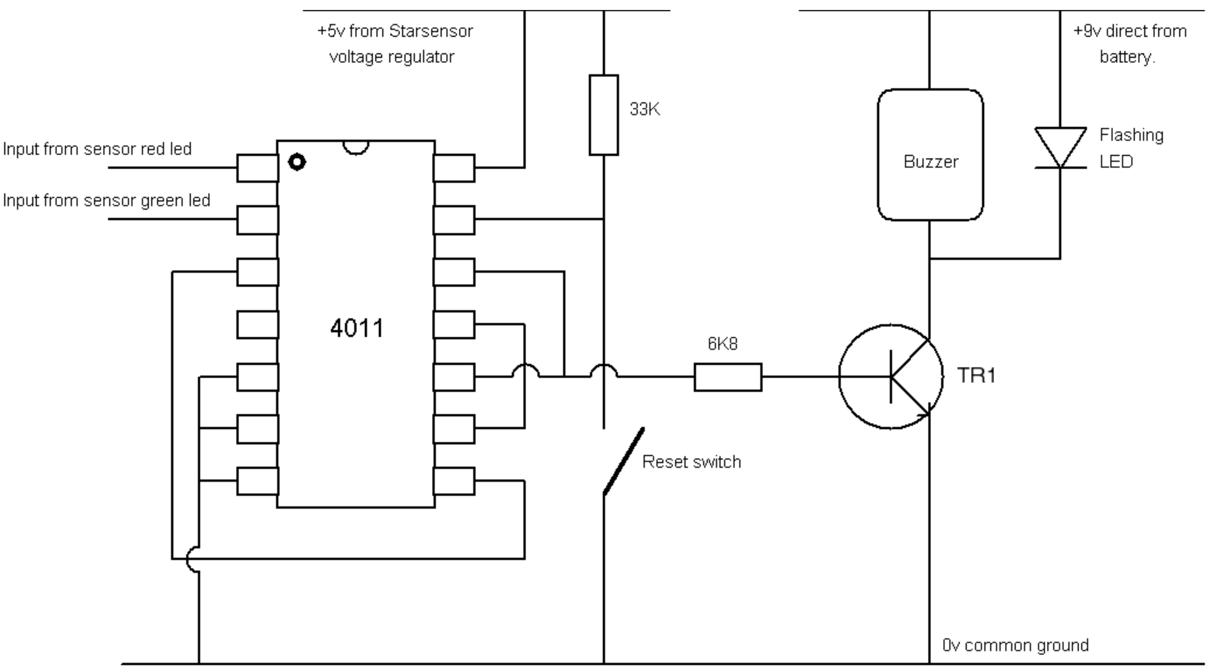
It works on the principle that the only time more than one hit light LED is illuminated is when you have just lost all your hits. By detecting the pulses at two of these LEDs, the buzzer can be made to sound only when pulses appear at both together. It senses this condition and latches on, buzzing away until you press the reset button.

Construct the circuit as indicated in the diagram. The wires LED1 and LED2 should be connected to one leg of the first green LED and one leg of the last red LED in the sensor, preferably the leg on the same side of each. The board needs to be powered from the same supply as the sensor, otherwise the circuit is unstable.

(Two circuit diagrams are included, until someone tells me if there is any important difference and whether a BC107 or BC184L is preferred)

Components

TR1 = BC107 or BC184L transistor
12V buzzer
Momentary push button switch
Bright visable LED
4011 Quad 2 input NAND gate
14 pin IC holder for 4011
6.8K Ohm resistor
1K Ohm resistor



