Super-PID – Closed-loop optical P.I.D router speed controller

Congratulations!

Congratulations on purschasing your Super-PID closed-loop router speed controller!

It has been designed to offer a high level of performance and reliability and can provide many benefits to your CNC router including; Quiet router operation, good low speed power, accurate tacho RPM display, router power display, accurate RPM adjustment and repeatability, increased tool life and router bearing life, reduced router heat, reduced energy consumption and the ability to cut and drill low melt-point plastics like polypropylene and polyethylene using low RPM.

Updates and more information.

Your Super-PID has a removable microcontroller, so the microcontroller may be unplugged from its socket and mailed back to the manufacturer to receive firmware upgrades.

When you first turn on your Super-PID it will display the firmware version on the display, which will look something like this; "Super-PID v1.0". If there is a new improved firmware available it will be mentioned on our website; **www.SuperPID.com**

Setting up your Super-PID.

Initial setup and testing the spindle sensor installation only requires a 5 volt supply. We recommend you do the initial testing using just the 5v supply, with no mains wiring connected.

First connect a clean, filtered regulated +5VDC supply; such as your existing stepper driver 5v supply, USB 5v supply from PC, or a REGULATED 5v plug-pack supply. The two wires from the 5v supply connect to the Super-PID low voltage connector (see wiring diagram).

When in STOP mode, the display bar shows what the spindle IR sensor sees;

When the spindle IR sensor sees black, the bar should be as low as possible (shown above).

When the spindle IR sensor sees white, the bar should be as high as possible (shown above).

Power up sequence;

1. "Super-PID v1.0" - displays Super-PID firmware version.
2. Checks for mains connected.
3. Tests 50Hz/60HZ frequency calibration.
4. Goes into Stop Mode.
5. Goes into Spindle View mode.

Spindle View Mode.

The bargraph displays the white/black result as seen by the spindle RPM optical sensor. This is the standard mode whenever your router is stopped and it allows easy testing of the spindle sensor before starting a cutting job.

Pot View mode.

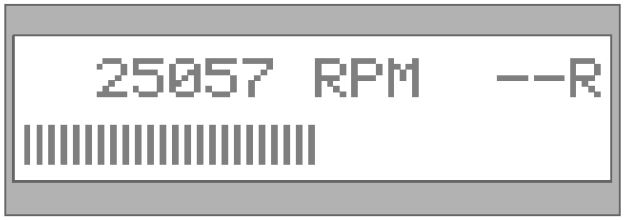
If you quickly turn the speed control pot when in Spindle View Mode, the Super-PID goes into Pot View Mode. The bargraph now displays the position of the pot knob. This allows testing of the pot.

Run Mode.

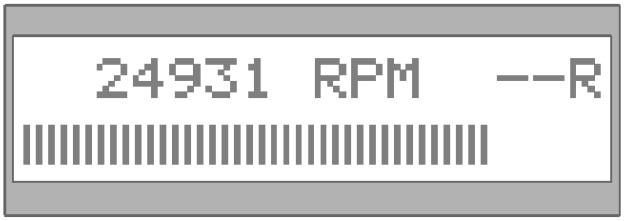
If the RUN input goes high (to 5v) and there is mains power connected, the Super-PID will go into Start Mode to bring the router up to speed and then straight into Run Mode. If there is no mains connected, the RUN command will be ignored.

When in RUN mode, the top line shows the router RPM.

At low RPM and not cutting, the power used by the router is quite low (see the POWER bar).



At higher RPM the router uses more power.



When taking a cut the power increases further. When the POWER bar reaches full the router is running flat out.

Super-PID advanced features.

The Super-PID has some optional advanced features. These are selected by a 4-pin jumper on the Super-PID circuit board.

