Electronics for Model Railways

Chapter 6

Point motors & servos

By Davy Dick

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In memory of Margaret

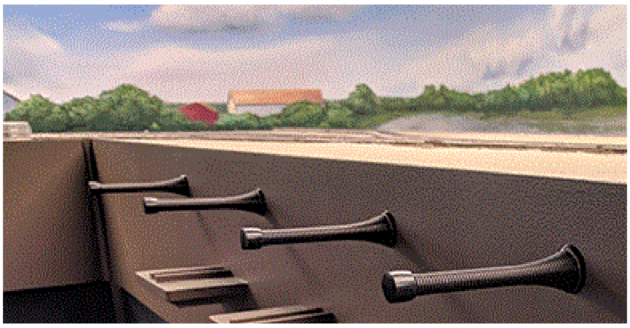
Contents

Point motors and servos

All layouts have points; some have a few points while others have scores of points.
Over the years, many different approaches to operating points have been used.
They all have one thing in common, the need to move the point's sliding tie bar back and forth to change the point's routing.

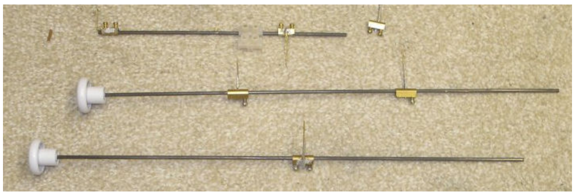
Manual operation

For many years, manual operation of points was the only option and some still prefer the tactile nature of this method.

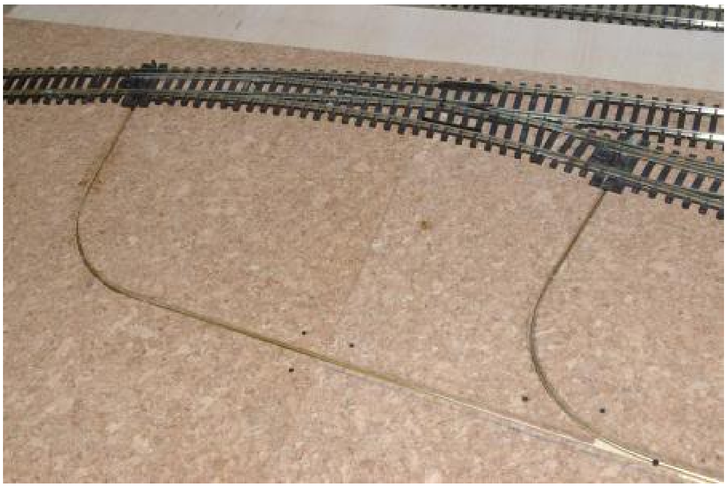


Some operators are happy to just lean over the layout and flick the point by hand, although this becomes more troublesome on larger layouts with points dispersed across greater distances.

A more organised approach is to use dowel rod or smooth planed square timber between the point tie bar and a knob, as in this image.
No more accidental derailing of trains while stretching across the layout.



Not all points can be used this way, either because they are in awkward situations, are remote, or are bunched together.



This is resolved using wire in tube systems, often connecting to lever frames.

This method is reliable, low maintenance and allows the wire to follow curved paths.

It can also be used in conjunction with other systems (e.g. along with a servo or solenoid that cannot fit in an inaccessible location).

It has a number of disadvantages.

- It can be tricky to install on layouts that have great height variations.
- It is difficult to install on portable layouts that multiple baseboards.
- It is useful that you can cover over the tube with scenery – as long as you remember where you laid it, to avoid drilling or cutting it later.

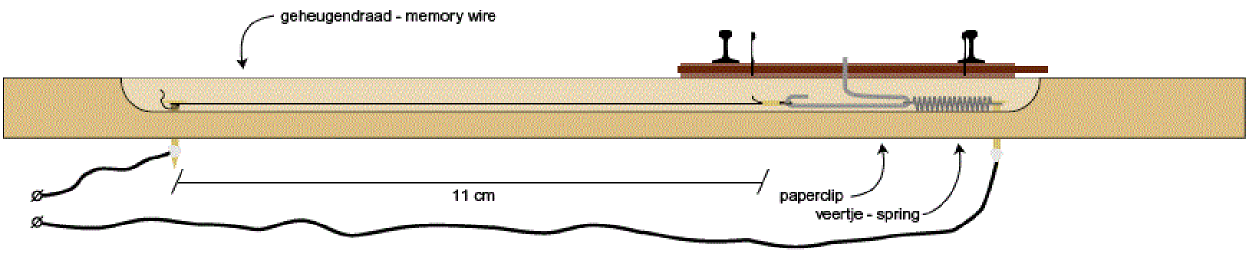
At the point, you can improvise the connection between the wire and the tie bar.
Alternatively, you can use the *'Blue Point Switch Machine Turnout Controller'.*
It looks a lot like a Tortoise motor but is is purely mechanical.
The tie bar throw is adjustable so that it can work with a range of points and gauges.
It also has a built-in DPDT snap-action switch for frog switching.

However, since this book is about model railway electronics, we will concentrate on their contribution to point operations. The available options are:

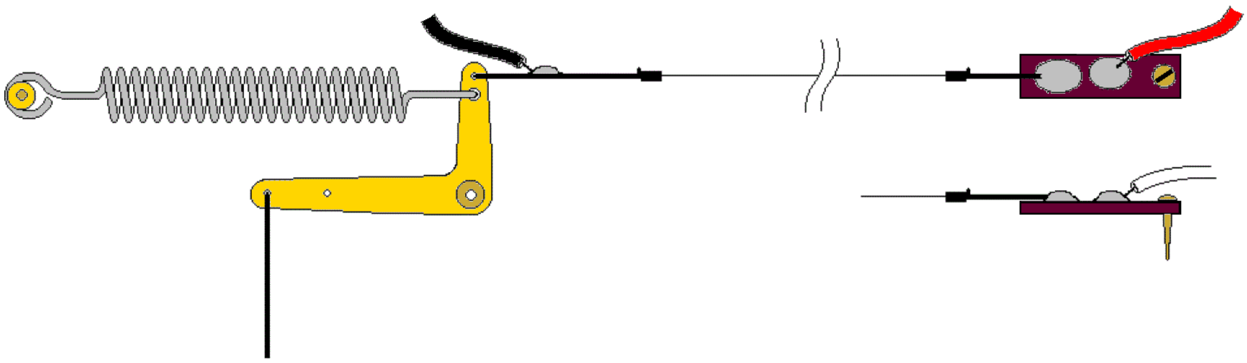
- Memory wire
- Solenoids
- Stall motors
- Servos

Memory wire

Memory wire has an interesting property – it shrinks when heated and restores to its original length as it cools again. It is heated by passing current through it (around 200mA depending on the wire gauge used) and shortens by about 5%. So, for a 4mm movement, we would need a length of 80mm (a 1/2” movement would need 10”).



We could use levers to get greater movement, at the expense of pulling power.

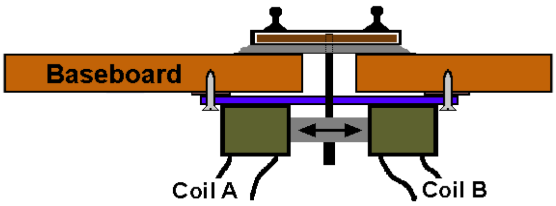


This illustration, taken from the MERG Technical Bulletin G19/1, shows how memory wire can be used to operate a point.

Power connections are made to each end of the memory wire, normally using bolts with washers, crimps or terminal blocks. You can't solder directly to memory wire, as the excessive heat will result in the wire losing its special properties.
When sufficient current passes through the memory wire, it shrinks and pulls the lever rightwards. In so doing, it moves the point's tie bar. When the current is withdrawn, the wire slowly restores to its original length and the spring ensures that the lever moves back to the right. The shrink time takes around 1 sec and the restore time is around 1-3 secs.
The wire's power is generally fed from a constant current source (e.g. an LM317), as excessive current leads to overheating and shortens the life of the wire. Power to the wire can be fed through switches, power transistors or Darlington arrays (e.g. the 2003A).
It is not a very popular method, as it needs constant current to keep a point set in the operated mode, and it takes up a lot of space under the baseboard.
See MERG Technical Bulletins G19/1 and G19/2 for further reading on memory wire.

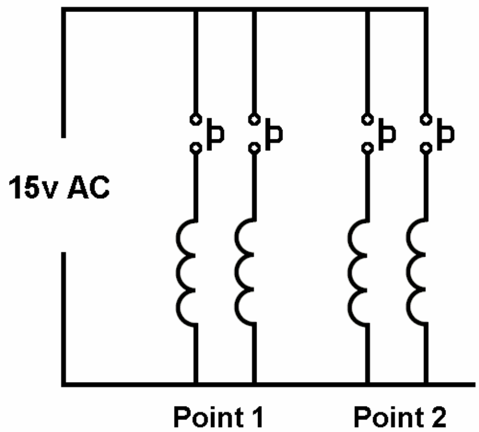
Solenoids

Solenoid-operated points was by far the most common system in use for many years, and is still popular today due to its simplicity.
A solenoid was described in the first chapter as a wire coil that acted as an electromagnet to exert a pull on a metal rod.
We can use two such coils, slightly spaced apart, with a common moveable metal rod.
If coil A is supplied with current, it pulls the rod deeper leftwards into its coil. Supplying current to coil B produces a pull in the opposite direction.



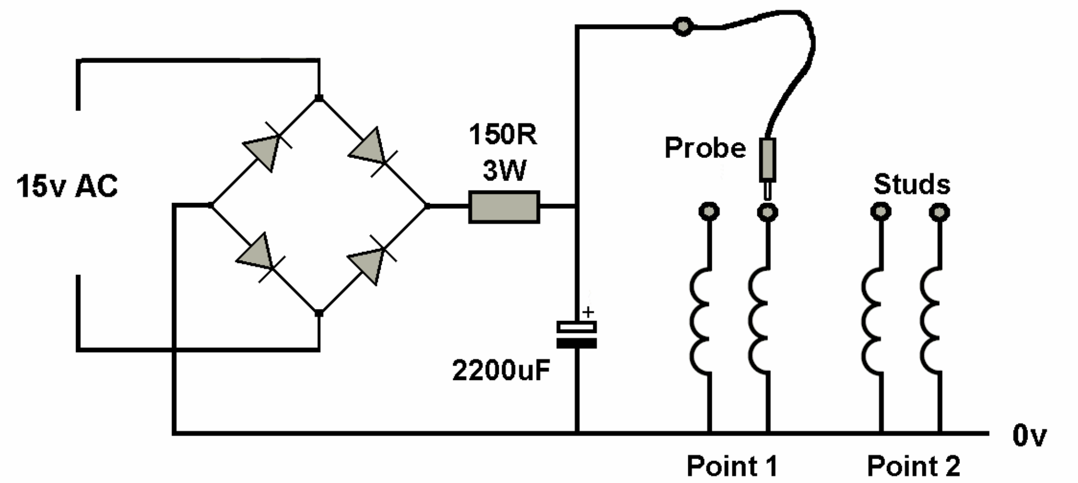
In this example, an operating pin is attached to the rod and it too slides left or right. As it does so, it moves the point's tie bar.