Smart Sensor

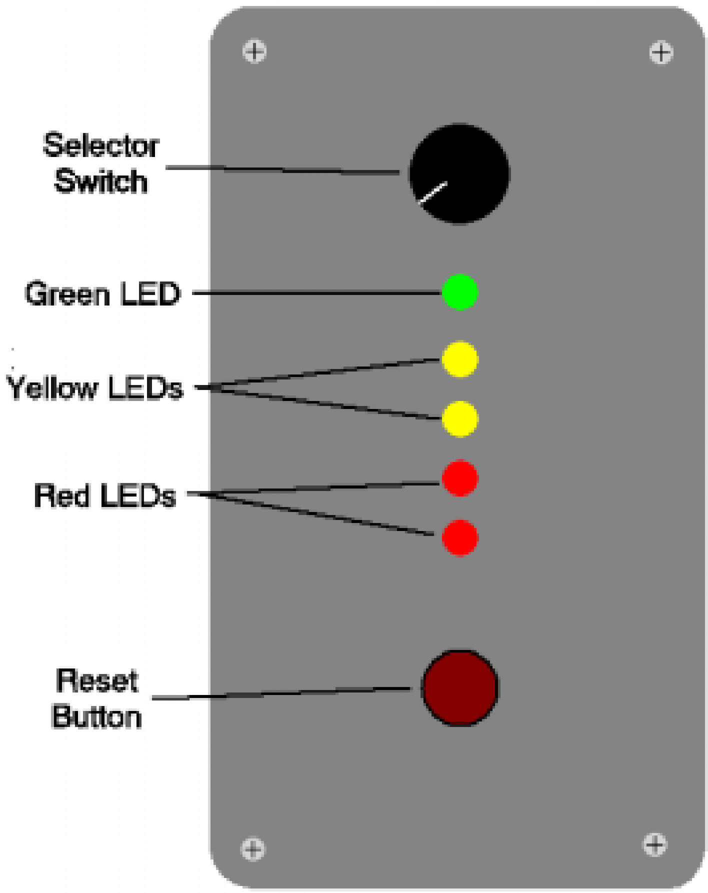
The Smart Sensor from Dave Bodger is one of the possibilities for replacing broken sensors.

Other Circuits

The C.I.A.B Medical Unit

This unit was an attempt to introduce an easily accessible, cheap and playable medical facility into club games. Several clubs agreed to use these units in inter-club games so that medical rules were simplified and understood by all those attending. These units tend not to be used anymore.

The unit consists of a hand held box, with five coloured LEDs on its face. There are also two switches, a push button type to reset the unit and a four position switch to turn the unit on and select the intensity of healing required.



On resetting, the unit lights the bottom red LED and makes an audible buzz. Then in sequence the LEDs light and go out again from the bottom up, each with a similar buzz. Once the unit has completed its cycle of lights, the patient is said to be healed and may reset their sensor.

The first setting is used when the patient is on any green or yellow sensor light. The second setting is used when the patients red sensor light is lit. The final setting is used when the patient has been stunned (all hits taken).

The cycle times for the unit for each of the settings are 20 seconds, 40 seconds and 60 seconds respectively. To be used the unit should be placed on the patients chest and while in use not other actions should be taken by either patient or the medic.

Components

Component	Maplin Code
Stripboard	JP47B
Wire	BL00A
6V buzzer	FL39N
Rotary 4 way switch	FH44X
Knob	FE74R
Universal project box	YU53H
Push button switch	FH59P
5 x LED holders*	XX33L
PP3 battery clip*	
555 timer IC	QH66W

*Not essential

4017 decade counter	
2 x BC184L transistors	QB57M
2 x 10 micro Farad capacitors	
1 x 0.1 micro Farad capacitor	
3 x 1K Ohm resistors	
2 x 10K Ohm resistors	
3 x 220K Ohm resistors	
2 x 470K Ohm resistors	
2 x Red LEDs	WL27E
2 x Yellow LEDs	WL30H
1 x Green LED	WL28F

Hide 'n' Sneak Modification

These interesting little toys made by Worlds of Wonder are ultrasound emitters and detectors that allow you to locate the one with the other. A little annoyance with these is the method of turning on the emitter, it requires its top to be tapped by the detector until a light turns on.

This has two distinct disadvantages:

1] You cannot carry the emitters in the same bag as the detector, as they stand a chance of being turned on by accident, wasting batteries.

2] You have to remember to turn on the emitter before leaving the detector with someone else.

A simple modification to rectify this is to open up the smaller emitter and locate the magnetic switch wrapped in foam at the top of it. Remove this switch and replace with one of your own choice, mounting it on the emitter.

