GPS Vehicle Tracking Beacon Installation Best Practices Guide

Preface

There are three primary aspects to the installation of a vehicle tracking beacon; power connections, antenna installations, and mechanical mounting of the beacon. The Installation Guide included with each beacon is intended to provide a simplified, pictorial guide for straightforward installations. This document is a supplement to that guide, intended to help installers with more difficult or non-standard installations. It will also help with troubleshooting of installations that don't initially work correctly and will help an installer become more proficient and faster at repetitive installations.

The beacon's power wiring harness must be connected to the vehicle's electrical system at a minimum of three points; power, ground, and ignition sense. Each of these three wires must be connected to an appropriate connection point in the vehicle. Finding and determining the suitability of the appropriate connection point for each wire is described in detail in subsequent sections of this document. Additional connection points between the vehicle and the beacon are required if the beacon's inputs and/or outputs will be used to sense or control vehicle functions.

In order to perform the steps outlined below it will be necessary to use a good quality multi-meter. DC voltage up to 36 volts and resistance down to less than one ohm will need to be accurately measured.

Caution: When working with vehicle wiring, be very careful that no bare wire, and no tool that comes in contact with a wire, ever makes contact with ground (the vehicle's chassis). This will probably blow a fuse, and could also cause heat and fire. It is always preferable to disconnect the vehicle's battery before doing any work on the vehicle's electrical system.

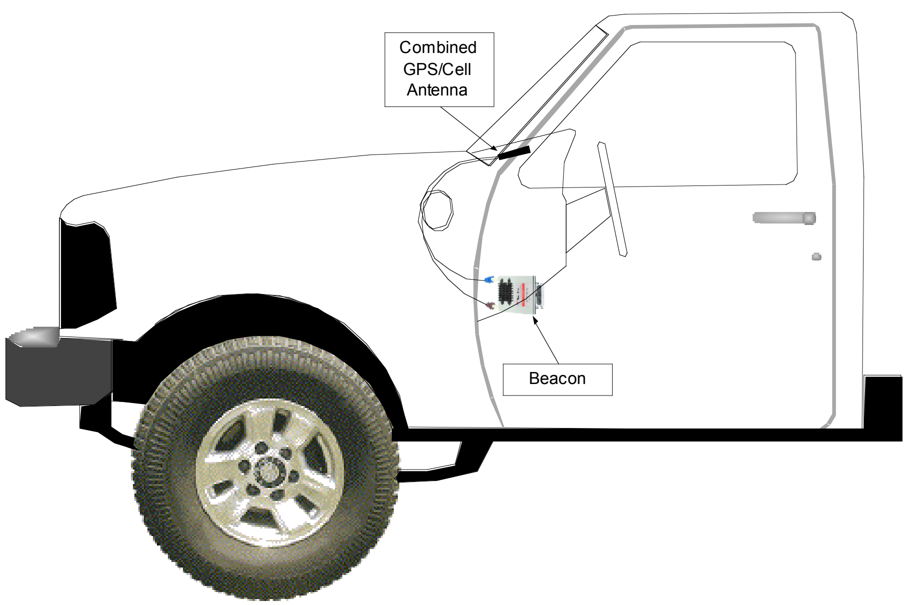
Mounting of the Beacon

Mounting the beacon itself is a critical part of the installation that is often mistakenly considered less significant that the other aspects. It is very important to determine an appropriate location for the beacon and to affix it securely in place. Determining the best installation site is based on several factors:

- Adequate space
- Visible or concealed installation
- Visibility of the indicator LEDs (if desired)
- Availability of a power connection point
- Secure mounting points
- No excessive vibration
- No excessive heat
- Adequate moisture protection
- Routing of the antenna cables

Preferable installation locations for many vehicles are under the dashboard, under a seat, in the trunk, or inside a console. Beacons are generally meant to be installed inside the passenger compartment of a vehicle, not externally or in the motor compartment. In some trucks or vans it is possible to mount the unit on a side wall, firewall, or internal wall. Beacon models designed specifically for assets other than vehicles may be more weather resistant or may have available weatherproof mounting enclosures.