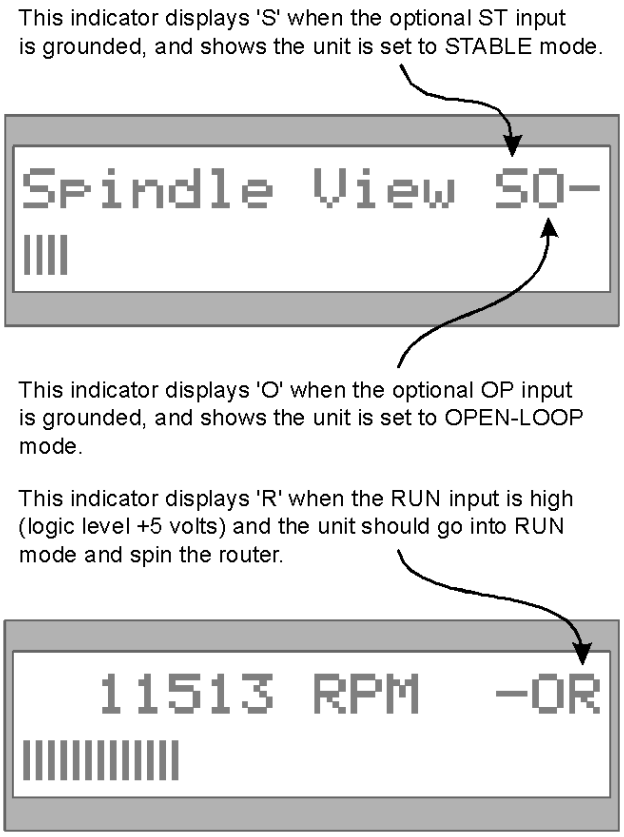
Open-loop Mode.

Joining terminals 3 and 4 selects Open-loop mode. In Open-loop mode the Super-PID ignores the spindle speed sensor, and performs just like any crude router speed control knob. Open-loop mode may be useful for testing, or to operate the router when the spindle sensor is disconnected or removed.

In Open-loop mode there is no P.I.D. speed regulation, so low speeds will have very little power and you may need to crank the speed up to cut successfully. Also, in Open-loop mode there is no safety power reduction

if the router jams or siezes. You might choose to add a switch between these two terminals to allow Open-loop mode to be quickly selected.

Stable Mode.
Joining terminals 1 and 2 selects Stable mode. Generally this mode should not be needed as the Super-PID has already been tuned for good stability. In Stable mode the Super-PID uses de-tuned P.I.D. values to provide a more highly damped system. The good result is that stability is increased (especially at very low speeds) when using an unstable router or fussy cutting tool, so this mode may occasionally be useful. However the tradeoff is that regulation is reduced so the speed will droop a small amount when cutting. Like Open-loop mode, Stable-mode can be useful in rare situations but should not be considered the best setting for general use.



Controlling router speed from your PC.

If your PC or control software has a 0v-5v speed control output, this can be connected to the Super-PID (at the PO input) instead of the pot, allowing the PC to control the speed of the router as well as turning it on and off. If your control software outputs a 0v-10v signal, this can be converted to 0v-5v very easily using just two 10k resistors as a voltage divider.

The 0v-5v signal sets the router speed from 5000-30000 RPM. However, the relationship is semi-log not linear. The semi-log scale was chosen to provide the best feel of the pot control for easy adjustment by hand. If you are using a PC to set the speed it will require some experimentation to find the voltages needed for particular RPM. See www.SuperPID.com for more info.

Installation in a safe box.

The Super-PID must be installed in a safe, insulated box before it is used! A typical safe box would be any plastic electronics enclosure that fully surrounds the Super-PID and ensures the Super-PID circuit board and its mains power connector cannot be touched by the user. Suitable plastic enclosures can be found cheaply at hobby electronics stores and may also be available from www.SuperPID.com.

High and low voltages and opto-isolation.

The Super-PID circuit board is divided into 2 sections; the high voltage section that controls the mains power to the router, and the low voltage section that contains the brain circuitry, the display, and the speed control pot.

The two sections are fully isolated from each other, using opto-isolators. In use, the low voltage section can safely be electrically connected to your PC and other grounded devices but the high voltage section is dangerous and should be connected ONLY to your AC mains supply (ie; the power point) and to the router.

Grounding (Earthing).

The Super-PID does not require grounding and you should NOT connect ground to any part of the high-voltage connector. However, your router may have a 3-wire power cable, where one wire is ground. In that case you can connect the mains ground to your router ground if desired (see wiring diagram). It is not advisable to connect the mains ground to the low-voltage ground on the smaller connector, the low voltage ground is usually connected elsewhere (like at your PC).