The illustration shows the simplest possible method of operating a couple of point motors.
Each point motor has two coils and each coil is connected across the power supply when its push button is pressed. It is common practice to join two ends of the coils together, requiring only three wires to to be connected to each point motor.
Push-buttons are used instead of switches, as the coils would overheat and burn out if power was applied for too long.



Although this systems works, solenoid point motors are more commonly used with capacitive discharge (CDU) systems. They avoid burnouts and provide a more reliable performance.

This basic CDU circuit rectifies a 15V AC supply and uses it to charge up a high value capacitor.
The connections from the point motors (apart from those that are commoned) are wired to studs on a control panel. The positive end of the capacitor is wired to a floating lead with a probe on the end (an 'electric pencil').

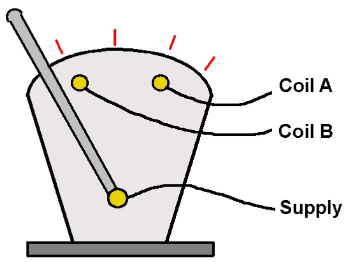


When the probe is touched to a stud, the capacitor provides a short duration burst of high current into that particular coil. This ensures that the solenoid snaps over successfully. The capacitor's charge is soon exhausted and so cannot provide a damaging continuous current. The resistor limits the current coming from the supply, if the probe is kept on the stud for too long.

The capacitor then needs to be recharged and this is done through the resistor, ready for the next operation. The charging delay is usually between 0.5 sec and 1 sec. This delay slows up setting up routes of multiple points. You only need one CDU circuit, no matter how many points you have on your layout.

While operation by push buttons produces a neat control panel, the sparking across the switch contacts and the high current surges they handle can lead to short life and unreliable operation.

For this reason, manufacturers have produced *'passing contact switches'*.
The switch has a lever that can rest in three positions – in the middle and at each end of the travel. The lever is connected to the power supply. As it is moved between the middle position and any of the outer positions, it rubs against a contact that is connected to one of the solenoid coils. As long as the operator pushed the lever all the way, the contact is only momentary and enough to discharge the capacitor through the coil.



Passing contact switches are useful in replicating a signal box lever frames, but are not suitable for operator's control panels.

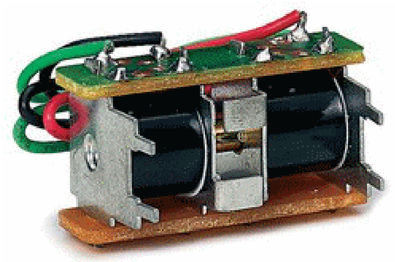
Over the years, this basic system was improved upon by using power transistors (high-power devices acting like switches) to direct current through solenoid coils. This allowed ordinary pushbuttons and switches on control panels to be used, letting the transistor do all the heavy switching. It also allowed other devices to switch the points (any electronic device such as train detectors, logic circuits and computers).
A further improvement is using more sophisticated electronics to recharge the capacitor more quickly.

Solenoid point motors

Solenoids are described as point *'motors'* when they don't actually contain rotating motors. Later, as we shall see, there are point-operating devices that do use rotating motors – but all the main brands of solenoids are described as motors (or sometimes as *'point machines'*). Solenoid motors are all pretty much alike in the way they provide linear motion. The main differences, apart from price, are:

- Some also include changeover switches, so that when the point is moved the switch can set the point's frog polarity (more on this later), light panel LEDs, etc.
- Some are designed to clip onto the underneath of the point, making installation easier, assuming you buy the same brand of point and solenoid.

Hornby



The images show two Hornby solenoids that have different styles for mounting. They operate on 12V DC or 15V AC and are recommended to be switched with Hornby passing contact switches.

The first is the R8014 standard point motor. You can clearly see the two coils. The four metal lugs are designed to be plugged into the underside of their points; a rectangular slot is cut in the baseboard to allow the point motor to fit. Alternatively, they can be mounted above the baseboard and hidden in a Hornby trackside hut that includes an extension arm to move the point.

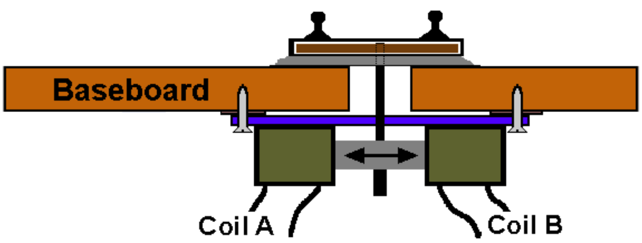
If fitted below the baseboard, an extending rod transmits the mechanical movement from the solenoid to the point's tie bar.

The second image shows their R8243 surface mounted point motor. This is designed to connect directly to a Hornby point. Neither model includes a changeover switch.

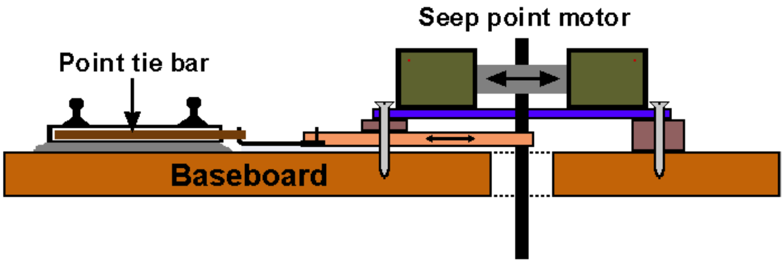
Seep

This solenoid operates from 12V to 25V, AC or DC.

They make two models; the basic PM-2 and the PM-1 which is physically identical but has a built-in switch. However, the switch uses a sliding metal washer to rub against the tracks of a PCB (printed circuit board) which limits its useful working life.



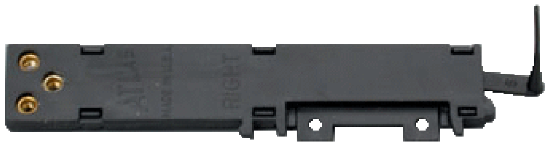
As the image shows, it has a very simple design and is expected to be screwed underneath the baseboard, as shown in the illustration. The operating pin protrudes through a hole/slot in the baseboard and slides the tie bar.



The Seep point motor can also be fitted above the baseboard, if preferred, as shown in the second illustration.
The motor has to fixed above the baseboard using spacers, to allow room for an extension arm to slide back and forth.

Atlas

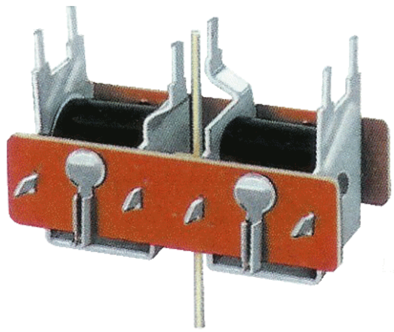
The basic Atlas point motor has its coils encased, with just the three connection points visible.
It has a slim profile but, unlike other point motors, only has a flimsy plastic operating rod.



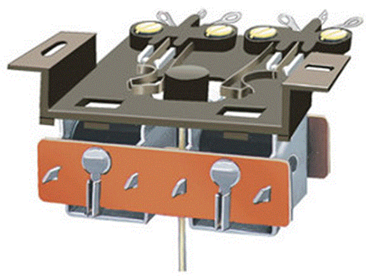
The second image is of the Atlas Deluxe Undertable Switch Machine.
It has a similar mechanism but embeds a DPDT (double pole-double throw) relay for use in frog wiring, panel lights, etc.

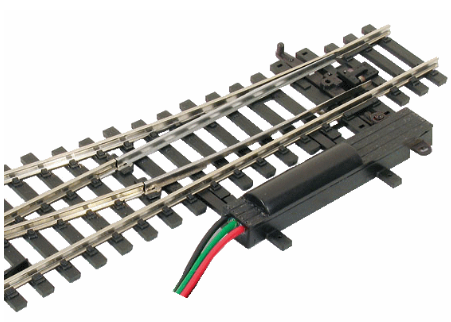
Peco

Like Hornby, Peco manufacture solenoids that plug directly underneath their own brand of point, resting in a slot cut out of the baseboard.
The image shows the basic PL10 model, operating on 16v AC.
Peco also sell a PL-9, which is a plastic mounting plate to make it easy to fit the solenoid above or under the baseboard.
If fitted under the baseboard, they recommend the PL10E, which is identical to the PL-10 but has a longer operating rod.
The other item sold for the PL-10 is the PL-13 accessory switch. It fits under the PL-10 and is operated by the lower part of the solenoid's operating rod.   It provides a single changeover switch.   Again, it uses a sliding metal washer contact with possible long term problems.



If you need two changeover switches, or simply more reliable switches, they sell the PL-15 accessory switch, as shown in this image.



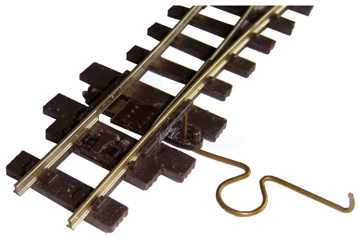


This image shows the PL-11 model, which is designed to snap on to the side of a Peco point.   Due to its smaller size, the use of a CDU is recommended to ensure positive point switching.