Example Installation Location



Orientation of the beacon is not critical to its performance but consideration should be given to visibility of the indicator LEDs. In some instances visibility is desirable and in other it is not. The LEDs do provide feedback about the operation of the beacon, so easy viewing is desirable for unconcealed installations. For covert installations, however, the LEDs should be hidden from view. Some installers even cover them with layers of electrical tape to completely block the light.

The beacon should be placed where the power wiring and antenna cables can be routed properly, without getting in the way of normal vehicle operations. This means leaving some room around the beacon so that the connectors are accessible.

Attaching the beacon to the vehicle can be a challenge, especially if it is located under the dashboard where there may be no such thing as a panel or clear open space. In cases like this it is usually preferable to use plastic cable ties to attach the beacon. The cable ties offer a flexible mounting system that dampens vibration yet securely affixes the beacon in any orientation. Cable ties can strap the beacon to brackets, wire bundles, or sturdy fittings of any kind. If the beacon has mounting holes these are the best connection points for the cable ties. It may not be necessary to use all mounting holes; two or three are usually adequate. If the beacon comes with a mounting bracket, this bracket will contain mounting holes that should be good connection points for cable ties. It is not necessary to cinch the cable ties completely tight. As long as the beacon won't rattle or swing around it should be fine. If no mounting holes or brackets are available it is necessary to wrap cable ties completely around the beacon. This should be done in two perpendicular planes (criss-crossing straps) so that the beacon can't slide out of place.

Electrical Connection Methods

Making electrical connections will often involve connecting a wire in the wiring harness cable to an existing wire in the vehicle. There are several methods of making electrical connections, some of which will be discussed here in order to help the installer determine the appropriate method for each circumstance.

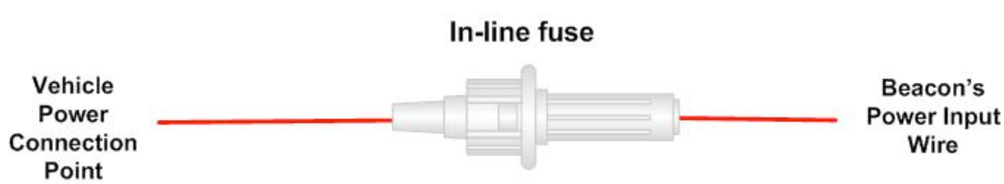
Some installers attempt to simply strip the insulation from wires, twist them together, and insulate them with electrical tape. Clearly this is not adequate. Twisted wires have no consistent electrical connection and are mechanically unsound.

A common type of automotive splicing connectors are known as Insulation Displacement Electrical (IDE) connectors. These are available from many auto parts and electrical supply stores. IDE connectors are not recommended for durable beacon installations. These connectors make contact by slicing through the insulation of the wire with sharp internal blades which then come in contact with the internal conductors. The benefit is quick, easy connections that can me made with a simple hand tool. The drawback is the reliability of the connection. The slicing action punctures the wire's insulation and cuts into the internal conductors. This weakens the wire's mechanical strength, possibly reduces its current carrying capability, and exposes it to corrosion.

The recommended connection between vehicle wires and the beacon's wiring harness is a soldered connection. This is best performed by cautiously stripping a ½ inch section of insulation from the vehicles wire using a razor knife. Next, wrap the bare end of the beacon wiring harness wire several times around the exposed vehicle wire. Use a soldering iron and rosin-core solder to make the electrical connection. Be sure to get both sections of wire hot enough to melt the solder till it flows freely between the strands of wire. The connection should be held still until the solder cools and solidifies to a shiny metallic bead. After the soldering is complete, wrap at least 5 layers of electrical tape around the connection point, ensuring that the tape adheres to the wires' insulation creating a sealed layer of insulation.

Power Connection

Note: It is important to use a fuse for the power connection to all beacons. Use either an inline fuse or an accessory fuse with a separately fused connection for electrical accessories.



Install the fuse as close to the vehicle connection point as possible. This will allow the fuse to protect against short circuits in the beacon's wiring harness as well as within the beacon itself.

Power for the beacon is supplied via the V+ wire of the power wiring harness. Connect this wire, through a fuse, to the appropriate connection point in the vehicle as described below. Check your beacon installation guide to verify the color of the V+ wire and the range of DC voltage it can be connected to. Most vehicle electrical systems are either 12 or 24 Volts DC. Most beacons will work within that voltage range.

