SVE BULLETIN

SPECIAL VEHICLE ENGINEERING – BODY BUILDERS ADVISORY SERVICE

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General Electrical Practices

Models Affected: All Ford Truck modified vehicles

Purpose:

This bulletin is an attempt to provide a source of general best practices for modifications and/or interfacing with any Ford Truck electrical system.

General Practices:

Prior to any alterations of the OEM electrical systems, the battery's negative (ground) cables must be disconnected and positioned to prevent re-contact with the negative post. This precaution will minimize the potential for dead batteries and possible damage to vehicle circuitry. Prior to arc welding or plasma cutting on the vehicle, refer to QVM Bulletins Q-114 (E-Series) or Q-123 (F250-550) on the BBAS website (www.fleet.ford.com/truckbbas).

An electrical load analysis must be preformed prior to adding circuits to the existing OEM wiring. The total circuit current draw, including additional circuits, must not exceed 80% of the OEM circuit current protection rating for fuses located in the passenger compartment and 60% of the OEM circuit current protection rating for fuses in the engine compartment. All added circuits must be properly fused as described in the Fusing and Circuit Protection Section of this bulletin. Refer to the Quality Program Guidelines, Appendix X, on our website for load analysis worksheets and information.

Do not modify the OEM wiring to the Powertrain Control Module (PCM).

Do not splice into the PCM systems for add-on devices.

Do not splice into the vehicle sensors for add-on devices (i.e. brake switch, backup switch and transmission manual lever position sensor).

When the battery cables are disconnected from the battery, the PCM and radio memories will be lost.
NOTE: The vehicle's engine performance and transmission shift schedule will be affected until the Powertrain Control Module (PCM) "relearns" the lost data. This action usually requires a few miles of normal driving.

Modification to the OEM starting system, charging system, or wiring is not recommended. If the OEM alternator is not adequate for the application, refer to **Alternator Sizing** section. Your aftermarket alternator should provide the necessary hardware, wiring and instructions to assure your needs are met. Any aftermarket alternators should not exceed 15 volts output on vehicles equipped with active glow plugs (diesel engine equipped vehicles).

Do not move, alter, or add to OEM electrical ground points.

Do not splice into the stop lamp circuit at the stop lamp switch.

Wiring added to an OEM circuit must be either of the same or greater (larger diameter) gauge as the OEM wire to which it is being attached, depending on the length of the added wire and the current draw of the added load. Refer to Appendix III of the FTQP/QVM Guidebook on our website.

All added underhood and underbody wiring must be cross linked polyethylene, high temperature (minimum 125 °C) insulted wire. SAE Specification J1128 SXL, GXL, or TXL wire, or equivalent, is acceptable. Refer to QVM Bulletin Q-94 for definitions of "underhood" and "underbody".

Normal PVC insulated wire may not be used under-hood or underbody.

All added wiring should be color coded or labeled to aid in servicing identification.

Added wiring and wire harnesses should be properly routed and retained. Plastic or rubber coated metal clamps should be used to retain (carry the weight of) wire harnesses. The use of plastic tie-wraps should be limited to bundling the harnesses. Never tie-wrap or clamp wire harnesses to brake or fuel system lines or components (including OEM brake/fuel line retainer brackets).

All additional under-hood and underbody wiring should be protected with high temperature (minimum 125 °C) nylon convoluted tubing. All wiring should be routed and secured neatly to avoid any functional or visual issues. Under-hood and underbody wire routings should be clear of sharp edges (.75" minimum) and direct sources of heat (4" minimum). Wiring located in the passenger compartment should be routed away from high temperature areas over the muffler or catalyst. Added heat shielding near exhaust components may be needed.

Wires routed over, through, or near sharp edges must use rubber edge guards, grommets, or convoluted tubing.

Convoluted tubing used in the passenger compartment may be of lower temperature rating if kept separate from the high temperature rated convolute and both are clearly labeled.

Unshielded wiring should not be routed over the exhaust system or come in contact with any heat shields. Any wiring harness heat shielding should provide abrasion and heat protection for the wiring.