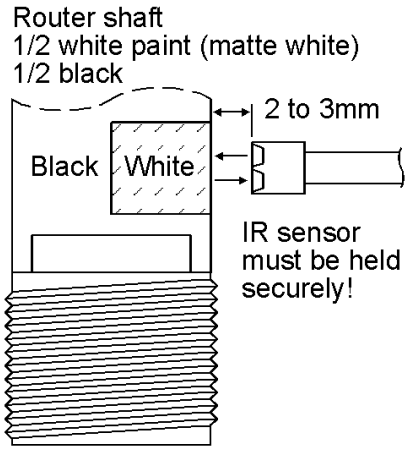
Router compatibility.

Super-PID is suitable for use with routers and other universal type motors like; routers, circular saws, electric die grinders, handheld drills etc. Universal motors have brushes, are cheap lightweight motors, and usually very noisy at full speed.

The router (or other tool) must NOT have an inbuild speed control, or its inbuilt speed control needs to be disabled. Many of the inbuilt speed controls go "click" at the full speed setting, this is usually a bypass switch that disables the inbuilt speed control and these tools can be used with Super-PID after clicking their dial into the full (disabled) position.

The router spindle RPM sensor.

The infra-red sensor must be mounted in a place approx 3mm (1/8") from the router output shaft, or some ROUND part of the router that spins. Super-PID uses this sensor to detect the router speed and to precisely control the speed in a closed-loop.



The shaft should have a black area and a white area that the IR sensor can detect. In most cases, a large spot of white paint on the black shaft will work ok, however if possible paint half the shaft white and leave the

other half as black metal (or paint half white and half black). The best paints are matte, ie matte white and matte black. An easy to obtain matte white paint is sold as "Liquid Paper or White-Out". More durable paints can be bought cheaply as model aeroplane paints in small jars. Enamel paint may be best as it is more resistant to scratching. Clean any oil off the surface with alcohol first before painting.

Spindle sensor operation.

Important! For proper operation the IR sensor must be pointed at a place on the round shaft which has just ONE white area and ONE black area (and no other areas or colours). This gives one pulse per shaft rotation. Messy paint or multiple splotches will cause erratic operation. Painting the 6-sided collet nut is not recommended as the flat areas may cause bad readings.

The IR sensor should be mounted securely so it cannot move, and so it remains pointed at the same place on the router shaft and at the same distance. The IR sensor should not be swamped with direct sunlight, or any bright lamp shining directly into the IR sensor.

Adjusting the spindle sensor.

The IR spindle sensor has no electrical adjustent, for simplicity all adjustment is done by adjusting its distance from the router shaft.

Connect a 5v supply but do not connect the mains supply, the Super-PID will go into Spindle View mode. The best sensor adjustment is one where the black area makes the bar as low as possible (very near the bottom) and the white area makes the bar as high as possible (very near the top). This was already tested when your Super-PID was made so it should be quite easy to get a good adjustment. In most cases all you need to do is position the IR sensor at the right distance from the shaft (about 3mm or 1/8").

If you have trouble getting the bar to show the results as mentioned above, the most common cause would be a white area that is not white enough, or a black area that is not black enough (or both). Remember that matte surfaces work better than shiny surfaces.

Keeping the spindle sensor clean.

We have found the IR sensor to be quite tolerant of most particles, but you should regularly check and if needed clean the sensor and painted areas with a soft brush that will not scratch the paint (like a small soft paintbrush).

In the event of a build up of dust or a large chip blocking the sensor, the result will vary. Sensor problems can cause erratic speed fluctuations, and a total sensor loss will cause "safe" mode and keep running the router on about 40% power until the problem clears.

Connecting AC mains power to the Super-PID.

Special attention must be paid to the mains wiring that connects to the 4 pins of the larger connector. This includes the incoming mains power (A and N), and the two wires that go out to the router (MA and MN). All wiring to the mains and to the router must be capable of 10 amps and be rated as suitable for mains wiring. Suitable wire can be found in mains leads and extension leads etc.

Router Control connections.

If the RUN input is not connected the Super-PID will run automatically, this enables it to be used stand-alone with no PC required.

If a PC or control device is connected, it sends a 5v logic signal to the "RUN" connection; +5v = RUN, 0v = STOP. The PC or control device also needs to be connected to the low-voltage ground. If you wish to control the Super-PID manually (ie; stand-alone with no PC), simply connect a switch between the "RUN" connection and the low-voltage ground. When the switch is closed, the router will be STOPPED.