It is critical that the main power source for the beacon be continuously available, i.e. it is not switched off when the vehicle is off. It must remain above 12 volts and can not be tied to any other switch in the vehicle. Test to be sure that your selected power source is unaffected by switching on and off any lights, turn signals, audio system, heating system, horn, etc.

Current draw is another consideration. Most beacons will draw an average of only about 200 mA, but may draw up to 3 Amps for short periods of time during transmission of data. Current draw affects two aspects of beacon installation – the fuse capacity, and the total circuit capacity.

The fuse you install at the beacon power connection pint should be at least 3 Amps for all beacon types unless otherwise specified in the beacon's specifications or installation guide.

Make sure to connect the beacon's power to a circuit that can handle the additional current draw of the beacon. Some vehicle circuits are current limited as a result of isolating them from other vehicle systems. As an example, the circuits to power the audio systems may be isolated from other systems to reduce noise.

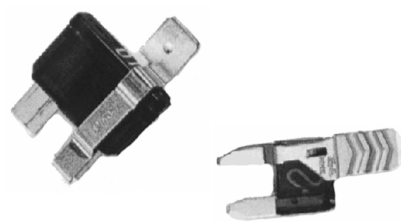
If the beacon is connected directly to the vehicles battery it will certainly have adequate current delivery capability. If it is connected to some other circuit of the vehicle it must be tested to ensure that the maximum current is available. An adequate test would be to connect the beacon temporarily and ensure that it can provide tracking points to the user portal (see the getting started guide for instructions). If the temporary electrical connection fails to adequately power the beacon, it must be connected to another source within the vehicle; in general, the closer to the battery the better.

A good source of power can usually be found at the ignition switch. It is also possible to find adequate power sources at certain lights and at high power devices like seat adjustment motors. An indication that the chosen power source can supply adequate current will be the gauge of the wire. If it is very thin, such as 18 Gauge or lighter, it is not meant to carry high enough currents to supply the existing circuit plus the extra current demands of the beacon. Connect to the heavier power wires in the vehicle.

If you connect power at the fuse box of the vehicle you can connect to the raw power input directly from the battery, avoiding consideration of other components connected into a vehicle circuit. The easiest way to do this is with a Fuse Tap or an Accessory Fuse. These are available at virtually any automotive parts store, and even at Radio Shack. Many on-line auto parts vendors offer these type of devices as well. Following are some examples of the different types of fuse taps and accessory fuses available, for both full-size and miniature automotive fuses

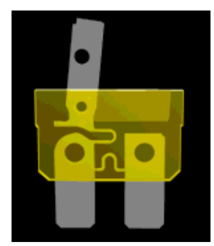
<u>Fuse Taps</u>

Tap into an existing fuse by making contact with the power input to the fuse

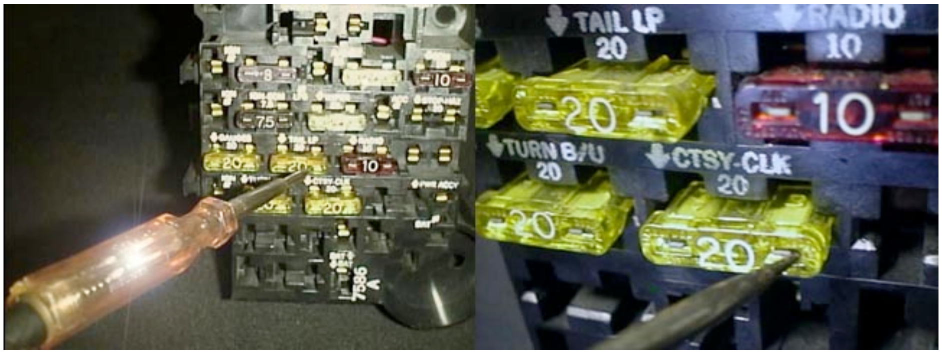


<u>Accessory Fuses</u>

Replace an existing fuse with a special fuse that provides two circuits, the original one plus a secondary connection. These devices usually provide separate fuses for each circuit.