Non-solenoid point motors

Although a proven generally reliable system, the solenoid/CDU combination suffers from a number of problems:

- The long runs of wire between the switches and the solenoids requires heavy gauge wire to avoid voltage drops, due to the heavy current they have to carry.
- The fast operation of the solenoid armature produces annoying noisy thumps and clicks.
- The fierce operation of the points can loosen and damage point parts.
- The fierce operation of the solenoid's armature can hit the end so hard that it slightly rebounds, resulting in the point blades not lying flat against the stock rails.
- The movement of the point blades is too fast to look realistic.
- Most solenoid point motors have no adjustment – the armature simply travels from one extreme to the other. The user has to employ mechanical corrections to make the required point travel match the solenoid's actual travel. This usually involves fitting an omega loop between the solenoid and the point's tie bar, to absorb any unwanted movement (the shape of the loop allows it to compress or stretch). It may also involve fitting levers to adjust between the difference in tie bar throw and solenoid throw.



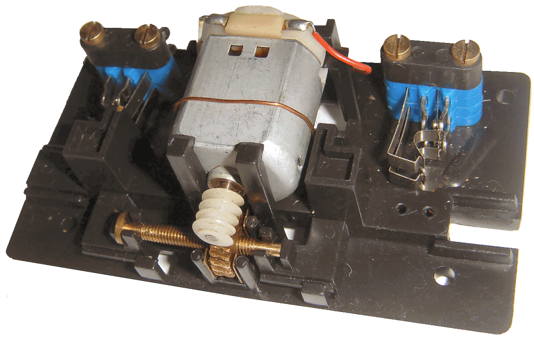
Most of these problems are solved by using motor-driven mechanisms.
They have the following advantages:

- They don't rely on short bursts of heavy current, so wiring is less crucial.
- They are much quieter when moving the point blades.
- There is no thump at the end of travel, so less wear on point parts.
- They produce a more definitive end stop, with no bounce back.
- The slow movement of the point blades is much more realistic.
- In some cases, you can set the end points, eliminating the need for omega loops.

Note

If your point has an over-centre spring fitted, so that the blades snap to either side once they pass the mid position, this should be removed to allow the smooth movement that motorised mechanisms provide.

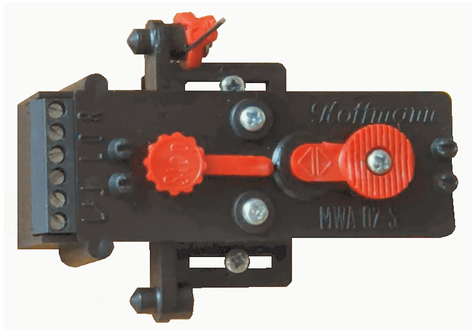
Fulgurex



The Fulgurex point motor is not the most popular seller but we start with this one because you can clearly see how it works (the other brands have their mechanisms encased in plastic).
A DC motor drives a worm and worm gear to produce a linear movement.
A rod to operate the point's tie bar can either be attached vertically to the moving bar (for under the baseboard mounting) or horizontally to the moving bar (for above board mounting). The motor runs on 10V-14V DC at around 200mA.

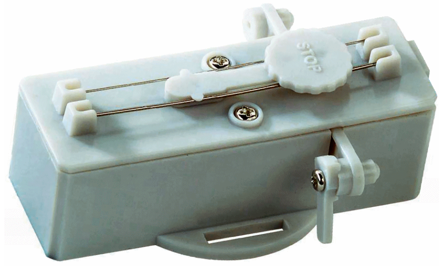
There are two layers of switches on each side of the motor.   The bottom layer is used to switch off the motor power when the bar reaches the end of its movement. The two upper sets of changeovers are available for frog switching, lighting LEDs, etc.   It is fairly large at 85mm x 50mm.

Hoffman



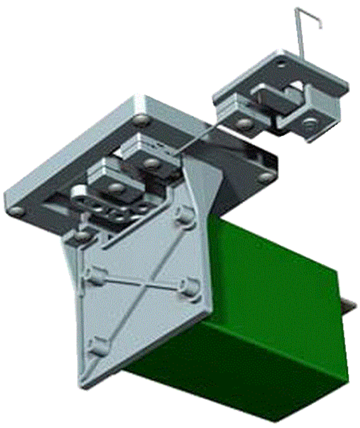
This is the Hoffman MWA02-S Point Machine.
It works on 16V at a fairly high current of 1A.
It has built-in limit switches that cut off power to the motor when the operating lever reaches the ends of its travel.   The operating wire rests on on a moveable cam that allows the lengths of travel to be adjusted.
It also contains an internal changeover microswitch.
It is substantially smaller at 68mm x 24mm.

Conrad



Like the Hoffman, the Conrad point motor works on 16V at 1A.
This motor moves faster than other motorised mechanisms but is still slower and quieter than solenoids.
Part 219999-62 is the basic mechanism and Part 219998-62 includes a changeover switch (using copper brush contacts which are not as reliable as microswitches in the longer term.

Tortoise



The Tortoise switch machine works different from the others above, as its motor is continuously powered.   It is known as a *'stall motor'* because it stalls at the end of each throw, avoiding the need for cut-off switches.
An unloaded tortoise draws 4mA while running, rising to around 15mA at stall.   The constant current means that there is constant tension between the point blades and the stock rails.
It is intended for mounting under the baseboard and is quite large at 60mm x 55mm x 85mm.
It has two built-in changeover switches.
MERG Technical Bulletin A06/2/2/2 covers the Tortoise in more detail.

Cobalt iP

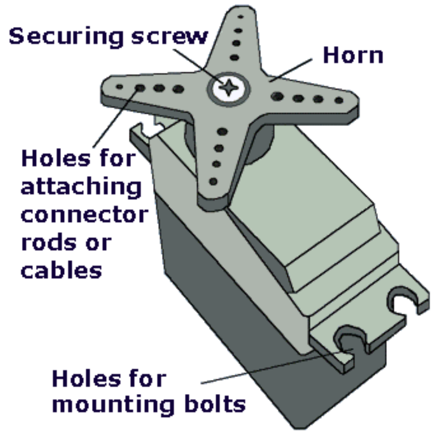
This slow-motion point motor has a DCC decoder built into is body, so it can be switched by your DCC controller.
It also has three SPDT switches.

Servos

Servos have become very popular in model railways in the last few years.
Servos are available in a large range of sizes, for industrial/military uses such as automatic machine tools and satellite tracking to domestic hobby uses such as autofocus cameras and radio controlled planes and cars.
It is the smaller, lighter servos that are common in model aircraft that are now found in railway layouts. Apart from their use in operating points, they can be found in semaphore signals, crossing gates and barriers, uncouplers, cranes, and a variety of lineside animations (moving people, animals, cars, aerials, radar heads, guns, etc.).

Solenoid mechanisms and most motorised mechanisms only move an operating rod between two fixed positions. This leaves the user to make mechanical adjustments to ensure that the point motor movement is accurately reflected in the required movement of the point's tie bar.
With servos, this task is eliminated. A servo can be made to stop at any position in its mechanical range – it does not have to go from absolute end to end. So, the servo can be made to move the point tie bar by the exact amount needed each time.
Not only can you decide where its end stop points are – you can decide what speed you want to move the point blades (from super-slow to the snap speed of a solenoid).

As the illustration shows, a servo is a plastic box with some mounting lugs, an output shaft that partially rotates. Apart from a connecting cable, there is nothing more on the outside.



Think of a servo as a motor that turns an output shaft (called a 'horn') through about 180 degrees (see later). With appropriate external electronics, the horn can be rotated to a precise point in that rotation.

Benefits

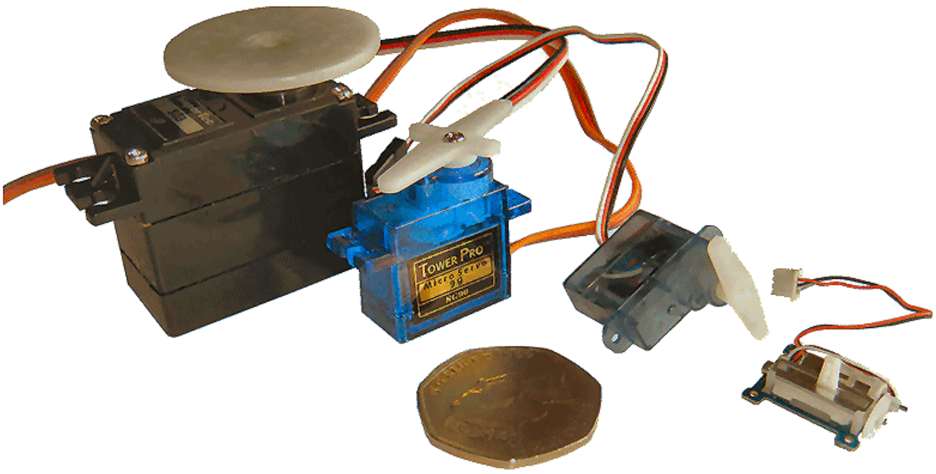
- Readily available from many sources.
- Cheaper than point motors.
- High torque.
- Accurate repeatable positioning.
- Can provide a fast movement like a solenoid, or can provide a slow smooth movement, which is more realistic and more gentle on point parts.
- Speed can be varied for each direction (e.g. to mimic a semaphore signal arm).
- Adjustments are electronic or computer based, rather than mechanical. So, point settings can be carried out remotely from the point.
- Unlike a solenoid that is either fully one direction or the other, servos can be rotated to many different positions (e.g. for a turntable, or flying a flag at half-mast).
- No annoying ‘thump’ as with solenoids.
- Works for all gauges
- Works with DC, DCC, CBUS, EzyBus, etc.

Drawbacks

- Normal point motors can be fitted 'straight from the box'. Servos need additional mounting arrangements and additional control circuitry.
- Unlike solenoids (with fixed distance movements) or Tortoise-like motors (with microswitches to set end stops) servos need to have a source of electrical pulses to determine their positions. Hence the need for extra electronics.
- Servos don't come with mounts for baseboards, unlike devices designed for model railway use. Modellers have to make their own mounting brackets, or buy commercial mounts that often cost more than the servo.
- Requires a little more technical expertise to construct and set up.
- Most servos work at around 5V, which is not a common power output from loco controllers – hence the need for extra electronics.
- Cheaper servos wear out after only 25 hours of use (on the other hand, that is 30,000 point operations based on 3 seconds per point movement).

Choosing a servo

With such a variety to choose from, its best to look at their specifications.
This image shows some of the smaller servos that are available. In most cases the middle two servos are employed for most tasks.