Finishing the installation.

Once the sensor has been mounted and adjusted the wiring should be fixed and made tidy with cable ties etc. If possible the IR sensor wire should be kept away from all power wiring including the router power cable and cables to stepper/servo motors, to reduce the chance of the sensor wire picking up electrical noise.

The Super-PID in its safe electrical enclosure should be mounted somewhere that allows easy access to adjust the speed knob and to see the tacho display.

Using your Super-PID.

To use the Super-PID you must have a 5 volt supply connected, the sensor set up at the router, and the mains power and router cable connected. If there is no control signal on the RUN connector the Super-PID will be automatically in the RUN mode so BE CAREFUL the router will start up when all the power is connected!

To adjust the router speed you simply turn the speed control knob. Speed can be varied between 5000 and 30000 RPM, however your router may not be capable of 30000 RPM so the top speed is limited to what your router can do.

If you have connected the "RUN" connector, your Super-PID can be controlled from a PC or other logic level control device like a break out board. This input selects between RUN mode and STOP mode.

Reading the Super-PID display.

The Super-PID has sophisticated display features. When in STOP mode, the display shows the "Spindle View" bar for IR sensor testing, or if the speed control knob is turned it shows "Pot View" for pot testing.

Other display features include displaying the mode when the mode changes, ie; STOP, START and RUN modes. It also displays the "Mains freq" test when the Super-PID tests your mains power and synchronises to it.

In RUN mode, the display shows a Tacho (RPM meter) on the top line. This tacho is crystal locked, making it extremely accurate (to within +/- 1 digit). The tacho is a very useful tool for setting cutting speeds from feed charts and for avoiding resonances. It also allows you to replicate good cutting speeds from job to job.

As the tacho is very accurate you might be tempted to try to set speeds too perfectly. This is a waste of time. For example 10100 RPM looks like it's a long way above 10000 RPM, but in reality there is only 1% speed difference, which will not affect cutting performance in any significant way. It is also normal for the RPM to vary by a couple of percent when cutting.

When in RUN mode, the bottom display line shows the POWER bar. This bar represents the amount of power the Super-PID is feeding to the router motor. At lower speeds and light cutting loads the router needs very little power which can be seen by the Power bar being small. As the router makes a deeper cut you can see the Power bar increase, because the router is using more power now to maintain the same speed. At high speeds the router may require a lot of power just to overcome air drag, and of course with large cutting loads the router will require more power too.

The Power bar is a useful feature that helps to adjust feedrates and cutting depth, and as a safety feature to show when your router is using a lot of power for a given situation.

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What is PID?

P.I.D. (Proportional-Integral-Derivative) is an industrial control system used to maintain equipment at a constant speed. This is a "closed loop" speed control where the speed is measured with a sensor, and the power to the machinery is automatically adjusted to give a constant speed. One of the main benefits of closed-loop control is the ability to run at low speeds while still producing good power, and P.I.D is considered to be the king of closed-loop systems because it offers good speed, power and stability.

Why Super-PID?

The PID system in the Super-PID has been specifically designed for router spindle use, and it has additional qualities added over the traditional PID system. These additional qualities include morphing of the PID values over different RPM ranges to give the best performance at all RPMs, tuned "sag" values designed for CNC spindle use, and asymmetrical PID tuning to match the router motor's asymmetrical needs when speeding up and slowing down.

Super-PID performance and limitations.

Because the Super-PID was specifically tuned for routers (for CNC cutting etc) it provides good, strong performance at all motor speeds. You will find your router can now be used for cutting at very low speeds like 5000-10000 RPM, low speeds which were previously not available with most routers.

However there are some limitations. Although the Super-PID is capable of feeding full power levels to your router at low speeds this is not advisable. At low speeds the router's internal fan is not pumping as much air and the router cannot cool itself as well as it can at high speeds. Also the motor design of the router is simply not very efficient at low speeds as the motor magnetics are optimised for the router's advertised speed range (generally about 16000 to 30000 RPM).