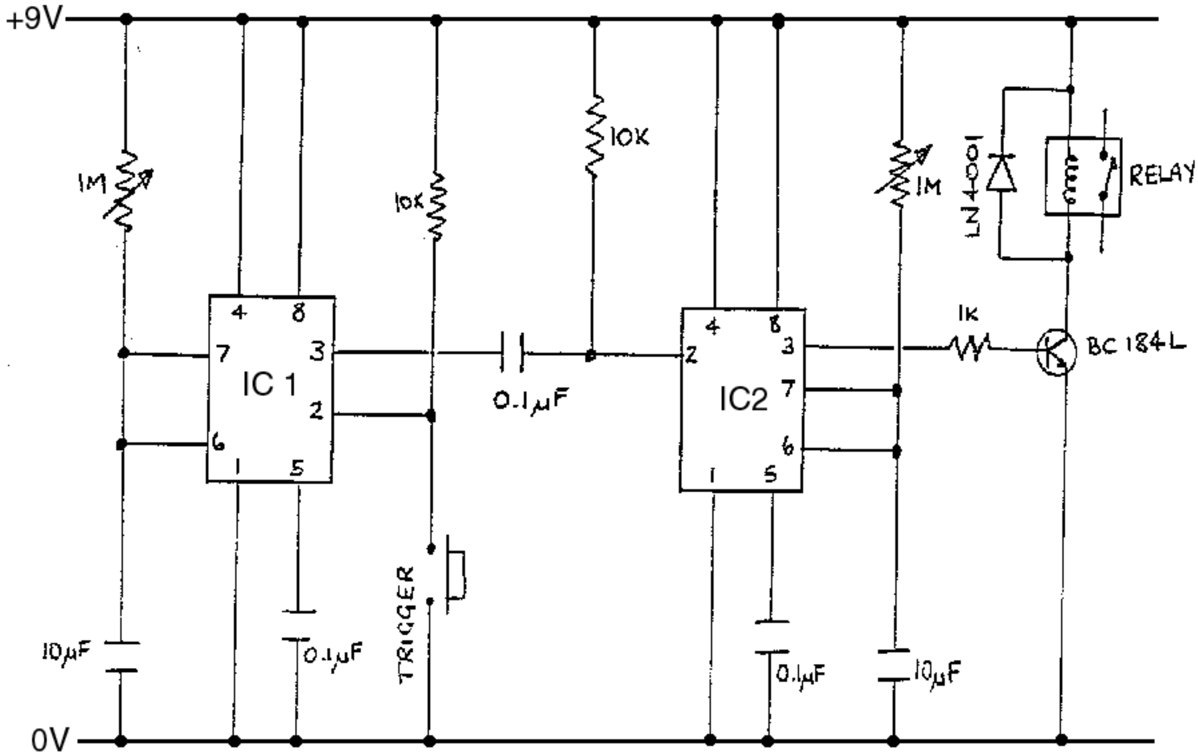
Hand Grenade/Mine Delay Circuit

This is a very simple circuit but also a very useful one. It allows any circuit of the users choice to be activated for a pre-set period of time, after a pre-set delay. Thus it is ideal for triggering mines, hand grenades or any special effect such as a flash cube.

The initial trigger may be a simple push button perhaps held open by a pin arrangement as in a hand grenade, or as a complex as a passive infra red movement detector. The only condition is that the trigger is closed either permanently or momentarily.

IC1 is connected so that when the trigger is pressed, its output at pin 3 becomes positive for a period of time determined by the variable 1M Ohm resistor and the 10 micro Farad capacitor on the left of the circuit. The variable resistor can be altered to make this "on" period anything up to about 10 seconds. When this period finishes, the output at pin 3 drops to negative and it is this drop that triggers IC2 on its identical cycle. Again the length of cycle can be altered using the second 1M Ohm variable resistor.

Triggering IC2 causes its output at pin 3 to become high. This causes the transistor to conduct and the relay to close. The relay contacts can be used as a switch to operate any other circuit.



Both IC1 and IC2 are NE555 chips or equivalent.

Power Supplies

All electronic circuits require power supplies to work. For our purposes, this is supplied by the use of batteries. There are many different types of battery, but the ones we are interested tend to fall into one of several categories.