Added wiring should be located to avoid, or secured away from, rotating parts (i.e. cooling fans, engine belts, transmission shift controls, brake or accelerator pedals, etc.). Wiring in the engine compartment shall provide at least 1.5" clearance to the engine to allow for engine roll.

Any added wiring should not contact the brake lines or fuel lines.

All wiring should be protected from fastener damage during the build process and from abrasion by any unfriendly surface.

Connectors, splices and eyelets in the engine compartment, under-body or in "wet" areas of the passenger compartment are recommended to be sealed to prevent corrosion and the wiring from drawing moisture into the harness.

Wiring should not be routed through wheel well areas where they may be damaged by tire or road debris, unless appropriately protected with shielding.

Modifications to vehicle charging systems must be done in such a manner as to not cause electrical overload of the OEM wiring, overcharging of chassis batteries, etc. Refer to the Ford Truck Body Builders Layout Book or contact the Ford Truck Body Builders Advisory Service prior to incorporating any charging system modification.

All wiring splices should be twisted, then soldered and sealed, or crimped and sealed using the proper size crimp connector to match the wires being joined. Sealing of the splices will protect from water intrusion in "wet" areas and prevent strain breakage of small gauge wires (20 – 22 gauge).

Do not ground the body to the transmission or transmission crossmember.

Ground the Second Unit Body to the frame in at least two locations, and if required, add an additional frame to engine ground cable to improve the ground path to the battery.

The steady state key off current load for any vehicle's main battery or batteries should not exceed 28 mA. Refer to **Key Off Load** section.

All current load added by body builders should be evaluated for key off loads. If possible, a supply for the load should be ignition key controlled (i.e. RUN only, RUN/START only, etc.).

Powered equipment should be evaluated for operation in different operation modes (Transmission in Park, Parking Brake set, etc.). If the operation of the equipment is to be limited to specific operation modes, then the power source should be active during the operational mode only. If the operational mode includes engine running, use the main batteries for power source for this equipment.

Transmission of high power, through a wire, will generate an electro-magnetic field around the wire. Wires carrying low power signals may experience induced electric noise in excess of the low power signal if they are near the high power transmission wire. For this reason, high power transmission wires should be routed away from any OEM harnesses. The spacing should be maximized and should never be less than 12 inches (304.8 mm) for battery voltage or one inch (25.4 mm) per volt. Higher voltage alternating current (AC) circuits may require twisted pair or grounded shielding to allow their placement on the vehicle without affecting other low power circuits.

The replacement or extension of any cable from the batteries or alternators must have the same resultant resistance as the original cable. This can be accomplished by changing wire gauge to a wire gauge that has the needed resistance per foot specification or by adding a parallel cable that provide a resultant resistance equal to the original cable. The larger the diameter of the wire the lower the resistance per foot specification for that wire gauge. Do not modify the alternator battery sense ("A") line circuit.

All electrical devices that have inductive loads (i.e. electrical motors, relay coils, PTO clutch pump clutches, etc.) must be provided with isolation discharge paths for the reverse voltage generated when power is disconnected from the device. The disconnection could be an intentional disconnection (i.e. a switch, relay, timer, etc.) or an unintentional disconnection (i.e. a blown fuse, damage to a device in series, disconnection of a wiring harness connector, etc.). Either case will cause a large reverse voltage pulse of very short duration to be sent through any connected electrical conductor. The short duration precludes the use of fuses as protective devices. Additionally, any connection between a device with an inductive load and the OEM electrical system should be isolated with a relay. Contact the manufacturer of the electrical device for proper instructions to add a discharge path to their device.

Splices made between wires of smaller gauges should use tape on both sides of the splice for strain release.

Accessing Power:

Do not tap (piggyback) into either side of any fuse in the OEM interior fuse panel or under-hood power distribution box, or splice into any power circuit that feeds into either one of these components.

When adding circuits with higher demands than the host OEM circuit can provide, relays should be incorporated into the system. The OEM wiring may be utilized as a single source for the relay coil. Power to the added circuit will then be supplied directly from the vehicle battery or additional aftermarket battery(s) through the relay.