Servo specifications cover these factors:

Torque

A measure of the 'turning power' of a servo. It measures the amount of 'push' or 'pull' that the servo can handle before the motor stalls. Torque is measured in ounces*inch or kilograms*centimetre. Consider a servo that is rated at 2kg*cm, and has a horn with a hole drilled through it that is exactly 1cm distance from the horn centre. The servo would stall if it had move a mass of 2kg at that point; any mass less than 2kg can be moved by the servo. If the hole in the horn had a distance of 2cms, it would stall at 1kg.
It makes sense – the further out from the centre of the motor, the less able the motor is at handling mass. The horns that are supplied with servos have a number of holes at different distances out from the centre (see the earlier drawing). These allow operating rods, cables, etc. to be attached to them.

Servos are available in a wide range of operating torques. For example, the DYS0206 has a torque of 1.5Kg.cm, while the mighty Multiplex RHINO digi 4 has 24.47Kg.cm.
For comparison, the smallest servo in the photograph has a torque of 1.5Kg.cm, while the largest has a torque of 3Kg.cm. For operating lightweight fittings (e.g. signals or crossing gates) even the least-endowed servo will have no problem.
If you intend to keep using centre-sprung points, a little extra torque is required, compared to other points.

Operating speed

Retailers describe the servo's speed (or transit time, or servo turn rate) as the time the servo takes to rotate a certain amount. Thus, the Protech B305's speed is quoted as taking 0.2 seconds to rotate 60 degrees (0.25sec/60) and the tiny DYS0206 has a performance of 0.12s to rotate 60º. Servo speed is important when used to fly a model aeroplane but even the slowest operating speed is fast enough for model railway applications.

Weight

Again, this is very important for model aircraft but not normally a significant factor for railway modelling.

Size

This is less of an issue for operating points, as there is usually sufficient space under the baseboard. Smaller servos might prove useful inside small buildings and structures (e.g. people moving inside a signal box, or where a point has to be operated from above the baseboard). The most commonly used servos are significantly smaller than point motors.

Type	Case size	Possible uses
Large-scale	60mm x 51mm x 28mm	Robots, heavy work. Mostly non railway
Standard	38mm x 35mm x 19mm	Heavy work on layout
Mini	28mm x 25mm 16mm	Medium / light work
Micro	22mm x 16mm 10mm	Light work, small places
Ultra	20mm 15mm x 11mm	Linear (sliding door, semaphores)

Performance

The construction of the servo and the materials used have an effect on how smooth and reliable the servo operates. Compared to model aircraft and boats, servos in model railways would not likely suffer the same amount of constant use during a session. While an aircraft operator is constantly altering servo settings (i.e. many thousands of changes) during a flight, points or signals will probably enact much fewer changes in a session. Nevertheless, reliability can be enhanced by purchasing servos that offer improved construction such as higher-quality motors, double ball races, long life bearings or long life motor brushes.
The higher quality servos are designed for sudden acceleration and fast sequences of movements.
Servos with metal gears and metal output shafts have the most strength, handle the highest torque and are used where heavy or jarring loads are being handled. However, the gradual wearing away of the metal results in accuracy being slowly lost over time.
Nylon gears are cheaper, suffer much less wear but are less durable in adverse conditions, being prone to snap the shaft or a gear wheel when over-worked.
Karbonite gears are stronger and even more long-wearing than nylon gears and are found in servos such as the Hitec HS-6965.
For most railway applications, the cheaper nylon geared-servos are quite sufficient.

Here is a typical advert, providing specification details of a commonly used servo:

Tower Pro SG90 Heli/Aero Micro Servo A

Tower Pro A Grade Servo - A tighter and better manufactured SG90!

The weight of 9g is including the horn, this servo is only 8.5g without horn. Fast 0.9/Sec/ 60 degree speed and a whopping 1.6kg torque put this servo into a performance bracket of Servos twice the price and more ! Featuring an excellent quality casing and nylon gears this servo will suit Futaba, JR, Hitec, New Sanwa and many other radio systems with the same polarity.

This servo comes complete with fittings - when comparing prices check the servos are with fittings - many competitors charge extra for fittings!

Specification

Dimensions (mm): 11.0 x 22.0 x 22.0
Weight (grams): 8.5
Speed (sec): 0.11
Torque (Kg.cm): 1.60
Ball Raced: No

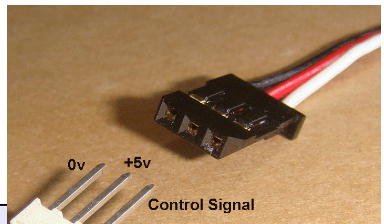
Price

£2.99 Each
4 for £11.00
10 for £25.00

Analogue / digital

Servos are available both as analogue (by far the most common) and digital versions. Both use the same motors, gears, etc. The difference is in the electronics inside the servo. The analogue servo checks its position 50 times per second and adjusts the rotation if required. The digital servo checks and adjusts 300 times per second. This results in faster operating speeds and a more constant torque. Digital versions are more expensive and provide no real added benefit for the tasks performed in model railways.

Connections



Most servos have three wires exiting the casing and terminating in a 3-pin socket connector as shown in the image. The wires are colour-coded and their uses are:

Wire Colour	Signal	Description
Red	+5V	Draws anything from 10mA to over 1A, depending on how powerful the servo is (read each servo's specification)
Black (sometimes brown)	Ground (OV)	Common connection for both the supply and the input signal.
White (sometimes Yellow or Orange).	Signal input	The incoming signal to the servo, to set the servo's position. The input can be fed from transistors, ICs (both TTL and CMOS), PICs, etc.

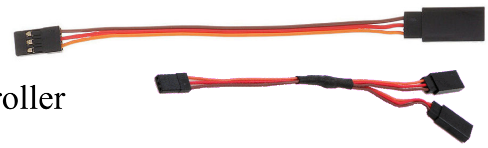
Most servos seem to use red, black and white wires but this varies between manufacturers. Also, most servos use the same order of wires on the connector with the red wire in the middle. Again, this is not always the case, so check before connecting.
The socket has square holes spaced 2.5mm apart, to accommodate PCB header plugs. These are available from MERG, Rapid, Farnell, etc. They can be purchased as 3-way single row PCB header plugs but is more economic to buy a 36-way strip and cut it into twelve 3-way pieces.

Note

The socket is not polarised, so the plug can easily be inserted the wrong way round. It is up to you to ensure that the plug is wired to match the servo socket – and is inserted the correct way round.

Extensions and splitters

The servo has a short connecting lead and this length can be increased by adding an extension lead.
You can also operate two servos from the one servo controller using a 'Y' splitter.

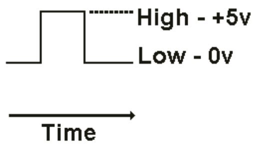


Control signals to the servo

Assume for the moment that the three wires from the plug are connected to some electronic device that is capable of controlling the servo (more on servo controllers later).
The servo, in addition to its motor and gearbox, has a small printed circuit board with its own electronics, including some noise suppression. The internal electronics translate the state of the incoming signals into the rotational position of the output shaft.
The servo operates on an input signal of 5 volts.

Low signal, also known as logic 0, is 0 volts
High signal, also known as logic 1, is +5V

The ground wire (usually the black wire) is held at zero volts. The red wire supplies the power to the servo and is held at +5V.   In fact, various servos can operate over a range of supply voltages from 3V to over 7V, depending upon the model.   However, its best to work on a standard of a +5V supply, since this is a voltage that all servos can expect to operate at.
The remaining wire sends +5V pules from the controlling electronics to the servo. Many people place a 10k resistor in series with the lead to the signal input, to limit the signal current into the servo.
The input signal sits at low level and is taken high for a certain period of time before being returned to low. This looks a square wave pulse as shown in the illustration.

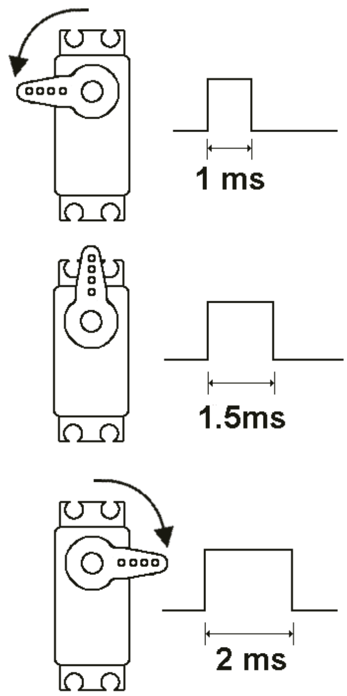


Timing and rotation

The control of the servo depends on this simple proposition:

The width of the input pulse to the servo determines where the output shaft rotates to.

So a particular pulse width should always result in the same movement of the servo horn.
All servos are designed so that a pulse width of 1.5ms rotates the output shaft to a mid position.
For the purpose of the illustration, a pulse of width 1ms (a millisecond – a thousand of one second) makes the output shaft rotate to its most counter-clockwise position and a pulse width of 2ms rotates the shaft fully clockwise.
This relationship between pulse width and rotational position is shown in the diagram. This supposes that the servo has a 180-degree maximum rotation. In practice, servos can be found with maximums that vary from around 90 to 180 degrees.

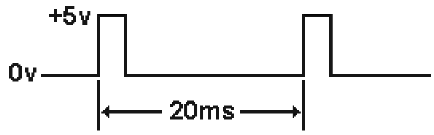


Some servos allow an input pulse to be as short as 0.6ms and as long as 2.4ms.   An example is the Geekservo 9g 270, with a 270° rotation (available from RoboShop, Pimoroni, etc.).

Note

While all servos of a particular make and model are identical, the range of available rotation and the pulse width required for that range could vary between different models. Modellers might consider sticking to one model for identical operations (such as points), or ensuring that replacement/additional servos have the same specification as those currently in use.

Other, physical, alterations to the servo are possible to obtain continual rotation with no ends stops. This is not normally needed for our purposes (if you need a rotating motor – buy a motor!) but interested readers can find details on this via Google.



Normally, pulses should be sent to the servo 50 times per second (i.e. every 20ms) to keep the shaft in any fixed position.
So, for example, to keep the shaft in mid-position, pulses of 1.5ms duration would be sent every 20ms. Many experiments using different servos has shown that while desirable, this is not strictly necessary.