The most popular choice for batteries in weapons at the moment seams to be Nickel Cadmium. Sarah Clark and Alex have given up on rechargeables in sensors as they are more trouble than they are worth. They recommend instead using Lithium batteries.

Single Use

Lithium

At £5 - £6 each these are expensive initially but last about ten times as long as even Duracell at low current use and are relatively eco-friendly. One Lithium will last for several weekends.

Alkaline

These are the next most expensive non-rechargeable battery per unit. Typically they have life spans of 6-7 times that of a standard battery and are ideal for long continuous applications such as our sensors.

Examples of these include Duracell, Ever Ready Gold Seal, and other supermarket own brands. The own brands are usually a bit cheaper and not necessarily and worst as they come from the same manufactures.

High Power

These batteries fall between the standard and alkaline batteries both in performance and type. If alkaline or rechargeable batteries are outside your price range, these are a good option.

Ever Ready Silver Seal is an example of this type of battery.

Standard

These are for the seriously cash strapped. Probably no good for sensors unless the game is only going to last a couple of hours. The need to replace these batteries more often probably means that it would have been cheaper to buy High Power or Alkaline.

Rechargeable

These batteries have had a bad press when used in sensors, but this is not necessarily the case so long as you don’t mind changing batteries to a charged one every couple of hours (depending on usage). They are however a good option for weapons.

Although more expensive to buy, and you need a charger, these sorts of batteries should work out cheaper in the long run because you just keep recharging them.

The down side is typically a lower voltage. Expect 1.2 to 1.25 volts from cells equivalent cells normally giving 1.5, and up to 8.4 volts from your rechargeable PP3 type instead of 9 volts so you may need more of them.

Nickel Cadmium (NiCAD)

These batteries should give you at least 700 charge/discharge cycles min. (400 for PP3 type) if used correctly. Watch out for the ‘memory effect’ though which can cause problems and mean you don’t get a full charge. Since less need to be manufactured (because they are reused), these are greener than non-rechargeable batteries.

Ni-Cads have several advantages (along with a few disadvantages).

- They are rechargeable. You can cover the cost of buying them and the charger unit after a handful of cycles. Chargers are available which can run off of a car battery so you can recharge them "in the field".
- They are ideal for supplying large amounts of current in short bursts, because of their chemical and electrical construction. They are far better in this respect than an equivalent sized alkaline battery.
- They are only slightly heavier than the zinc or alkaline batteries they replace.
- They retain a significant proportion of their charge for up to a month after charging.

Their main disadvantage is a problem called "memory effect". If you recharge them after using only a small proportion of their whole charge, after a few cycles the capacity of the battery seems to drop down to the level of that small proportion. The problem seems worse if you regularly "fast charge" them. This is caused by the chemicals used in their manufacture. It can be avoided by allowing the batteries to become almost fully discharged (down to 1 volt per cell) and then recharging them slowly (normally for 14 hours) once every 5 or so cycles. Special chargers are available which have an automatic discharge circuit that can be used to prevent this effect. As these chargers are little more expensive than a standard charger, they are to be preferred if you have a choice when buying. The Maplins 'Universal NiCad Battery Charger & Discharger' (Order Code RZ18U) is useful in this respect if you have separate batteries rather than a battery pack.

Duracell Special Batteries Ltd. sell the DX15 battery charger that will fast charge NiCad battery packs and remove the memory effect at the same time. It costs £99 (at last check) unfortunately, but could be a good club purchase as you can recharge 2 or 3 packs per hour off of a car battery with it.

If you allow NiCads to become completely flat (less than 1 volt per cell) it is possible that recharging will not recover them and you may have to throw them away. Allowing them to get too hot (more than 40ºC) during charging can cause the same problem. Beware of hot summer days! Always recharge them the day before a tag event to ensure peak performance.

Nickel Metal Hydride (NiMH)

Like NiCAD, but lightweight, reliable, zero memory effect, higher capacity, long life and ecologically safe to dispose of. Oh yes, and even more expensive!

The improvement in capacity depends on make and type, but can be 60-80% better than with NiCAD.