The draw off of an E-Series auxiliary battery should never exceed the current capacity of the auxiliary battery, its fuse, its wiring to the alternator and the auxiliary battery relay. The current system is limited to 40 Amp continuous current draw. The current limit on the auxiliary battery mandates that current draws that are Ignition Switch controlled (i.e. Hot in RUN, Hot in RUN/START, etc.) should be sourced from the main battery. Only circuits that are uncontrolled (can function with the key off) or require key off current should be connected to the auxiliary battery.

The power supply wire for added circuits from the battery should be properly sized, include appropriate fusing, and should be connected as follows:

- For circuits requiring a maximum total of 30 amperes, make the connections at the starter motor relay's positive terminal, not at the battery terminal. This will aid battery serviceability.
- For circuits requiring more than 30 amperes, make connections directly to the battery's positive terminal. Route the wire along the battery cable to provide a neater wire routing and assist battery serviceability.

Fusing and Circuit Protection:

All electrical connectors, fuses, and circuit breakers which are exposed to hostile environments (under-hood or underbody) should be properly positioned to facilitate servicing and properly protected (covered/sealed) to minimize corrosion.

Added electrical circuits should be protected by a fuse or circuit breaker, labeled, and positioned to facilitate servicing. Fuses and circuit breakers located in the engine compartment are to be sealed to minimize corrosion.

Auxiliary Batteries vs. Multiple Batteries

The auxiliary battery was designed to provide "Key Off" power without draining the primary battery which would cause a no start condition. The auxiliary battery should power circuits with significant "Key Off" loads or that will function when the ignition key is not in the run position. **Circuits requiring a total of more than 40 amps during engine operation should never be connected to the auxiliary battery.** They should be connected to the primary battery. This is to avoid damage to the auxiliary battery relay.

Multiple batteries are not offered as standard or optional equipment on gas engine Ford trucks, but utilization of multiple batteries can provide significant power for short periods of time. This power output may even occur at low engine rpm's without adversely affecting the electrical system of the vehicle. Utilization of a wheelchair lift in a stopped vehicle (i.e. van, bus, etc.) is a good example of such an application.

An auxiliary battery is defined as a battery that is relay isolated from the primary battery and the alternator. The relay isolation is controlled by the ignition switch position. The Ford E-Series auxiliary battery is isolated unless the ignition key is in the "RUN" position. This battery is intended to provide power to key off loads without loss of the primary battery's starting capability.

Multiple batteries are defined as two or more batteries being charged from the vehicle's alternator that are electrically in parallel with each other. This does not include batteries that are isolated by battery isolators or relays.

The utilization of high current "Key On" loads should be handled with a multiple batteries alternative rather than an auxiliary battery. High current is defined for Ford E-Series vehicles as greater than 40 amps.

An auxiliary battery can be altered and become part of a multiple batteries set with the primary battery. This modification is done by removing the auxiliary battery relay and replacing the relay with a set of battery cables to the primary battery. The cables should be connected to same polarity (in parallel) on each end. To determine the proper gauge of the cables refer to QVM Bulletin Q-102.

Wheelchair Lifts

Installation of a wheelchair lift into a vehicle is a significant modification to the vehicle affecting the electrical system. The types of wheelchair lifts vary from manufacturer to manufacturer. For this reason, several electrical characteristics of the wheelchair lift will determine the preferred way of connecting the wheelchair lift into the vehicle's electrical system. These characteristics are:

1. Key Off Load Amperage Draw
2. Operating Amperage Draw
3. Discharge Path for Electric Motors

The <u>"Key Off" load amperage draw</u> of all equipment connected to the vehicle's main or multiple batteries should not exceed 28 milliamps. If a wheelchair lift's inclusion into the vehicle's electrical system would cause the amperage draw to exceed 28 milliamps, the wheelchair lift should be connected to an auxiliary battery or an isolated battery bank. Remember, auxiliary battery loads are limited to 40 amps. If the wheelchair lift and other devices connected to the auxiliary battery exceed 40 amps, utilize an isolated battery bank.

The <u>operating amperage draw</u> of a wheelchair lift needs to be added to the other equipment on an amp/hour basis for determination of the effect over time of the wheelchair lift on the electrical source of the wheelchair lift. This amount should take into account any multiple uses of the lift and the number of times on average it will be used per hour. This amount will assist in the determination of the size of batteries and the number needed for any wheelchair equipped vehicle. The amperage draw will also affect the result of the alternator sizing calculations. Refer to the **Alternator Sizing** section.