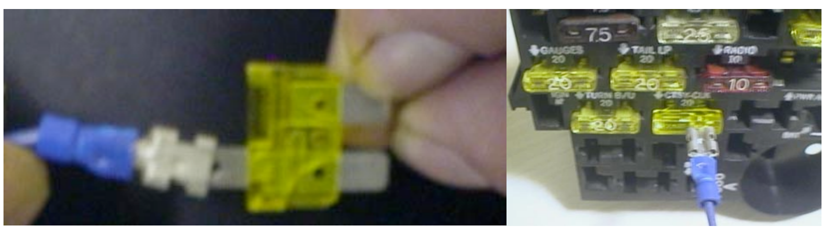


To find the best power connection point in a fuse box, use a voltmeter or test light to find a fuse for a circuit that has continuous power when the ignition key and all vehicle accessories are turned off.



Remove the fuse and use the test light or voltmeter to verify which side of the fuse connection is “hot”. Either replace this fuse with an accessory fuse or place a fuse tap onto the removed fuse on the hot side fuse terminal.

Crimp a slide connector on to the power wire of the beacon wiring harness, and slide it onto the fuse tap or the accessory terminal.



Grounding

Grounding is every bit as critical as the power connection. On virtually all vehicles the chassis is ground. If it is possible to connect the ground wire of the beacon's power wiring harness to the vehicle's chassis this is the best connection. Be sure the connection method does not add resistance. A crimped-on ring terminal or spade terminal screwed to the chassis should be adequate. Make sure that the chassis connection point is not painted or coated with any insulating material such as grease, wax, plastic, or anti-corrosion coating.

If connecting directly to the chassis is not possible, it is critical to determine the resistance between the desired ground connection point and the vehicle's chassis. It is not adequate to measure the voltage of a connection point to determine if it is ground. In other words, a wire that measures zero volts is not necessarily a ground wire.

A resistance of no more than 1 (one) ohm between the connection point and the vehicle chassis should be allowed. This is critical! If the resistance is any higher, the voltage differential between the power source and ground, at full current, may drop below the minimum voltage required to power the beacon.

If connecting to a ground wire rather than the vehicle's chassis, be sure the ground wire is a heavy gauge so it can carry the full maximum current of the beacon. Do not connect to thin wires of 18 Gauge or lighter. Connect only to the heavier ground wires of the vehicle. Remember, the full supply current of up to 3 Amps will also flow to ground. Heavy ground wires can be found at the fuse boxes, ignition switch, and some of the lights and motors in a vehicle.

Ignition Sense

The important factors for the ignition sense connection are considerably different from those of the power and ground connection. The ignition sense connection does not draw much current, but it may be more than simply a voltage that is switched ON and OFF with the ignition key.

On Contigo's beacon model 6200 the ignition sense input defaults to the off position, meaning that if it is not connected to the vehicle's power it will indicate to the beacon that the ignition is off, limiting the beacon's functionality. The good news about this type of ignition sense is that any electrical circuit in the vehicle that switches between 0 and 12 volts with the ignition key is a suitable connection point. There is no need to worry about the resistance to ground when this circuit is in the 0 volt state.

It is important to understand that on some beacon models, if the beacon's ignition sense wire is not connected, the beacon defaults to an ON state rather than an OFF state. This is done to allow the connection of the ignition sense to be optional. If not connected, however, the features of these beacons will not save power or data transmission while the vehicle is off. Contigo's beacon model 7100 uses this type of ignition sense.

To allow the connection of the ignition sense to default to the ON state, an internal pull-up resistor is used in these type beacons. This resistor pulls the voltage on the ignition sense line up to 12 volts (assuming a 12 volt vehicle) when it is left disconnected. In order to get the voltage down to a level where it will indicate "ignition off" the resistance to ground must be very low.

Remember that zero volts is not equivalent to ground. If a connection point rises to 12 volts when the ignition is ON but merely disconnects when the ignition is OFF, it will not switch the beacon's ignition sense. It will be equivalent to leaving the ignition sense disconnected, which some beacons detect as ignition ON.

As a result, the ideal ignition sense connection point is where 12 volts appears when the vehicle's ignition is ON, and zero volts AND a low resistance to ground appears when the vehicle's ignition is OFF.

Ignition sense connection points can typically be found at the ignition switch, at the fuse boxes, or at certain vehicle systems that are switched with the ignition. Examples are seat-belt detection system, audio system, heating system, and some lights.