Lead Acid 'Gel-Cell'

One other contender is the lead acid "gel-cell", so called because of the acidic jelly-like compound used as an electrolyte. These are of heavier construction than NiCads and take up more room but can be easily obtained in very large capacities and are normally of 12 volt rating, although 6 volt versions are available. They are capable of delivering very high currents, but their output voltage drops more than a NiCad would while they are doing it. They also need careful charging and should not be charged with a car battery charger, which can damage lower capacity cells by over charging them. They must be charged with a constant voltage, current limited, supply - limits are normally shown on the battery casing. They are good for static weapons, such as sentry guns.

Single Batteries v Battery packs

A single 9V PP3 battery has the same voltage as six of the smaller batteries. However it will not be able to supply as much current to a circuit and will run out sooner. In almost all cases a guns performance can be improved by using a battery pack rather than a single PP3.

It may also be possible to use more voltage than the gun was intended for but I take no responsibility whatever if you decide to try this trick, as you may damage it.

Multiple Power Packs

It is possible that when building your own guns you will choose to have multiple separate power supplies to run the gun, sound system, ammo counter etc. Unless you are using relays to completely isolate these circuits instead of transistors to just switch them on and off, you will need to connect the negative terminals of all the battery packs used together. This is to give all the power sources and circuits a common reference level. Many circuits will not work with each other properly unless this is done.

Electronics for the Innocent

Many good books exist on the subject of electronics construction for beginners and I suggest you read one of them before embarking on these projects however this section should cover the basics needed for the circuits in this document, and serve as a quick reminder.

Values and Units

Resistors

Values are measured in Ohms and are usually marked using a colour code convention to indicate their resistance.

Black=0, Red=1,

Sometimes the multiplier is put in the place of the decimal point (2.7K becomes 2K7 and 27Ω becomes 27R) to make it clearer when printed on small components, or in bad hand writing!

For example the 'R10' in a Star Sensor is 2700Ω (Ohm)= 2.7k (kilo ohm)= 2K7 = Red, purple, red.

Capacitors

Values are measued in Farads, however 1 Farad is a very large capacitor for most of the electronics we are interested in so you are more likely to come across micro Farads or pico Farads, often written as μF or pF.

Some types of capacitor have a polarity that has to be observed.

Formula

Electrical

V=I*R, I=V/R, R=V/I where V=volts, I=current(amps) and R=resistance(Ohms)

Optics

The focal length of a lens is related to the magnification by the formula:-

Focal Length *in mm* = 250 / (Magnification - 1) and/or

Magnification = (250 / Focal Length *in mm*) + 1

The other way of describing a lens that you may encounter is in Diopters, which is a measure of the power of a lens. This is related to focal length by the formula: -

Focal Length *in mm* = 1000 / Diopters.

Therefore by substitution: -

Diopters = 4 x (Magnification - 1) and/or Magnification = (Diopters / 4) + 1

From all this you should be able to calculate the radius of the lens by the following formula: -

Lens diameter ≅ Focal Length x (TANGENT of the viewing angle)

Handling Precautions

These precautions to remember are good practice always, however for some types of devices they are more important. Ex. CMOS, MosFet.

Except where necessary, never work on a circuit that is connected to a power supply, even a battery.

Always make sure you are earthed when working on circuits, either by using an anti-static wrist strap, or by touching something metal that you know to be earthed before you start, and regularly there after.

And one last important point – the pointed end of a soldering iron just might be HOT!

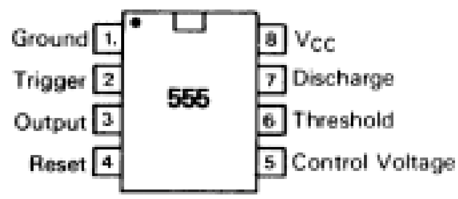
Soldering

Always use only as much heat as you need to melt the solder. Remember that the heat will travel along track and legs, and excessive heat may damage components.

When soldering onto old test points or connections, try to use as little heat as necessary and have a little solder on the iron already to help the old solder melt.