All wheelchair lifts installed on Ford vehicles should have a discharge path for the reverse voltage generated by electric motors when the power is turned off. Failure to have a discharge path can result in damage of other electrical equipment installed by the modifier and electrical devices installed by Ford Motor Company. The resultant damage to Ford electrical devices may not be repaired under warranty. The wheelchair lift manufacturer can provide information about the presence of a discharge path on their electric motors.

Alternator Sizing

The sizing of alternator capacity need for a vehicle is more complex than just determining the peak output of the alternator. The use of the peak output off the alternator to identify the alternator has caused some modifiers to assume that this is the output they will receive at all times. This is not true. The effective output of an alternator is determined by estimating the output over time and engine rpm. By utilizing the **Adjusted Alternator Output** worksheet (available on our website), the effective alternator output can be determined for any application. With this information, it is possible to determine if an alternator meets the electrical needs of a modified vehicle. The alternator's effective output should meet or exceed the needs of the electrical system. This will insure full alternator and battery life and reduce the possibilities of "no start" conditions for the end-users.

The following is and example of calculating the effective alternator output:

Example

A vehicle will be idling normally 18% of the day (shift). The vehicle will have the idle kicked to 1700 rpm for 30% of the day. The vehicle will be traveling through city traffic 45% of the day and on the highway 7% of the day. The alternator to be considered is the Ford 110 Amp alternator. Using the alternator curve at 200°F and the pulley ratio for the alternator, both are provided on our website, the output of the alternator for the four rpm levels.

	% of cycle	Engine RPM	Alternator Output	Weighted Amperage
Normal Idle	18%	650	64	11.52
Raised Idle	30%	1700	91	27.3
Low Speed Driving	45%	900	74	33.3
High Speed Driving	7%	2400	97	6.79
	100%		Adjusted Output	78.91

Cycle is defined as the work day.

The effective alternator output for this application is 78.91 Amps.

For your application, determine the raised idle speed (engine rpm), the percentage of four categories and the alternator output for the four categories. Fill in the information on the worksheet. If the percentage column does not equal 100% an "Error" statement will appear below the percentage total value. If this message does appear, check your percentages and insure that they total 100%. Use the adjusted output figure to determine the maximum load for the selected alternator.

Compare your effective alternator output with your load analysis. Refer to load analysis information in the **General Practices** section of this bulletin. All continuous load combined should be no more than 95% of the effective alternator output. The total load analysis with all continuous loads and all momentary loads should not exceed the effective alternator output by more than 20%. If your system does not meet both of these conditions, then your alternator's size (output) needs to be increased.

LED Lighting

The Light Emitting Diode (LED) displays can be used to replace incandescent bulbs. The higher cost of LED displays can be offset by the reduced maintenance and reduced current damage over incandescent bulbs. The low current requirement of LED displays does cause some flashers to perceive the LED display as a bulb out condition. This can be corrected by using another flasher.

The E-Series 3 pin flasher can be replaced by commercially available LED capable flashers. These flashers can be non-solid state (audible click) or solid state (no audible click) with 2 or 3 pins.

The F250-550 truck 5 pin flasher has a Ford LED capable flasher (YC3Z-13350-AA) that can be purchased through your local Ford dealer's parts department.

In both cases, current LED capable flashers should not be used on vehicles with bodies under 80" wide. The reason for this is the lack of bulb outage circuits required to meet FMVSS 108 for turn signals notification of the driver that a "bulb" is not functional. Aftermarket suppliers may develop flashers for LED circuits which meet FMVSS 108 requirements.

Hall Effect Sensor and Ammeter

In the past, determining the current of a circuit on a vehicle has required the use of a high current ammeter or known resistance shunt with a voltmeter. Both of these solutions require the wiring to be modified, the voltage source to be disconnected for installation and the circuits to be altered to measure the current. Hall Effect sensors are an alterative that does not have any of these drawbacks and the standard installation time is also less then the previous two solutions. The best practices solution for reading large currents (>20 mA) is utilization of Hall Effect sensors.

