

## R/C Combat Vehicles

# Remote Triggering of Paintball Markers

by

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### Markers

When the marker is cocked a small spring moves a sear into position to hold the bolt/striker/hammer. Retracting the sear allows the firing mechanism to operate. See [here](#) for some photos by Steve Tyng of a sear and a hammer.

A “semiautomatic” marker uses gas pressure, an electric motor, or some other arrangement to recock the marker after each shot.

- **Mechanical**  
When the trigger is pulled it retracts the sear directly or through a mechanical arrangement.
- **Electronic**  
When the trigger is pulled a micro switch is closed to complete an electrical circuit. Typically a solenoid retracts the sear. Solenoids may be purely electromagnetic or they may use gas pressure as well (in which case they may be called “electro-pneumatic”). A large capacitor is typically used to hold enough charge to activate the solenoid very quickly. Some electronic markers include circuitry to operate the firing action multiple times (a fixed number of times (*e.g.* 3) in “burst” mode, continuously in “fully automatic” mode).

### Switches

Switches are available in a wide variety of configurations. Some of the attributes relevant to R/C Tank Combat are described here.

- **Switch Type**  
The mechanical arrangements to activate the electrical contacts include:



**Slide** – a protrusion is moved to one of several defined positions in a linear arrangement. Two states (on or off) and three (center-off) are common.



**Toggle or Paddle** – a lever, arm, or similar is fixed at the base and can be rotated to one of several defined positions in a linear arrangement. Two states (on or off) and three (center-off) are common.





**Rocker** – an actuator (usually concave) is operated by pressing one end or the other. This type typically has two states (one end or the other down) or three (center-off).



**Push Button** – a button is depressed to activate the switch. This type typically has only two states (pressed or not).



**Rotary** – a knob or wheel is turned to one of several defined positions. Some rotary switches allow continuous rotation; others limit rotation so the knob can only be turned back and forth through a partial rotation. A key lock switch uses a removable key in a lock as the actuator. A thumb-wheel switch has part of an actuator wheel exposed.



**Push Pull** – a knob is pushed in or pulled out to change the state. Most switches of this type have only two states.



**DIP** – using the same dual in line package (DIP) footprint as common integrated circuits (ICs) a DIP switch consists of one or more very small SPST switches in a package suitable for mounting on a printed circuit board (PCB) or similar. They are often used to allow selection of options for an electronic device.

- **Action**

The result of activating the switch can be:

- **Momentary** – the switch is closed (or opened) only while the mechanism is activated. For example a momentary push button switch only changes state while button is depressed.
- **Latching** – the switch stays in one state after being operated. For example a common household light switch stays on when pushed down and stays off when pushed up (or *vice versa*).
- **Alternating** – each activation of the switch changes the state. For example a push button switch might alternate between on and off states with each press of the button. Many modern electronic devices have a single “power” button that alternates.

- **Form**

The arrangement of the electrical contacts is described in terms of:

- **Poles** – the number of sets of contacts. A single-pole (SP) switch has one set of contacts; a double-pole (DP) switch has two sets in parallel, both activated at the same time by the mechanism. SP and DP switches are common, but the number of poles can be much higher. For more than two poles a numeric notation is used, *e.g.* 3P, 4P.
- **Throw** – the number of contacts switched for each pole. A single-throw (ST) switch has two contacts which are connected in the “on” state and disconnected in the “off” state. A double-throw (DT) switch has three contacts: a common contact is connected to a second in one state and to a third in the other state. Some DT switches have a “center-off” state where the common contact is not connected to either of the other two – these are inconsistently described as triple -throw (TT) or center-off (CO) (beware that “CO” can also be used to mean “changeover” meaning more than one pole!). Center -off DT switches are common for manual switches but not relays.
- **Normal state** – the position of the switch in the inactive position (if there is one). A normally-open (NO) or “push-to-make” switch has its contacts disconnected if inactive – it is normally in the “off” state. A normally-closed (NC) or “push-to-break” switch has its contacts connected in the inactive state and they are disconnected when the switch is activated.