Note: If connecting ignition sense at the fuse panel, follow the steps outlined in the power connection section about fuse taps and accessory fuses except select a fuse circuit the IS switched on and off with the vehicle's ignition, as outlined below.

Making the measurements to select the right ignition sense connection point are very particular. Two different parameters must be measured and they can not be measured with the same settings of the multi-meter.

The first parameter to measure is voltage. The voltage of the ignition sense connection point must switch between 0 and 12 volts with the ignition (0 volts whit ignition OFF, 12 volts with ignition ON). The second parameter to measure is the resistance to ground with the ignition OFF.

Caution: Do not attempt to measure the resistance to ground of the ignition sense connection point when voltage is present, i.e. when the ignition is ON. This could damage your multi-meter.

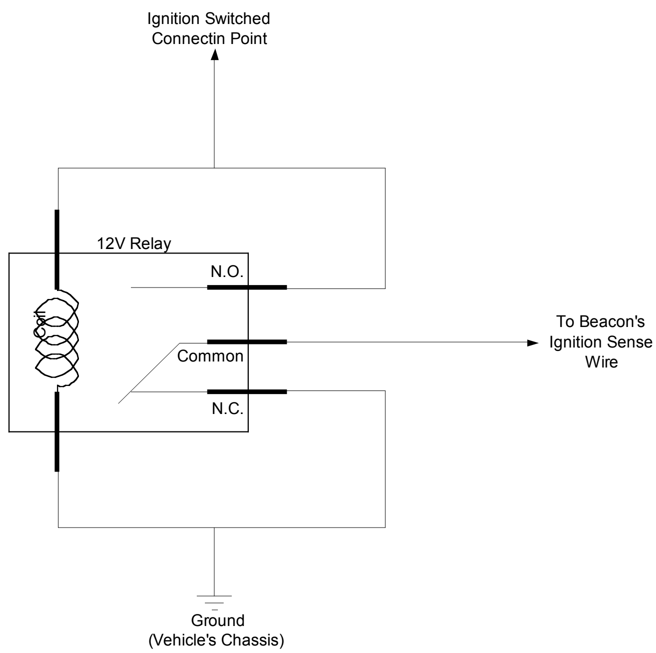
After first ensuring that the voltage at the connection point is zero with the ignition off, measure the resistance to ground. It must be below 20 ohms, preferably below 10 ohms.

Alternative method for ignition sense

If it is difficult or impossible to find a suitable ignition sense connection point in the vehicle an alternative is to use a less critical connection point and a relay. In this case "less critical" means a connection point that changes voltage from about 0 to about 12 with the ignition but doesn't provide a low resistance connection to ground when the ignition is off.

The principle behind this method is that a voltage change will switch a relay, and the relay will switch the ignition sense wire between power and ground.

The relay must be wired as shown in the following diagram. Be sure to use a double contact relay and connect the normally closed (N.C.) contact to ground. This will ensure that when the vehicle's ignition is off the beacon's ignition sense wire is grounded. Use your multi-meter to measure both the voltage and the resistance of the relay output before connecting the beacons ignition sense wire to the relay. The relay must operate on 12 Volts DC but the current carrying capacity is not critical – anything above about ½ Amp is plenty.



Inputs and outputs:

Some beacon models provide inputs and/or outputs. These allow remote monitoring and control of vehicle or asset functions via the Mobile Monitoring User Portals. Inputs to a beacon provide feedback, or monitoring, of vehicle/asset functions, while outputs provide remote control of functions such as door lock/unlock, ignition disable/enable, or remote engine starting.

Inputs

There are two categories of inputs, analog and digital. Analog inputs can provide monitoring of a continuously variable parameter such as temperature, pressure, tank level, etc. Digital inputs are more common, and they provide feedback of switched parameters such as door opened/closed, motion detected, lock engaged/disengaged, or panic button pushed.

Some continuously variable parameters are actually better monitored via a digital input than an analog input. An example is the temperature of a refrigerated transport trailer. A programmable temperature alarm device can be installed in the trailer and adjusted locally to trigger an alert upon breaching specified temperature thresholds. The alarm trigger output from this type of device is usually switched voltage or the actuation of a relay. Either of these is an ideal connection point for a digital input on a mobile monitoring beacon.