Where a servo is under strain, such as supporting a weight or acting against a spring, repeated pulses are required to ensure that the load does not move the shaft from its chosen position. In other situations, such as centre-sprung points, a few pulses are sufficient to move the blades, which are then kept, in place by the spring. Also, light loads such as signals and swing gates do not require constant refreshing, as the friction in the servo gears is sufficient to maintain position.

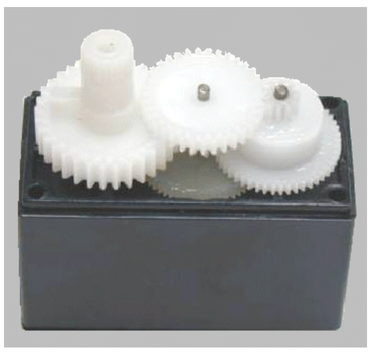
Where a stream of pulses is used, the pulses do not have to be at the exact 20ms rate. Anywhere between 15ms and 40ms works quite happily.
Repeating the pulses too frequently (e.g. 10ms) may cause servo jitter/chatter, produce a buzzing sound, or make uncontrolled movements. Repeating too infrequently (e.g. 70ms) may cause the servo to shut off and the shaft might lose its rotational position.

Also, the pulses do not have to be repeated at exactly the same rate. So, there could be a 25ms between some pulses and 35ms at another point in time.
This is because the <u>length</u> of the pulse is the most significant characteristic of the input signal

How a servo works inside

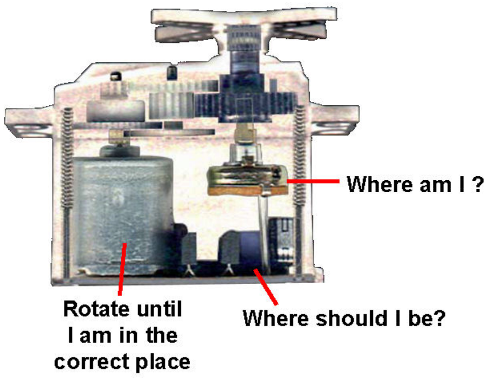
This raises two questions:

- How does the servo motor know when it has reached its required position?
- How does the servo automatically maintain its position, assuming a regular pulse stream?



The answers lie in the internal workings of the servo.
The image shows a servo with its upper casing removed.
On the left is the output shaft and this is rotated via nylon gears to a motor whose shaft can just be seen on the right of the servo.
Inside the case, there is a small potentiometer (variable resistor) connected to the output shaft. As the shaft rotates, the potentiometer's value is altered and the resulting change is fed back into the servo's circuitry.

This allows the circuitry to act as a ‘closed loop’. It knows what value should be fed back from the resistor for any given incoming pulse width. If both values correctly match, the motor is not energised since the servo is already in the correct rotational position.
If the value of the requested position (given by the pulse width) doesn’t match the current actual position (given by the value from the variable resistor), the motor is turned in the appropriate direction until the two values match. At that stage, the motor stops drawing power.



More technical explanation

The servo’s circuitry uses a pulse width comparator. It compares the width of the incoming pulse with a pulse from a one-shot timer whose period is set by the potentiometer value.
The difference signal feeds a flip-flop circuit whose outputs determine the motor direction and drive an H-bridge circuit to provide the high current to supply the motor
The in-built feedback mechanism will handle any external force that tries to alter its position. So, if a heavy load begins to turn a servo from its designated position, the movement is detected and the motor is re-energised to bring the shaft back to the chosen position. Just try turning a horn with your fingers when the servo is being sent positional pulses!

Servo accuracy

To be really useful, you have to be able to depend on the accuracy and repeatability of the servo's rotation – for any given pulse width, it must always rotate to the same position every time.
However, tiny overshoot adjustments must be minimised, otherwise the servo would be continually drawing current as it makes tiny jittering movements back and forth.
For most servos, therefore, there is a trade-off between absolute resolution and ignoring tiny insignificant signal changes (known as the 'deadband').
Lets look at an example.

> A servo's incoming signal can vary from 1ms to 2ms – a difference of 1ms, or 1000µs (microseconds). There are no occasions when you would require the servo to take 1,000 steps to get from one end of travel to the other. For the sake of the example, let's say we are happy with using 50 different steps (still quite a lot). That means the width of the incoming signal would change by 20µs (1,000µs divided by 50 steps) to move to the next step. If the servo had a deadband value of 10µs, it would ignore all pulse width changes of 10µs or less – resulting in greatly reduced unwanted small movements, less current draw and less overheating of the servo motor and its electronic components.

In practice, servo deadbands vary between 1µs and 8µs.
In precision military and scientific applications very high specification servos are used with a very narrow deadband and this allows for greater resolution for the servos.
In a hobby situation, where the incoming signal cannot be guaranteed to be stable, or where cheaper servos are in use, a wider deadband allows for greater stability at the cost of resolution.

If we look at a servo with a 90º maximum rotation and a 2µs deadband, the resolution that is available would be 90 x 2 / 1000 = 0.18º, which is more than sufficient for all model railway activities.

Servo problems

Servo systems are generally very dependable but, like all electronic and mechanical systems, there are potential problems that may need addressed.

Buzzing

The servo's deadband prevents unwanted servo movement for tiny pulse width changes. But there are other problems that might prevent the servo reaching its deadband area.

- Sticky / blocked points – if the servo cannot move the point blades to the required position, due to debris on the track or a gummy tie bar, the servo will carry on trying to finish its task. The servo motor will buzz as it tries to reach its final stopping point.
- Incorrect alignment – the mechanical linkage between the servo's horn and the tie bar are improperly aligned, preventing the servo from reaching its final destination.
- Incorrect settings – the mechanical arrangements are fine but the servo has been given an incorrect final stopping point and is trying to move the tie bar beyond the stock rail.
- Poor power regulation – the glitches in the power supply to the servo, or its controller, or both, affect the voltages fed to the servo's internal comparator circuit. A servo only consumes a few mA when stationary but this can rise to 500mA when rotating, depending on the servo size and model.
- Interference – pickup of unwanted signals (noisy loco motor, DCC messages, CBUS messages, etc.) appear to the servo's signal wire input as movement instructions.

These problems can be resolved by ensuring that the points are kept clean and clear, the mechanical link between servo and tie bar are aligned properly, the servo is correctly configured and that the power and signal wires are routed to avoid interference.

Kicking

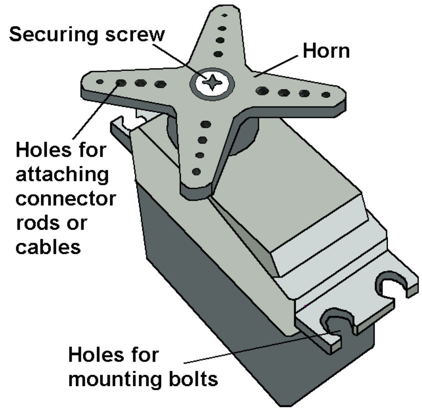
It is well-known that most servos produce a 'kick' (an unwanted movement) when they are first powered up. This is a feature of their internal electronics and is cleared in almost all cases by soldering a 10k resistor between the servo's signal wire and the +5V supply line. In some cases, it only effective if wired across the signal line and the 0V line. Configuration of the control electronics can also minimise this effect.

Twitching

Unlike the kick, which only happens during power up, servo twitching occurs during the running session.
This is almost always a result of external interference and can tackled by careful routing of layout wires, or placing a capacitor between the signal wire signal and 0v to shunt away any high frequency spikes on the signal wire.
Alternatively, the problem could be tackled at the servo controller end. If the servo needs to keep pressure on, it requires the constant repetition of the incoming pulses. Otherwise, the servo controller could be organised to stop sending pulses after a few seconds.

Although this looks like a long list of problems, in practice they are all either avoidable or are usually easily remedied.

Fitting servos

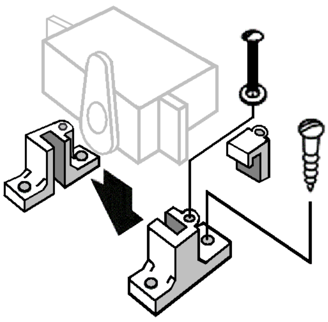


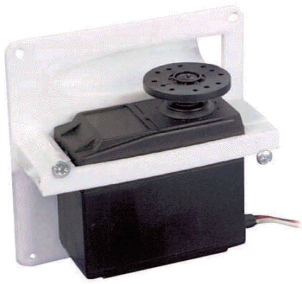
The illustration shows the key elements for fitting servos. Usually, the lever (called a 'horn') and fitting screw is supplied with the servo. Often, a selection of horn types is supplied. The horn has multiple holes drilled in it. The choice of horn, and the way it is used, allows a servo to provide either a rotational or linear motion.
There are mounting lugs lips on the side of servos; larger servos have four holes, two each short side and the smaller servos provide a single hole at each end. Some retailers also supply rubber grommets. These fit in the holes to provide a degree of suspension, which is useful in vibrating environments such as model aircraft.. They are often left unfitted to ensure accurate repeatable positioning of the servo horn.
There are two problems facing modellers:

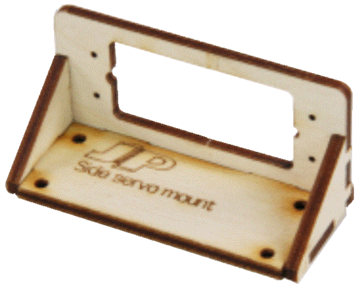
- Mounting servos to baseboards, inside buildings, etc.
- Fitting operating arms, cables, etc.

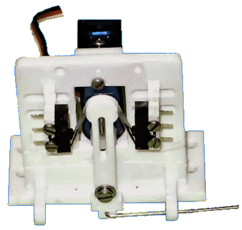
Commercial mounts

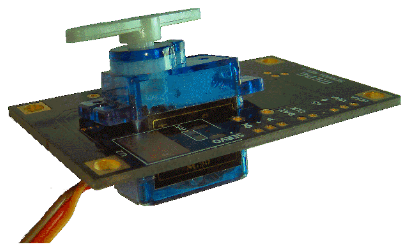
These images show a range of the mounting brackets that are available from dealers.