The number of poles and the throw are often combined, *e.g.* a single-pole, single-throw switch may be described as “SPST”. The normal state is often appended, *e.g.* an SPST normally-open switch may be shown as “SPST-NO”.

- **Break/make** – when a switch with more than one throw changes state it may be designed to “break” the first before “making” the second (break-before-make or BBM), or it may be designed to “make” the second connection before “breaking” the first (make-before-break or MBB). The distinction is important as two circuit paths will be temporarily connected as a MBB switch changes state but never with a BBM switch.
- **Form** – the combination of throw and normal state or break/make for a single-pole switch:
  - Form A: single-pole, single-throw, normally-open (SPSTNO)
  - Form B: single-pole, single-throw, normally-closed (SPSTNC)
  - Form C: single-pole, double-throw, break-before-make (SPDT-BBM)
  - Form D: single-pole, double-throw, make-before-break (SPDT-MBB)

The number of poles and the form are typically shown with a number and the form, *e.g.* a DPDT relay with BBM contacts may be described as “2 Form C”.

## Relays

A relay uses an electrical or electronic circuit to operate one or more sets of switch contacts. The switched contacts are electrically isolated from the switching circuit. Typically a small switching current is used to switch larger currents, *e.g.* a low current signal from a switch inside the cabin of an automobile operates a relay which switches a high current circuit for the headlights. Relay types include:

- **Electromagnetic (aka. Mechanical)**

A coil of fine wire is wrapped around a ferrous core to create an electromagnet. When sufficient current flows through the coil it pulls or pushes an iron armature which mechanically operates one or more sets of switch contacts. A spring holds the contacts in place when the coil is not energized. When the current to the coils is switched off suddenly (as is typical) the collapsing magnetic field creates a brief voltage spike that can damage electronic components and create “noise” on nearby signal lines. A snubber (consisting of a reversed diode, a resistor/capacitor network, or something more sophisticated) is typically included inside the relay or added externally to reduce the effects of such noise.



- **Solid State**

A solid state relay (SSR) has no moving parts – it uses only electronic components. Some SSRs use optical coupling to provide isolation between the switching and switched circuits. The switching component is typically one or more metal–oxide–semiconductor field-effect transistors (MOSFETs) which provide very low resistance in the “on” state. Unlike a mechanical relay the switched side of a direct current SSR is polarized so the switched circuit must be connected correctly.



Most electronic switches operate on the “low side” meaning they connect the switched circuit to ground (typically the negative side of the power supply). “High side” switches connect the switched circuit to the positive side power supply and are less common. It is important to select the correct type.

## **Remote Triggering**

A paintball marker is designed to be operated by a human pulling the trigger. Operating a marker mounted in an R/C tank combat asset or other remote location presents some engineering challenges. General solutions include:

- **Mechanical**

- A string, cable, linkage, or some other mechanical arrangement can be used to pull the trigger from a distance.

- **Wired**

- A simple switch is used to close an electrical circuit. A typical switch is momentary Form A. In some situations it may be necessary to use a relay, e.g. if the length of the wiring adds enough resistance to make switching unreliable.
- For a mechanical marker the circuit closed by the switch might operate a motor with a cam that presses the trigger.
- For an electronic marker the remote switch is typically wired in parallel with (or in place of) the original trigger micro switch. Wires can be soldered to the micro switch contacts and run out through an appropriate hole in the marker.