Hall Effect Sensors are commercially available sensors that detect the magnetic field generated in a wire when electrical current passes the sensor. The sensor allows for determination of the amount of current in the wire without altering the wire.

These sensors require special meters to read the output of the sensors. These meters can be purchased from the same source as the Hall Effect Sensors.

Radio Installation

The addition of any radio to a vehicle requires the analysis of the power source, grounding location, antenna connection and wiring to speakers. Purchase of an OEM radio prep option or replacement of an OEM radio precludes this analysis.

The fused power source should be as direct to the battery as possible. This will allow the battery's internal impedance to act as a power line filter for the radio. This will reduce the noise generated by other electrical devices being turned on or off. Other power sources can be used, but other vehicle electrical devices may add noise to these sources. This noise will affect the resultant signal at the radio speakers and is heard as a pop or hiss coming from the speakers.

The grounding location for a radio is critical for superior performance. Do not use any of the Ford grounding locations that are currently being used. This is to prevent problems on grounds for your radios and Ford electrical components. The creation of a new grounding location should be done after measuring the voltage difference between that location and the negative pole on the battery. This measurement should be done with an oscilloscope to allow changes in the ground voltage plane to evident. When a good grounding location is established, remember to reserve it for radio use only and do not add any other ground in close proximity.

The location of an antenna, the shielding on the antenna cable and its connection to the radio are all critical elements for good reception. This assumes that a properly matched antenna has been procured. The location of the antenna should be determined by a signal to noise ratio measurement. The highest signal to noise ratio measurement will provide the strongest signal to the radio. The shielding on the antenna cable should be properly grounded similar to the radio's ground. The antenna connection to the radio should be free of foreign materials to insure that a galvanic cell is not created. The possibility of creation of a galvanic cell is increased when dissimilar metals are used.

The wiring to the speakers should be routed to avoid any sharp edges or high current devices or circuits. The speaker wiring can be improved by utilization of twisted pair wiring. Additional grounded shielding or the use of shielded cable (i.e. coaxial cable) may be required when the wiring is forced to be in close proximity to high current devices or their power cabling. The routing of speaker wires near high current source should be the last resort.

Key Off Loads

A key off load is defined as a current draw on the battery when the ignition key switch is in the off position. The key off loads are important because the key off loads will lower the charge in the battery between vehicle uses. Also, the vehicle may require up to 60 minutes for body modules to enter sleep modes before a steady state Key Off Load can be determined.

Method 1
To determine the key off loads on a vehicle:

1. Insure that the key has been removed from the ignition.
2. Remove the negative battery terminal.
3. Connect an ammeter in series with the negative battery terminal and the negative pole of the battery.
4. Read the current on the ammeter. This is your key off load.

NOTE: With a multimeter or current meter in series, the maximum current rating of the meter may be exceeded if the dome lights or other accessories have not timed out.

Method 2 (Preferred)
This procedure can be done with a Hall Effect sensor as follows:

1. Insure that the key has been removed from the ignition.
2. Connect the Hall Effect sensor to the negative battery cable.
3. Read the current on the Hall Effect sensor's meter. This is your key off load.

Use of a Hall Effect sensor prevents memory loss in the Powertrain Control Module (PCM) and the radio. Use caution with Hall Effect / Clamp On current meters. Many are not sensitive enough to accurately register between 10 AND 30 milliamps. In addition, small movements of the meter along the wire may cause large differences in readings.

The key off load should not exceed 28 milliamps. If key off loads are in excess of this amount, use of an isolated or relay isolated battery (i.e. the aux. battery on E-Series vehicles with gas engines) should be utilized for the key off loads in excess of 28 milliamps. Isolation of the added batteries can be obtained by use of a solid battery isolator or continuous load power isolation (ISO) relay controlled by the ignition switch being in the run position.

Additional Notes

These best practices are intended as a recommendation for all electrical installation, but this bulletin does not supersede any other specific bulletin.

If you have questions, please contact the Ford Truck Body Builders Advisory Service as shown in the header of this bulletin.

Sincerely,

(Signed)
A. I. Jowa, ______________________________
Modified Vehicle Engineering Quality Programs and
Body Builders' Advisory Service