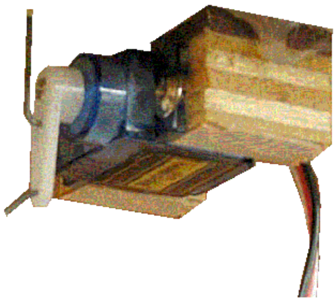


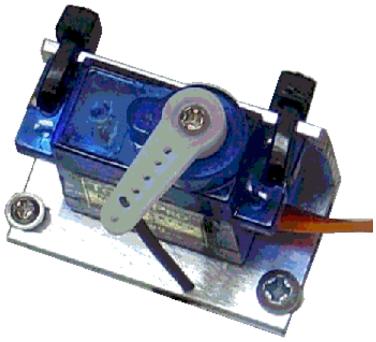
Top row: Small plastic mounts (eBay)
Solid one-piece plastic mount (SLEC Ltd) – plastic version from Conrad
Plywood self-assembly bracket (J Perkins)
Bottom row: Aluminium bracket (Active Robots)
Plastic self-assembly bracket, with two microswitches (MERG)
Servo1 PCB that acts as a mounting bracket as well as providing
the control electronics (MERG)

The images, which are not to scale, show that a variety of materials have been used in their manufacture.
Unfortunately, in most cases, the cost of the brackets exceed the cost of the servos themselves, although the MERG version is cheapest and provides additional facilities.

Home brew mounts

The relatively high cost of commercial mounts has led to hobbyists developing their own cheaper alternatives.
Modellers will provide endless alternative means of fitting servos and using them to operate devices. These images show three such approaches.





The servo on the left is screwed onto two small wooden cubes of the type that you buy as a bag's worth in a craft shop. The blocks are then glued to the underside of the baseboard.

The middle servo uses a piece of aluminium angle that you can buy in DIY stores. Two holes are drilled in the side and the servo is held in place by plastic ties. Two other screws hold the angle piece to the baseboard

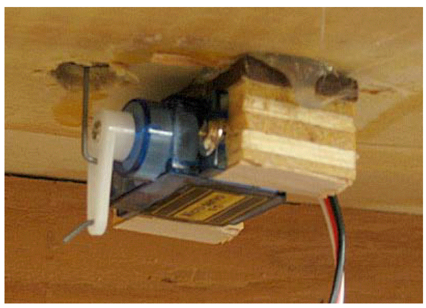
The servo on the right has been 3D printed.

All three methods allow the mount to be fabricated before fitting to the layout.

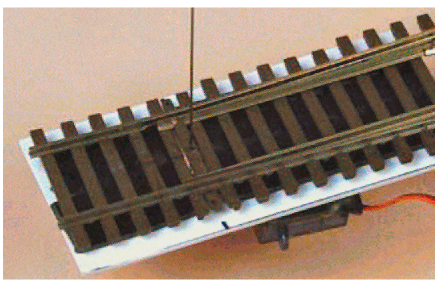
Attaching points to the servo

You can still use a servo to operate a point using the traditional indirect methods such wire in tube, omega loops, cranks and levers. In fact, this might be the best way for points that are not easily directly accessible through the baseboard.
For most servo users, however, the servo operates the points using a length of piano wire. There are two ways to achieve this:

Direct



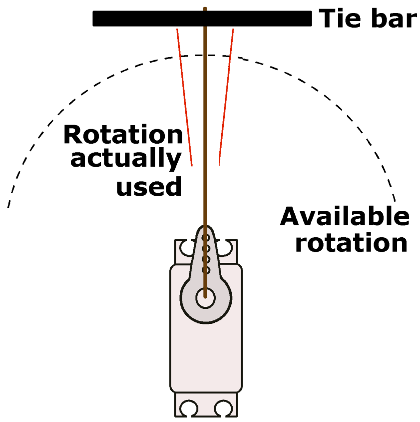
This is the most simple method and is shown in these images. The piano wire is connected to the servo horn, bending the wire through the horn holes (some even securing it with additional wire binding and enclosing with epoxy).



The piano wire passes through a slot in the baseboard and protrudes through a hole in the point's tie-bar. It needs no other mechanical linkage; as the servo rotates, the piano wire slides the tie bar.

This method works happily in many situations but has some limitations.

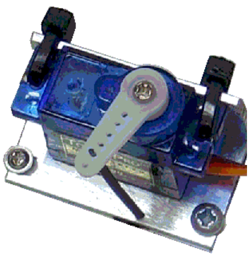
Consider this illustration showing the direct movement of the point tie bar with servo rotation. As you can see, the servo is capable of a much greater range of rotation than that being used to move the tie bar.
In fact, as the piano wire length is increased, the servo will rotate less and less to achieve the same amount of lateral movement of the point.
This has two effects:



- Although the servo can complete its arc of travel using many different step (e.g. 256 steps) the tie bar is moved end to end with very few steps (e.g. 8).
  This greatly affects the movement resolution, as a slow motion point change would finish in just 8 steps, resulting in a more jerky movement.
- Small changes in servo rotation result in large swings at the end of the piano wire. This turns small unwanted kicks into potentially large and destructive jolts of the tie bar, unless stringent steps are taken to minimise start-up kicks, interference, etc.

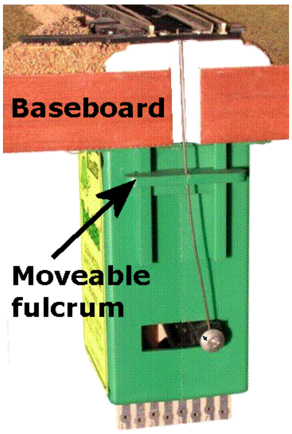
Pivot

This method is safer and more realistic.
Looking again at these two home-brew mounts, we can see that they also have long piano wire actuators – but the fulcrum is not at the servo end, it is near to the tie bar.



So we have the opposite effect of direct linkage. A large rotation of the servo results in a smaller lateral movement of the tie bar.
Thus, we have the horn rotating almost from end to end. The many steps to move the point provide smooth slow motion.
Also, any 'kicks' have no effect, since the servo works at its extremes anyway.

The hole at the fulcrum must be small to eliminate any wiggle room.



The pivot method is the most configurable, with plenty of options for tweaking the movement of the wire actuator.
The piano wire can be inserted in any hole in the horn arm, providing different amounts of leverage. You can also set the distance from the horn to the tie bar and the position of fulcrum.
Finally, you have the ability to change the servo's end stop positions in software.

The image on the left shows how the Tortoise point motor using a sliding fulcrum to adjust the amount of leverage.

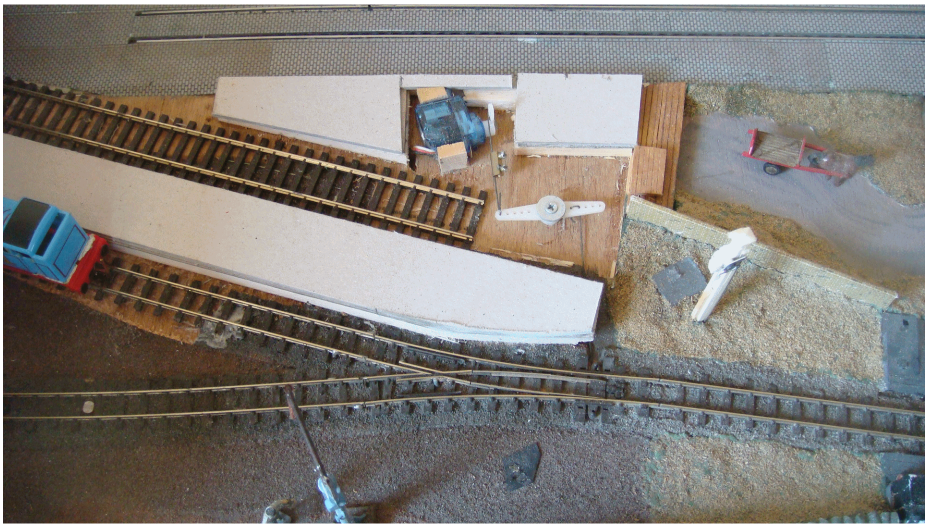
Indirect linkage

You cannot always fit a servo under a point; there may be a baseboard batten in the way, or another servo is too close by.

In those circumstances, you can fit a servo above the baseboard.

This image shows a servo embedded in the baseboard and connected to the point's tie bar using an omega loop.

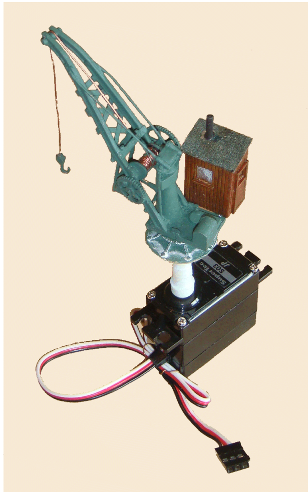
Sometimes there is the option of fitting a servo in a building, behind a wall, in a hill, inside bushes, etc.
This image shows a servo hidden inside a station and using a crank to switch the point.



If you want that authentic look, DCC Concepts has a range of point rodding accessories. The points can be operated manually with a lever frame or be controlled by point motors or servos.

Moving accessories

Servos are commonly used for point control but can be used for a wide range of lineside accessories, such as crossing gates, sliding doors, cranes, semaphore signals, uncouplers, grade brakes, etc.