The ignition sense input is a special case example of a digital input. It detects when a motor is on or off but, in addition to a simple message being forwarded to the mobile monitoring system, it can trigger changes in the behavior of the beacon itself.

Digital inputs fall into two categories as well – toggle or momentary. Some beacons allow each input to be configured as either toggle or momentary, others have predefined inputs of each type.

A toggle input would be one where a voltage change from low to high, as well as from high to low, can be detected. You may wish to monitor both or just one of these changes. Use these inputs to monitor things that switch state, such as a door opening. You can set up the system, via the users web portal, to monitor only when the door opens, or both the opening and closing of the door. Connection of the door switch to the input is the same for both cases. You always to want to affect a voltage change to the input of the beacon when the door opens and closes. It doesn't matter particularly whether the voltage goes from low-to-high upon opening or upon closing. Just be sure to coordinate the alerts you want with the action you want. All these settings are made via the user portal and should be tested thoroughly at the time of installation.

A momentary input is one where an action happens for a brief period of time and then automatically returns to its original state. An example is pushing a panic button or detecting motion. In these cases it is not desirable to send an alert upon both low-to-high voltage as well as high-to-low. Momentary inputs typically have a short time threshold, meaning that a motion detector, for example, would need to provide at least one second of detected motion before it would trigger the beacon to send out an alert. This helps avoid false alarms.

It is possible to use a momentary input to detect something like the opening of a door, but it would not detect both the opening and the closing of the door.

Outputs

Outputs are generally only available as digital outputs, not analog. Essentially that means they can only remotely control something that switches from one state to another. Outputs are available as two types, either toggled or pulsed. Toggled means switching from on to off or vice versa. Pulsed means switching state briefly and then automatically returning to the original state.

Contigo's model 6200 has configurable outputs, meaning they can be selected to behave as either toggled or pulsed. These outputs switch what is knows as a current sink. That means when they are in their normal state they essentially do nothing. They don't provide any voltage or current, they are just a high impedance, or open circuit, having no effect on any circuit they are connected to.

When these outputs are activated they sink current, meaning they present a low impedance path to ground. They do have a limited current capacity however, so it is very important to ensure that this limit is not exceeded by the circuit connected to the output.

A typical example of remotely controlling a vehicle function via a beacon's output is to have the output drive a relay, and have the relay switch some function in the vehicle. One common use of this example would be disabling and enabling a vehicle's ignition (see the example wiring diagram on the next page).

Activating a relay with a current sink type output is very easy. Just connect one terminal of the relay coil to vehicle power and the other end to the output. In most cases the relay activation coil sufficiently limits the current into the beacon output because it has enough internal resistance. For example, if the relay's coil resistance is 200 Ohms, and the vehicle's electrical system is 12 volts, the maximum current that can flow through the relays activation coil is 12/200 = 0.06A, or 60mA. The output's current capacity is specified as 350mA so the relay circuit is well within the range.