Another problem with high cutting loads and/or very low speeds is instability. Although the Super-PID P.I.D. system is tuned for excellent stability with routers, it can still be possible to push the router into unstable operation (speed oscillation etc). This occurs because of a number of issues; The router which is designed as a high RPM device has low rotor mass and a low flywheel effect. Also the mains power is applied in low frequency pulses (either 50Hz or 60Hz) and the magnetic armature of the router motor applies torque in pulses. Compounding the problem is the fact that most cutting tools apply 1 or 2 large pulses of load for every router revolution. All these issues compound at low speeds, especially at or below the mains resonance frequency which is either 50/100Hz (6000 RPM) or 60/120Hz (7200 RPM) depending on the mains frequency in your country.

As a result there is a limitation on how much cutting power can be used at very low speeds. Generally soft woods and plastics can be cut with quite deep cuts even at 5000 RPM, while hard woods and aluminium may require slightly higher speeds and/or lighter cuts. This should not be a problem as generally the required speeds and feeds for these materials and cutting tools are fairly high, generally above 10000 RPM.

Router performance and limitations.

The Super-PID was designed to give good, usable power at low speeds, and it does this well. But please remember there are limitations to what it can do, or more exactly; limitations to what your router motor can do. The Super-PID will not turn a 30000 RPM wood router into a 5000 RPM spindle for milling steel!

As the low speed performance depends on router type, a large diameter professional router has larger flywheel effect and larger overall torque and should be capable of significant cutting power at low speeds. A small diameter lightweight router (even a Dremel) can still be operated at low speeds but may be limited to lighter cuts. In both cases the Super-PID always provides a large increase in low speed power compared to the same router without Super-PID.

Heatsink requirements.

The Super-PID is supplied with a heatsink bracket. For light duty use with small routers up to 800W this should be sufficient. For larger routers and/or heavy duty use, please attach additional heatsinking to this bracket. A suitable size would be aluminium stock 4" x 1.5" by 1/8" or a small commercial heatsink of similar mass. Fan cooling my also be useful depending on the type of enclosure and the ambient temperature. The heatsink bracket and heatsink should be considered LIVE at dangerous voltages and kept away from all other metal components.

The ideal setup for heavy duty use would be a heatsink as described above and a small 2" or 3" computer fan, in a ventilated plastic enclosure where the heatsink and circuit board cannot be touched by the user.

Super-PID specifications;

Max router power; 1400W (120v AC countries, ~60Hz) or 1900W (240v AC countries, ~50 Hz)
Recommended router power; 1000W (120v) or 1200W (240v)
Slow-blow fuse type; 12 amps (120v) or 8 amps (240v)
Rated for continuous use/production etc
Speed control range; 5000 RPM to 30000 RPM
Requires 5v DC supply at 120mA
Autodetects 50Hz/60Hz mains frequency

Safety Warning!

Some parts of the Super-PID circuit board operate at lethal AC mains voltages. This is the same as many power supplies etc that have screw terminals that connect to the AC mains. If for any reason you do not feel confident connecting the 4 mains rated wires to this kit and securing the kit within a safe plastic enclosure then please return the Super-PID in unused condition and we will refund the purchase price. The Super-PID circuit board should NEVER be used unless it is in a safe enclosure where it cannot be touched. The manufacturer, distributor and retailer will not be held responsible for your safety or for your compliance with any local electrical and safety regulations.

Safety and wiring.

1. Read all Super-PID instructions before using your Super-PID.

2. Super-PID must be installed in a safe, insulated plastic box (see warning above) where the user cannot touch the PCB or the heatsink.