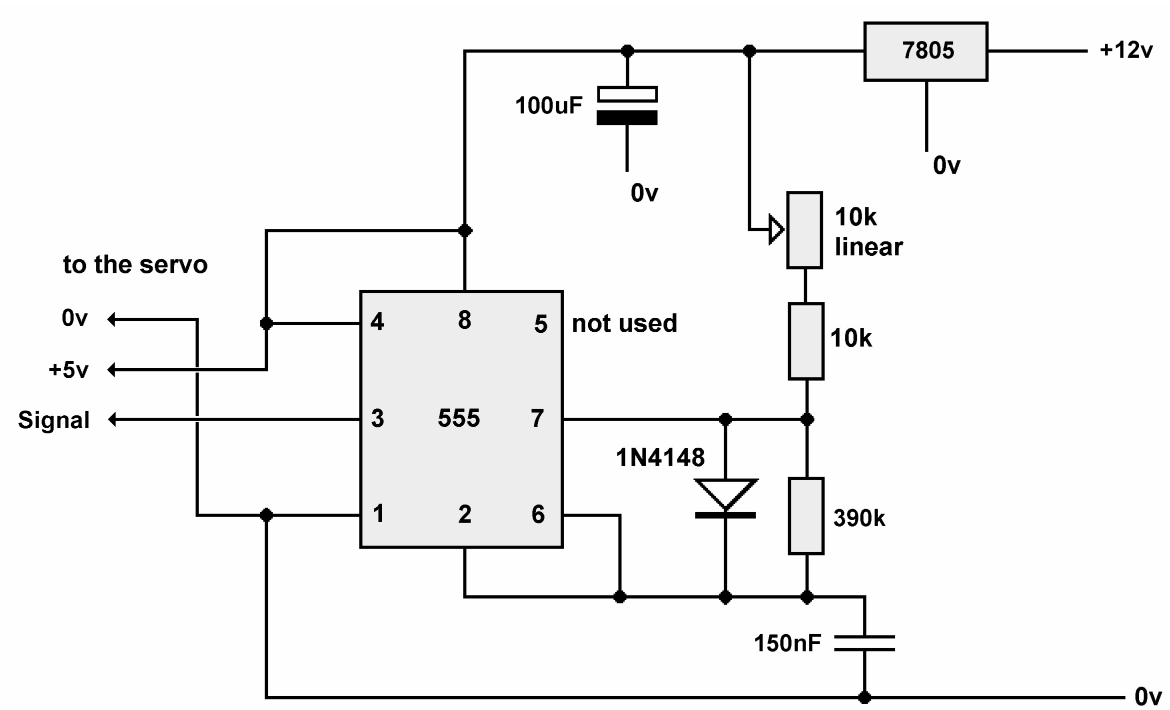
The image on the right shows a model crane epoxied to a plastic tube that is run through a hole in the baseboard and is a push fit on to a servo's output shaft.
Servo use is only limited by your ingenuity.
This is looked at in detail in the chapter on '*Animations*'.

Controlling servos

To control a servo, we need a source of pulses as described earlier. The circuit is called a 'servo controller' and can be built from transistors, 555 timer chips, flip-flop ICs or PICs. The circuits can be controlled from mimic boards or from computers.
They can be built from scratch, from MERG kits and from commercial control boards.

A basic home-brew controller

The circuit below is ideal if you want to experiment with servos without committing too much cash. The only costs are a cheap NE555 IC, a handful of components and a single servo. It is a tried and tested circuit and is available as a MERG kit.



The 555 chip is a timer IC which is just what is needed for creating timing pulses.
Servos expect to receive regular pulses on their *'Signal'* wire (the other two wires on the servo are for our 5V power). The pulses on the signal wire should vary in duration between 1ms and 2ms and be repeated every 20ms.
The 390k resistor and the 150nF capacitor are used to control the time between pulses, while these same capacitors are used in conjunction with the two resistors and 10k

potentiometer to control the length of the pulses. So, varying the resistance of the potentiometer controls the servo arm's rotation.

The circuit works from a standard 12V DC supply and uses a 7805 voltage regulator to bring the voltage down to 5V for the chip and the servo.
For more details on 555 timers, read John Matthew's article in the MERG Winter 2006/7 Journal.   Another very simple servo circuit is printed in the Elektor magazine Jul/Aug 2008 edition. This circuit uses a 7400 IC.

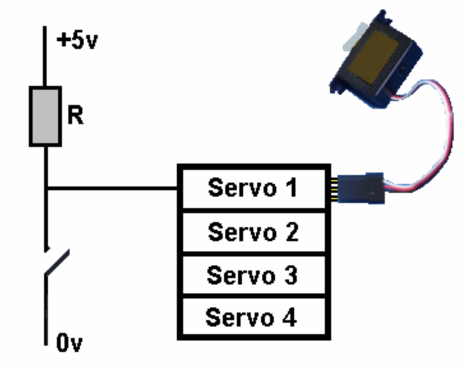
Although simple, their uses include:

- A cheap introduction to playing with servos.
- A module to test servos before fitting them on a layout.
- Manual control of aerials, radar heads, guns (great for kids).
- When you need to move to intermediate positions (e.g. a flag at half mast)
- Mounting a camera on the arm, so you can scan a hidden area of the layout.
- An asymmetric turntable for smaller gauges (the pivot point is near one end rather than the centre).
- Any manual control for occasional use.

For many purposes, a more comprehensive controller is required.

So, what are the requirements for a model railway servo controller:

1. Easily operated by switches (control panel)
2. Easily operated from other railway modules (e.g. track detectors)
3. Easily operated by a computer
4. Easy to set a servo's endpoints (the limit of travel in each direction)
5. Easy to set the speed of servo rotation, preferably with each end point being able to be set independent of the other (e.g. able to move fast in one direction but slow in the other direction).



The first three requirements are usually met by having a controller that has a separate input pin for each servo. Pulling the pin to 0v makes the servo rotate in one direction, while pulling the pin up to +5V makes the servo rotate in the opposite direction.   By operating from a simply change of voltage level, the servo controller input can be attached to anything that produces that voltage change. In most cases, this would be a simple on/off switch in the control panel, as shown in the illustration. Otherwise, any circuit that switches logic level (between +5V and 0V) can be attached to the servo controller input pin.

The fourth requirement, setting the end points, is either accomplished by a computer software application, or by using switches / pushbuttons on the servo controller board.

The last requirement, altering the speed of servo travel, is provided by some controllers, while others simply switch at a set speed.

Commercial controllers

The benefits of these boards are that they are supplied ready-built and tested.
There are three categories of servo controller:

- Industrial / military / scientific / medical – High specification, high price, modules that are not covered here.
- Model railway controllers.
- Hobbyist robot builders.

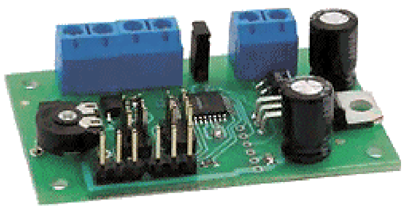
Model Railway Controllers

These three models are specifically designed for the model railway market.

Viessmann 5268 Servo-Control

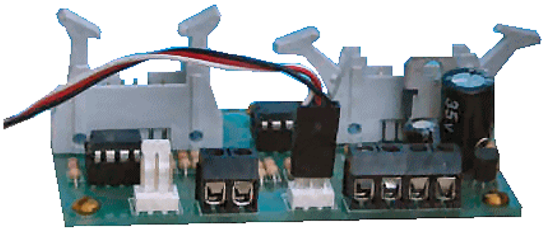
This servo controller uses a supply of 10V to 16V, AC or DC and converts it down to 5V to operate the servo.
Unfortunately, it only operates a single servo.
This is fine if you only want to have the odd feature here and there on your layout (e.g. a signal or a crane).
It is too bulky and is not cost-effective if you want to operate dozens of points.
The end stops are set using two separate adjusters.
There is no control over servo speed.

Conrad Train Module 73726



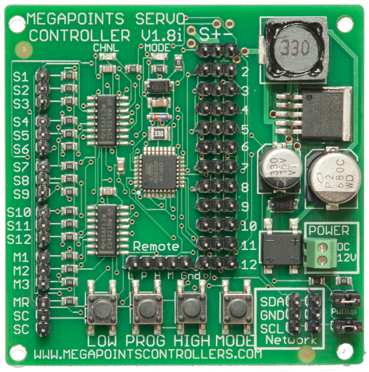
This controller is a little better, as it handles two servos.
It uses a supply 7V to 24V, AC or DC and converts it down to 5V to operate the servo.
Like the Viessmann, it is really only suitable for occasional servo use on a layout.
There is no control over servo speed.

Heathcote Dual Servo Motor Controller



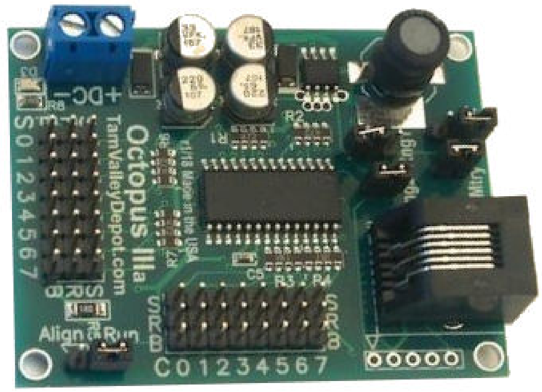
It uses a supply of 9V to 16V, AC or DC.
It also only handles two servos, limiting its appeal for point operations.
The endstops are set using two pushbuttons.
Seven different speeds can be set, using another pushbutton.
The sockets that can be seen at the back of the board are for connecting a remote setting box that replicates the boards pushbuttons. This saves you having to adjust point servos while crouching under a baseboard.
It has an interesting sequence facility, allowing you to control one servo from another. This can be used for crossing gates, as the second servo will only start to move when the first has finished rotating.

MegaPoints



This is the MegaPoints Servo Controller.
It can control twelve servos, either from its twelve input pins or from its own network interface.
Servos can be set up for endpoints, speed and semaphore bounce.
These settings are configured using a sequence of button pushes with LEDs showing selections.

Tam Valley



This image shows the Tam Valley Octopus III model.
It uses a supply of 7V to 18V, DC only.
The rows of pins along the bottom are for connecting 8 servos.
The rows of pins on the left are for connecting 8 toggle switches, or digital inputs.
Octopus III uses a remote board to align the servos and has automated endpoint adjustment as well as full manual control.
You can also buy a DCC add-on board to allow the servos to be operated from a DCC controller.

Robot servo controllers

A larger range of servo controllers has been developed for designers of robots.
They are more comprehensive and more complicated.
Some of the earlier controllers we looked at handled too few servos to be useful on a large layout. Robot controllers, on the other hand, can handle up to 48 servos from the one module. However, this is not as great an advantage as might be initially considered, since it would mean having a central servo controller with many extension leads snaking all over the layout to reach each servo.
The biggest drawback for most robot controllers is that they do not have a simple on/off switch approach to moving servos, relying instead on computer serial or USB port connections or special microprocessor signals.
Although they often provide extra facilities beyond simple servo switching, they require a degree of programming knowledge.
Here is a list of some robot servo controllers.