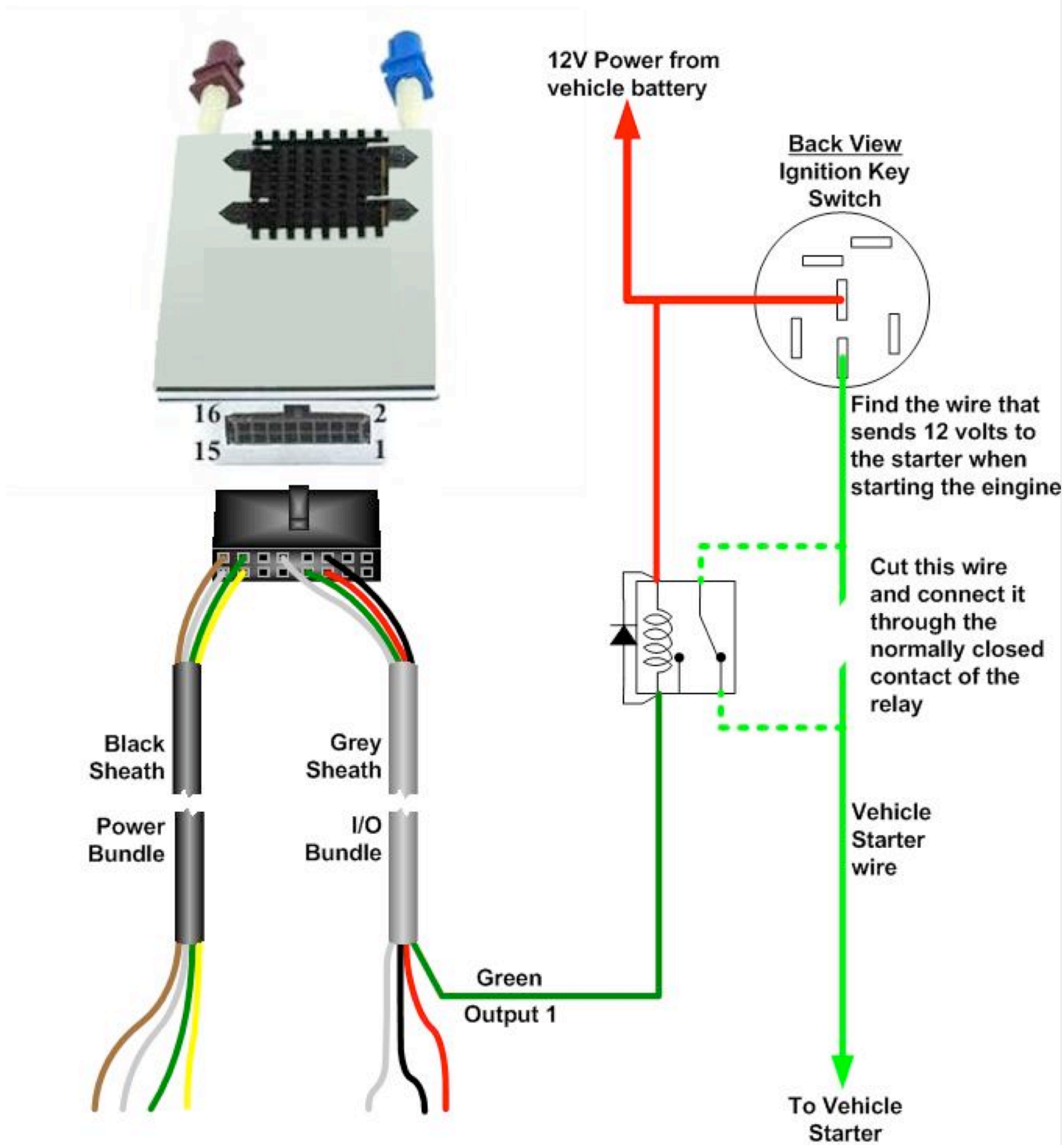
Another important consideration when driving a relay with a beacon output is the need for a protection diode. If a diode is not used across the relay coil the beacon could be damaged. The reason is that when a device with a coil, such as a relay, is deactivated it produces a power surge. It happens because a coil stores electrical energy, and when the supply of power that activates the coil is turned off that stored energy tries to push its way out of the coil. The diode allows the stored energy to loop back through the coil itself rather than forcing its way into the beacon output.

The appropriate protection diode for an automotive type relay with a 12 Volt DC activation coil is a 1N4148 or equivalent. It should have a Repetitive Peak Reverse Voltage rating of at least 75 Volts and a Forward Continuous Current rating of at least 300mA.

Ensure that the diode is installed in the right orientation, with its cathode (the end with the stripe) facing the 12 volt vehicle power.

Protection Diode for Relay
1N4148 or equivalent

Wiring Example
Using Output 1 for Ignition Disable/Enable



Installing Antennas

There are two antennas to install for most beacon models, the GPS antenna and the cellular (GSM) antenna. These may be combined into a single antenna device but will have two separate antenna cables. If they are separate antennas, the GSM antenna is typically a tall, pointed device and the GPS antenna a flat square or round device.

Note: Some beacon types have one or both of the required antennas built in. In these cases the placement of the beacon itself may be critical. Follow the guidelines on the beacon's installation guide and reference the GPS antenna guidelines below.

Some antennas have internal magnets for mounting so it is possible to affix them in position by placing them on an appropriate steel bracket. If no steel bracket is available, the antennas can be mounted with adhesive, tape, or plastic cable ties.