- **Wireless Servo Controllers**

- A hobby radio control (R/C) system is typically used. A portable transmitter sends radio signals to a small receiver, which controls one or more servos.
- The [Cheap Control Systems C12C Servo Controller](#) uses a Sony PlayStation 2 (or similar) game controller with a custom receiver to control up to 12 servos. Controllers are available in wired or 2.4 GHz wireless forms. The C12C comes with a socket that accepts both the wired plugs and the wireless receiver units.
- Custom systems using portable computers and WiFi have been developed by Doug Conn (see [here](#)) and others.
- A servo signal may be used to drive a typical R/C servo. An arm, horn, or cam on the servo shaft can activate the original trigger, a micro switch, or other device - see [here](#) for an example by Doug Conn, [here](#) for another by Chris Malton, and [here](#) for one by Steve Tyng. The trigger can be connected to the servo arm by wire or similar – Fred Thomson uses flexible picture wire to connect a fixed servo to an elevating marker. Several tanks use a servo with a cam to operate a micro switch to control a 12V car door lock actuator (a cheap, fast, reliable solenoid) which presses on or pulls the original trigger - see [here](#) for an example by Frank Pittelli and [here](#) for another by Steve Tyng (note that this one has a curved cam mounted to the base, rather than the typical cam mounted to the marker).

- **Servo-Compatible Switches**

A servo signal may be interpreted by an electronic device which then operates some type of switch. Examples include:

- [Dimension Engineering](#) sells several devices that take an R/C input and provide an on/off output:
  - The [PicoSwitch](#) has a typical servo lead to plug into a receiver. The circuit to be switched is wired to a pair of screw terminals which connect to the output of a SPST-NO relay. The switched circuit is isolated from the receiver circuit by the relay. A bright green LED is lit when the relay contacts are closed and an audible clicking sound can be heard as the relay changes state. A green LED pulses rapidly if no R/C signal is present on the input. The relay contacts are rated 1A at 24VDC.

- The [BattleSwitch](#) is very similar to the [PicoSwitch](#) but is larger and rated 10A at 28 VDC.
- The [DoubleSwitch](#) is very similar to the [BattleSwitch](#) but is larger and uses a double-pole, double-throw (DPDT) relay with each set of contacts rated 8A at 12 VDC.
- [Pololu](#) sells several devices that take an R/C input and provide an on/off output:
  - The [Pololu RC Switch with Digital Output](#) has two logic level outputs (which can drive other logic circuits, LEDs, MOSFETs, some relays, *etc* but not higher current devices like motors). One output indicates a valid R/C signal is present; the other indicates the servo pulses are wider than 1.6ms with 0.1ms hysteresis. The board is assembled and has holes for soldering wires.
  - The [Pololu RC Switch with Small Low-Side MOSFET](#) has similar functionality to the [Pololu RC Switch with Digital Output](#), with several additions:
    - An on board LED indicates the absence of an R/C signal (isophase flashing), an "off" signal (quick flashing), or an "on" signal (steady).
    - The "on" logic drives a lowside MOSFET capable of switching up to 3A at 30V. This can be used to drive small motors, large relays, power MOSFETs, *etc*. The MOSFET can be connected to the R/C supply or use an independent power source.
    - A fly-back diode (aka. snubber) rated to 20V is provided across the MOSFET output. This suppresses "spikes" from inductive loads such as motors and relay coils. For voltages above 20V (up to the MOSFET limit of 30V) an external diode can be used instead.
    - The board is assembled and is supplied with a set of header pins which can be soldered to the plated wire holes. Three holes are located with an empty hole alongside to allow use of a standard R/C female lead. The whole board could be plugged into a breadboard or similar prototyping equipment.
  - The [Pololu RC Switch with Medium Low-Side MOSFET](#) is similar to the [Pololu RC Switch with Small Low-Side MOSFET](#) but its MOSFET is rated at up to 15A. In addition to header pins it is supplied with an

interlocking pair of 3.5 mm screw terminals for the input and output power connections.