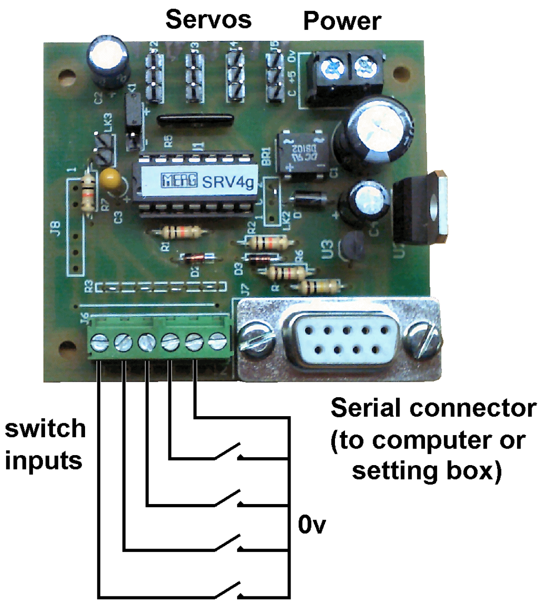
Website	Order code	Description
Www.proto-pic.co.uk	Pololu Micro Maestro 6 Pololu Mini Maestro 12	Drives 6 servos via a USB connection Drives 6 servos via a USB connection
www.rapidonline.com	Adafruit 815	Drives 16 servos via an I2C connection.
www.active-robots.com	16xRC Servo Phidget	Drives 16 servos via its VINT WiFi hub
www.robosavvy.com	Lynxmotion SSC-32	Drives 432 servos using USB or XBee

MERG controllers

MERG offers a number of controller kit options.
Two have input pins that connect to switches and other digital inputs, while others are designed to work with bus systems.

Servo 4

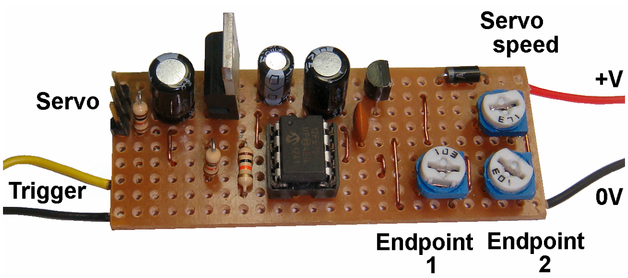
This image shows an assembled Servo 4 kit.
It uses a supply of 12V DC or 9V AC.
There are four servo connections at the top of the board. The four left-most connections in the lower screw connector block are the inputs that control the servos.
They are held at +5V internally but can be brought to 0v when they are wired to switches that are connected to the module's 0v line (the fifth connection). These switches would most likely be on a mimic board or control panel.
This module allows both a servo's endpoints and speed to be set, via the serial connector, using MERG's software utility (free to members).



You can program the board directly, if your computer has a serial port, or through a USB-to-serial adaptor if your computer only has a USB socket.
If you prefer, you can plug MERG's setting box into the serial connector, instead of using a computer.

EzyPoints

This module controls a single servo, requiring only connections to a 12V DC supply, the servo and a simple on/off switch to operate the point. (across the wires marked as 'trigger')
It is suitable for use on DC, DCC, EzyBus and CBUS systems and does not require a computer to set it up.



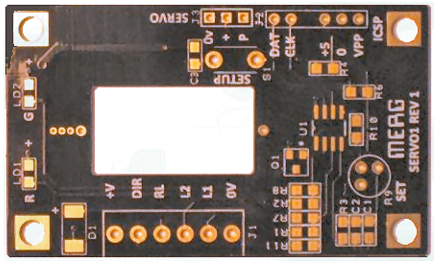
The picture shows a completed kit.
It has three trimmers and these are adjusted using a small screwdriver.

- One sets how far the servo rotates in one direction when the switch is closed.
- Another sets the servo position in the other direction when the switch is opened.
- The third sets the speed at which the servo arm turns.

The trimmers allow you to use the servo's endpoints for other purposes (e.g. 90º for a barrier gate, 45º for a signal, 140º for an animation, etc.).
You can choose either a maximum rotation of just over 90º or just over 180º.

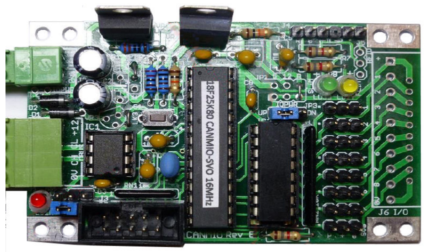
It is also capable of being operated by other MERG modules.
This allows, for example, the *remote* operation of points/features by connecting the outputs of a train detector module to the input of the EzyPoints module. Points/features can then be controlled from your control panel or DCC command station.
Example uses are detecting when a train is in a particular track section and station/yard lights coming on, doors opening, cranes moving, sounds being played, etc.

Servo1



This design from MERG member Trevor Stockill also operates a single servo.
However, it has a number of additional features.
The PCB has a rectangular slot with holes either side, as shown in this image. This allows a servo to be be screwed or bolted to the PCB, which has holes in each corner for mounting on a baseboard. This saves the expense of a separate mount.
It has two output connections that change state at end of the servos' rotation – ideal for LEDs. It has another connection for operating a relay – ideal for frog switching.
The servo's endstops are set with a pot and pushbutton.
Unlike the Viessmann or Conrad controller, the Servo1 lets you choose the servo's speed (using a single pushbutton).
It operates on either 5V or 12V DC.
It uses surface mount components (some as tiny as a grain of rice) which requires good soldering skills and good eyesight/large magnifier.
It is not available as a full kit, but the PCB and a pre-programmed PIC chip are available.

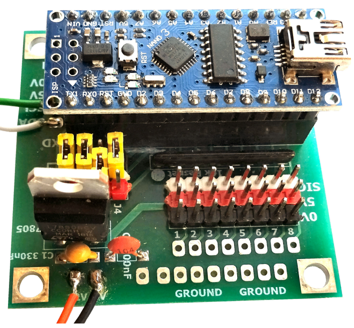
CANMIO for CBUS



The **CANMIO-SVO** module is designed for that use with the CBUS system (see the separate chapter on this). It operates at 12V and handles up to 8 servos with the option to have 8 digital inputs.
Servos plug directly into the row of three pin plugs.
The digital inputs could be used to provide feedback from microswitches on a point's tie bar (specially useful for automated systems).

EzyBus Output Module

This module is designed for use with the EzyBus system (see separate chapter). It has a row of 3-pin connectors for connecting up to 8 servos.



The servos can be used for points, gates, signals, animations, etc.
It also has another 8 digital connection pads whose outputs can either be made high or low. The digital outputs can be used for other non-servo point controllers, frog switching or for control of lights, sounds, relays, motors, etc.
You can have any combination of servos and digital outputs.
You could use a module as all servos, all digital outputs, half and half, or any combination.

Installing a servo

This depends on the exact nature of the installation – where it sits (above board, under board), the method of actuation (piano wire, levers, wire-in-tube), etc.
Lets assume for this explanation, that we have servo screwed on a mount, wired to a controller for under baseboard operation using piano wire.
Before screwing the mount to the baseboard:

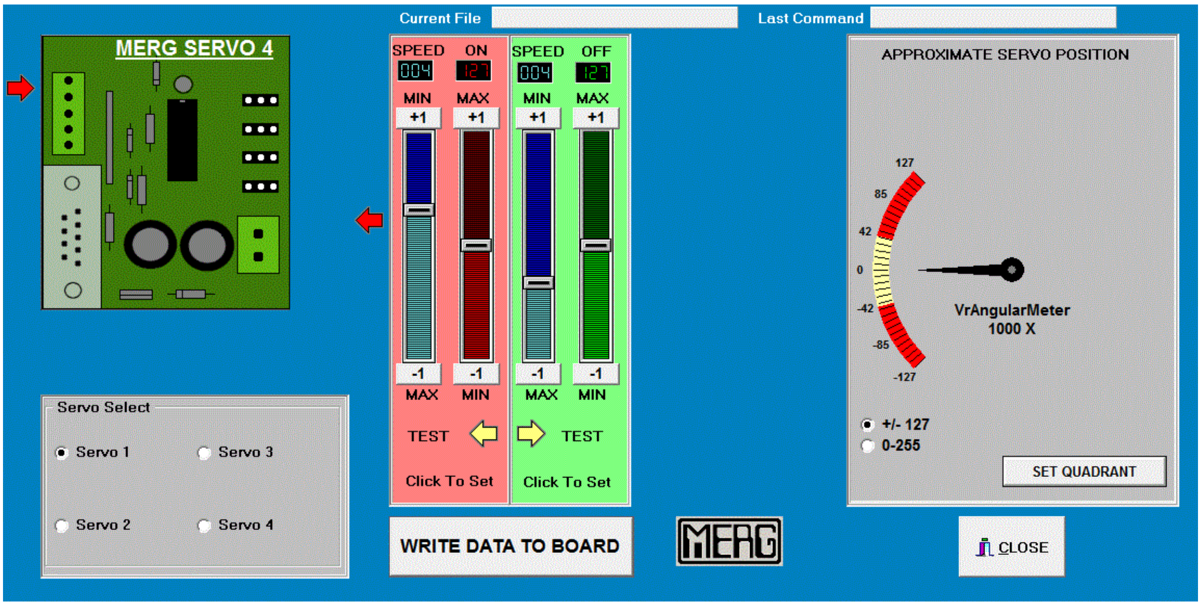
1. Use the servo controller to rotate the servo to its mid-position.
2. Fit the servo horn so that the hole being used for the piano wire lines up with this mid rotation.
3. Move the point tie bar by hand to mid position between both stock rails. Secure in that position with a piece of card/balsa/ foam.
4. Slip the piano wire through the hole in the baseboard from underneath and gently insert into the hole in the point's tie bar.
5. Move the servo and its mount to a position where there is no side pressure on the piano wire (i.e. the entire servo/wire/tie bar are in alignment).

Then:

6. Screw the mount to the baseboard.
7. Adjust both servo endpoints using the servo controller (this may be using pushbuttons, switches or software depending on the controller being used).

Configuring the Servo4 module

The software used to configure servos on the Servo4 controller can be downloaded from the MERG website.
When installed on your computer and run, it shows the following menu screen:



You choose which servo to configure by clicking in the "Servo Select" options.
The two left-hand sliders set the endstop and servo speed when the controller's chosen input goes high. The two right-hand sliders set the endstop and speed when the input goes low. As you move the 'ON' and 'OFF' sliders, the servo position is instantly altered. Also, you can click the "Test" arrows to check that the servo swings are satisfactory before selecting another servo to configure. When finished, clicking the "Write data to board" saves all the settings and the connection cable can be removed.