Useful Devices

555 Multipurpose timer/oscillator

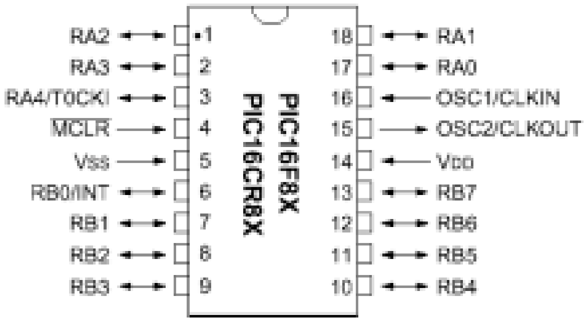


The 555, and its two in one package brother the 556, are IC timers suitable for monostable or astable operation.

The 555 and 556 are also available in CMOS technology. The spec, pin out and usage is much the same except for lower power dissipation and output current. You will also have to be more careful about handling.

See also: RS Datasheet 232-2217

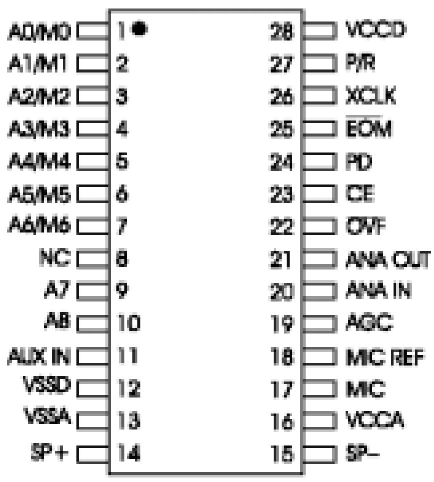
PIC 16F84 Micro-controller



The PIC 16F84 replaces the 16C84 and is probably the most popular micro-controller being used for intelligent weapon boards or sensors at the time of writting.

The PIC16**F**84 has replaced the PIC16**C**84.

ISD 25xx ChipCorder



The ISD ChipCorders are digital sound recorder and playback devices.

The come in 32, 40, 48 and 64 second versions, but since they all have the same memory capacity, the quality is better on the short time versions.

Suppliers, Sources and Contacts

Below is a collection of sources and suppliers. It is by no means complete, nor can I guarantee that these are the best places to go, its just a useful starting points recommended at the time of writing.

The first part lists possible contacts for various categories, the second path then gives you the contact details.

Who to contact

General Advice

For general help and advice, if you have email, subscribe to the UK Laser Tag Confederations mailing list (ukltc@onelist.com) via www.onelist.com.

Web Resources

http://www.hugme.com/games/tag/ Cannon Fodders Tag site
http://www.btinternet.com/~Sarah.Clark/lasertag/ Sarah Clark Tag site
http://www.compulink.co.uk/~lasertag/ Dave Bodger Tag site
http:// Phil Higgins Tag site

Commercial and Modified Tag Gear

StarLytes, Star Caps and Y-Rigs: Nigel Carr

Home and Custom Built Tag Gear

Complete Guns: Phil Higgins
SmartSensor: Dave Bodger

Parts for D.I.Y

SmartGun board: Dave Bodger
SmartLens assemblies: Dave Bodger
Standard Gun board: Phil Higgins
Digital Sound Gun board: Phil Higgins

Components

Electromail
Farnell
Rapid Electronics
Maplins Electronics

Clothing and Props

General military surplus and reproduction:
Anchor Supplies

Magazines

FIREFIGHT: Contact Mr D A Rees

How to contact

DSB Special Batteries Ltd
These people understand batteries inside-out.
Ruben House
Crompton Way
Crawley
West Sussex
RH10 2QR
☎01293 611930

Electromail
You have to pay for their catalogue
P.O. Box 33
Birchington Road
Corby
Northants
NN17 9EL
☎01536 204555

Farnell Electronics Components Ltd
They will send you a free catalogue
Castleton Road
Armley
Leeds
LS12 2EN
☎0113 263 6311

Maplin Electronics
Catalogue available at W H Smiths or Maplin stores
☎01702 554000

Dave Bodger
http://www.cix.co.uk/~lasertag/lasertag.htm
mailto:davebodger@bigfoot.com
Firefight fanzine Info page:
http://www.cix.co.uk/~lasertag/ff.htm

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