- The **Pololu RC Switch with Relay** is available [assembled](#) or as a [partial kit](#). It uses an R/C signal to operate a SPDT relay rated 8A at 30VDC. The relay could be replaced with a compatible “sugar-cube” style relay. The switched circuit is isolated from the receiver circuit by the relay. The board has a logic level output to indicate a valid R/C signal and another to indicate the relay is on. The “on” threshold is configurable, the on/off logic can be inverted, and a “safe-start” mode protects against unintended activation at startup or after loss of signal.
- [Hansen Hobbies](#) has several R/C switch products:
  - The [Pico Electronic Receiver Switch \(PERS\) V2](#) can switch a load of 3A continuous, 4A peak connected to the servo power supply up to 6V or to an external supply up to 20V. It is available with 4 different connectors including standard R/C, and it can be configured by soldering selected parts to provide a fail safe state (off or on) and/or reverse the switching logic.
  - The [Nano Electronic Receiver Switch \(NERS\) V2](#) is similar to the [PERS](#) but can switch a load of 4A continuous, 5A peak and the servo power supply can be up to 10V.
  - The [Micro Electronic Receiver Switch](#) is similar to the [NERS](#) but can switch 6A at 20VDC.  
*At the time of writing the Web site states that it is discontinued but will be replaced “shortly”.*
  - The [Onboard Mechanical Relay](#) is designed to work with the [PERS](#) or [NERS](#) and can switch up to 10A at 28 VDC.
- The [Firmtronic R/Switch](#) has a standard servo lead input and two 3pin outputs (one pin of each set is unused). The state of each output depends on the input pulse width. Note: There are (at least) two different data sheets for this device, with different state tables for the outputs. The data sheet on the manufacturer’s Web site at the time of writing shows 4 combinations of off and on states; a data sheet on a supplier’s Web site shows an additional “flash” state for each and a total of 9 combinations.
- The [Team Delta Engineering RCE200H](#) accepts an R/C signal and switches an external load that is electrically isolated. The standard unit does not come with a



servo lead, but some suppliers add it. The output is rated 10A at 60 VDC. Previous models (with a different last letter) had lower current ratings.

- The [Grand Wing Servo PC03](#) (also known as PC-3) is designed to turn a gyroscope unit off and on in model aircraft, but can be used as a typical R/C switch. The documentation is [here](#) but not linked on the Web site as of the time of writing.
- R/C switches from [Anvilus Machine Works](#) (Not available at this time):
  - The [Anvilus Machine Works](#) R/C Trigger has a standard servo lead input and a “JST”-style output plug compatible with the internal trigger socket of some electronic markers. The plug can be replaced or removed provided the polarity of the connection is observed. The output is an optically isolated NPN transistor so it can only be used to directly switch the “low side” of a circuit; it can be used to drive a PNP transistor or other device if “high side” switching is needed. The load switched by the R/C Trigger is limited to 50 mA.  
*This information is provided for the benefit of those who have this device – it is not available from the supplier at this time.*
  - The [Anvilus Machine Works](#) R/C Switch is similar to the R/C Trigger but can switch 150mA (suitable for driving a relay coil). It is supplied with bare wires on the load side.  
*This information is provided for the benefit of those who have this device – it is not available from the supplier at this time.*
- R/C switches from [Basic Micro](#) (Product status uncertain):
  - The [Basic Micro Bit Switch](#) is another MOSFET switch which can be operated by R/C signals. It is rated 3A at 24 VDC.  
*At the time of writing this product is no longer listed on the Basic Micro Web site but is available from several suppliers.*
  - (Product status uncertain) The [Basic Micro Power Switch](#) is another relay which can be operated by R/C signals. It is rated 10 A at 125 VAC (no VDC data given).  
*At the time of writing this product is no longer listed on the Basic Micro Web site but is available from several suppliers.*
- The [Turnigy Power Systems Turnigy Receiver Controlled Switch](#) is another R/C switch. It is supplied with a standard servo lead and two red wires for the

switched load. It is rated 10A at 30 VDC.