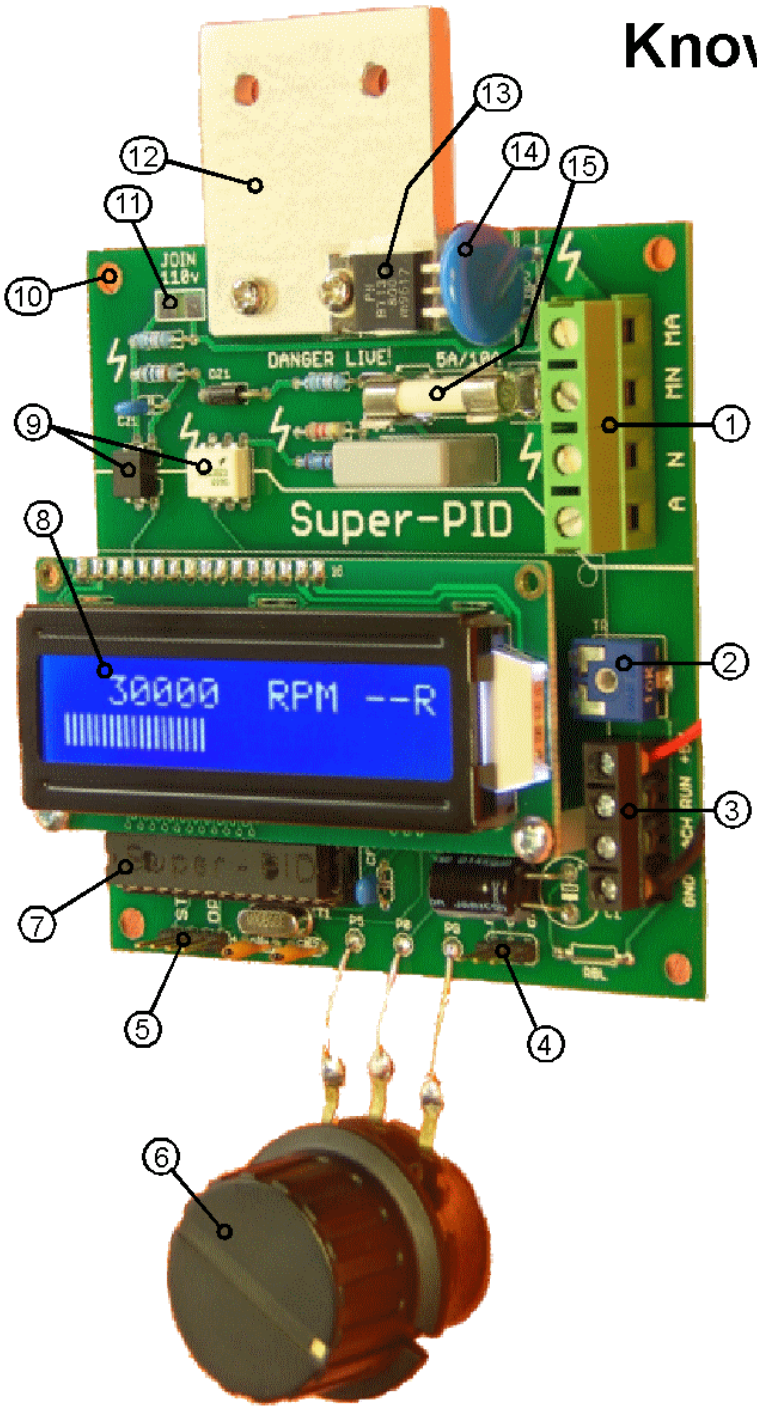
3. Super-PID has two different versions for 110-120vAC and 220-240 vAC. Check the mains power supply corresponds to the version Super-PID you have received. The 110v model will have the 110v selector jumper joined.

4. Read, and apply, all the safety rules and general safety instructions included with your router. It is always important to turn the router off using it's own inbuilt power switch before doing tool changes and at any time you may be in close proximity to the router.

5. In cases where there is severe electrical noise in the AC mains supply it may cause the Super-PID TRIAC to false trigger making the router give a small "kick". This is a normal feature of TRIACs and in most cases should not be a problem. If this is a problem a standard mains filter can be plugged in-line at the power point, or seek tech support from our staff at **www.SuperPID.com.**

6. The spindle sensor cable is at low voltage and is safe to touch, however it is good practice to keep it insulated from other equipment and metal objects.

Know your Super-PID



Components;

1. AC mains voltage connector
2. LCD contrast adjust
3. Low voltage connector
4. Spindle RPM sensor
5. Optional features connector
6. Speed control pot
7. Microcontroller
8. LCD display
9. Opto isolation
10. PCB mounting holes
11. Selector jumper for 110v AC
12. Heatsink Bracket
13. Triac
14. MOV surge protector
15. Mains fuse, slow-blow; 6A (240v models) or 12A (110v models)

Warning!

Some areas of the Super-PID PCB operate at lethal mains voltages. The Super-PID PCB must be enclosed in a safe plastic case before use so it cannot be touched by the user.

The heatsink bracket and heatsink should be treated as live!

All wiring to the AC mains connector must be rated for mains voltages and minimum 10 amps.

Connection diagram;