Positioning and orientation is critical for the GPS antenna but neither is particularly critical for the GSM antenna. If the two antennas are separate devices it is best not to place them in exactly the same location because it's possible for one signal to interfere with another. Try to keep them at least 18 inches apart.

GPS Antenna

Note: If the GPS and GSM antennas are a single device, follow these guidelines for GPS antenna placement.

GPS signals are much weaker than GSM signals. For this reason the GPS antenna used with most beacons is what is known as a directional antenna. It amplifies signals from one direction while attenuating signals from other directions. The signals that need to be amplified come from the GPS satellites, which may be located anywhere from straight above the vehicle to just above the horizon. The "top" of the GPS antenna is defined as the direction in which it amplifies received signals.

It is usually desirable to orient the GPS antenna straight up, but there are exceptions. If metal in the vehicle is blocking one or more directions, it is not useful to amplify signals from that direction. As an example, if the cab of a truck is all metal with the exception of the front and side windows, it is preferable to aim the antenna out the window, not straight up at the roof of the cab.

About GPS Signal Blockage

GPS signal blockage is a primary factor so the following information is critical to determining an appropriate GPS antenna installation location:

Signals will not penetrate materials such as:	**Signals will penetrate:**
Steel, including sheet metal	Plastic
Aluminum	Glass
Copper	Upholstery (vinyl, cloth, leather)
Wire mesh or screen	Fiberglass
Metallic coated plastic or glass	Styrofoam
	Carpet
	Wood

Additional signal blockage guidelines:

- Metal bars, pipes, and brackets above the beacon may deteriorate signals, depending on the size of holes, openings, or spacing between the metal components
- Radio antennas or defrost wires embedded in glass may degrade signals
- Tinted windows may use a metallic coating that can degrade signals

A simple rule of thumb is that materials that conduct electricity will block signals and materials that do not conduct electricity will not block signals. The thickness of the material is much less a factor than the conductivity. For instance, a thin film of aluminum foil will block signals almost completely while a thick human body will only partially block signals. The reason is that the aluminum is an excellent conductor of electricity while the body is a poor conductor.

Another grey area is where the conductor is not a continuous plane but a mesh, such as the metal springs in a vehicle seat. The rule of thumb here is that higher frequencies penetrate smaller mesh. GPS signals are a fairly high frequency so they will penetrate any conductive mesh with holes greater than about 6 inches across. This is important for places like a car trunk where the majority of the signal is entering through the back seat and the rear window of the car, down through the package shelf behind the back seat. Both the seat itself and the bracing for the package shelf typically contain metal mesh components. Some, but not all, of the GPS signal will be blocked out of the trunk space.

Metals of any kind will block signals, however small metal brackets or fittings above the GPS antenna are generally not a problem as long as they do not block a large percentage of the direction of signal reception.

Preferable GPS antenna locations for internal installation in many vehicles are:

Visible	**Concealed**
Attached to the inside of a window	Under, or inside, a dashboard or control panel
On the dashboard or control panel	Behind or under non-metallic trim panels
Under a non-metallic section of roof	Inside a non-metallic console
Attached to a sun visor	Under a seat

The best location for placing the GPS antenna inside a vehicle is on top of the dashboard, directly below the center of the front windshield. To improve the esthetics of the installation it is usually preferable to hide the antenna. Placing it directly under the dashboard, up near the windshield, can accomplish both excellent signal reception and a hidden installation. Be sure there is no metal between the antenna and the windshield. In most vehicles there are metal brackets in various locations throughout the bottom and middle of the dashboard but up near the top they are absent. In some vehicles there are even cavities in the top of the dashboard accessible through removable plastic panels. These are ideal GPS antenna installation sites.

Another possible GPS antenna installation site in a car is directly under the package shelf behind the back seat. In a truck or van the antenna must have visibility through the front windshield. Sometimes a console between the seats offers a reasonable antenna location. It must be a location where metallic objects will not be place on top however. Items like thermal coffee containers and metal clip boards have been know to interfere with beacon performance.

Antennas specifically designed for installation on the outside of vehicles or other assets are available. These typically require a hole to be drilled through the roof of the vehicle or some other upward-facing panel. The antenna cables are routed through the hole and the antenna is affixed in place using a sealant and a mechanical means such as bolts or screws. For more detailed information follow the antenna manufacturers’ guidelines for these types of antennas.