*At the time of writing this product is not listed on the Turnigy Power System Web site but is available from several suppliers.*

## Timing Issues

Some devices can be left on indefinitely without problems (except running down batteries used for power), but others can be damaged if left on too long. A car door lock actuator is designed to be “pulsed” and typically a spring resets it when the power is removed. If the power is left on for a long time (more than a second or so) the solenoid coil can overheat and burn out.

There are several approaches to limiting the “on” time of a firing mechanism:

- **Manual control**

The operator must remember to turn off a toggle switch or similar device. This is much easier if the switch is a momentary push button that turns off as soon as it is released.

- **Electronic timing**

A monostable multi-vibrator (commonly call a “one-shot”) is a circuit that is stable in one of two states and switches for a fixed period to the other state, then back to the stable state. For our purposes the output is usually “off” but when the one-shot is triggered it turns “on” for a fixed period of time (typically some fraction of a second is sufficient – some electronic markers can fire 30 times per second or more if paint balls can be fed in that quickly). The output could be used to drive a relay, semiconductor switch, or similar.

There are many approaches to building inexpensive one shots. The [555 timer IC](#) has been around a long time and there are plenty of examples online of suitable circuits. Other devices used include logic gates and specialized monostable ICs. Typically a resistor/capacitor (RC) network determines the period (on time) of the output in response to a rising edge (low-to-high transition) at an input.

There are now several very inexpensive microprocessor platforms that could be used to provide accurate timing for firing mechanisms along with input signal processing. Examples include Arduino, ATMega328, Microchip Technology PICs and the derivative Revolution Education PICAXEs, and Raspberry Pi.

## Isolation

The circuitry in an electronic paintball marker might produce “noise” that can interfere with the electronics in a receiver, or *vice versa*. Good practice is to isolate the logic circuits from the load circuits where possible. Some techniques for this include:

- Use separate power supplies. The grounds (almost always the negative sides) of all systems should be connected to provide a common reference level where needed. If a relay, opto-isolator, or similar is used the switched circuit need not be connected to the switching circuit.
- Use large capacitors (*e.g.* 33 $\mu$ F tantalum or aluminum electrolytic) to “decouple” the systems and small capacitors (*e.g.* 100nF ceramic or polyester) capacitors to suppress noise.
- Keep wiring as short as possible. A wire with a varying current flowing through it is the basis of radio, so short runs reduce the amount of radiation into and out of all those little “antennae” you are using.
- Use shielded wiring. The outer braided or foil layer is connected to ground and suppresses radiation into and out of the inner wire/s. A cheaper alternative is to use twisted wiring – the twisting is not as effective but helps somewhat and also tends to make each wire affected about the same by noise which appropriate circuits on the receiving end can subtract.
- Use metal shielding. Where appropriate enclose assemblies in metal sheet or foil that is electrically connected to the ground side of the power supply.
- Use relays or semiconductor devices to isolate logic from load. Opto-isolators use photo-transistors to provide complete electrical isolation, and are available as discrete components and embedded in other devices (*e.g.* in some solid state relays).

## Tips

- Leave the original trigger mechanism, some part of it, or an alternate mechanism (*e.g.* a small push button switch) in place so that you can manually fire the marker. This makes it much easier to test (*e.g.* when you manually cock it as you are setting up).
- If you have an electronic marker leave the solenoid and sear in place. You can relocate the electronics somewhere convenient and run a pair wires (preferably shielded or twisted) to the solenoid. See [here](#) for an example by Doug Conn.

- Use fly-back diodes across inductive loads (*e.g.* electro-magnetic relay coils). A [1N4001](#) costs only pennies and provides a path for the brief current spike when the coil is suddenly turned off. Make sure the reverse voltage rating exceeds the supply voltage where it will be used.
- To check which side is being switched use a multimeter to measure resistance between switch contacts and the power supply rails with the system powered off. If the resistance is zero (or very close to it) between one switch contact and ground then it's a low side switch and you can easily use the low side devices described above. If the zero resistance path is to the positive side of the power supply you'll need a high-side switch.