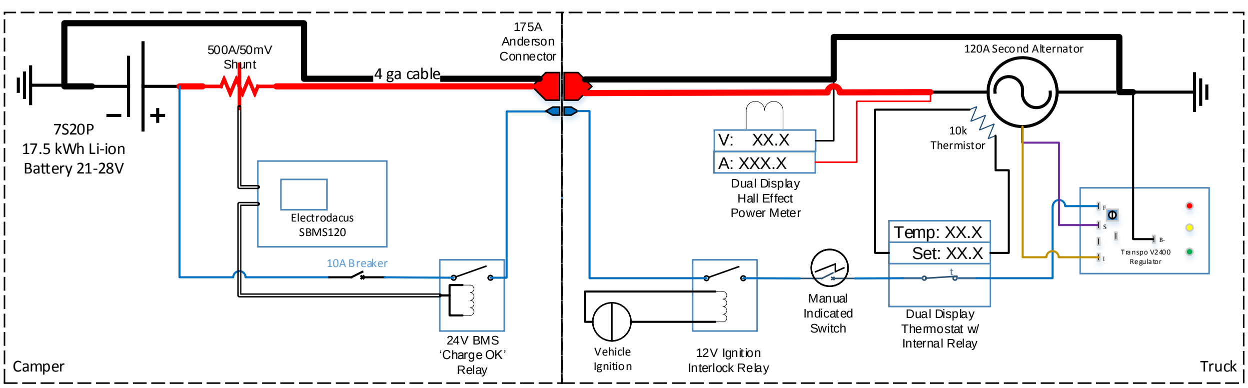
Charging a Li-ion Camper Battery Directly from a 2nd Alternator

My camper battery is a 7S (24V) configuration based on LiMnNiO2 chemistry of Nissan Leaf batteries. I have 35 packs with 17.5kwh capacity. They are mounted in my current test bed camper, a Lance 1130, in a 2” tall ‘spacer’ attached to the underside of the camper. (see battery system link) I am normally able to keep them charged with 560w of solar but periodically I need or want to charge them more directly. I removed the on-board generator to save weight and space so my only other option is from an engine driven alternator.

Because I operate a 24V battery system, I had 2 choices, a DC-DC ‘boost’ converter based battery charger, drawing power from the 12V vehicle system, or a second alternator operating as a separate 24V system (could also add a second 12V alternator to support the DC-DC charger but that seems silly). The DC-DC charger has the benefit of having microprocessor control of the charging cycle but at a much lower ampacity. That lower capacity was also a result of deriving its power from the one and only 12v alternator which would have almost certainly needed to be bigger. The potential conflicts with power demand by the vehicle and the desire for redundancy and capacity led me to the second solution; install a second dedicated charging alternator and convert it for 24V operation.

To get a picture of what I am about to discuss, below is a diagram of my system.

Charge Monitoring and Control for Second Alternator



It is worthwhile describing the factory configuration of the primary alternator and options to fully understand the potential of alternator power in the 04-07 6.0l family. My truck is a 2004 F350 SRW. The stock primary alternator is 6G series, 110A, ‘small case’ model which was found (by the market) to be inadequate and was upgraded to a 135A ‘large case’ model in 2005. Since it is a (near) direct drop-in, I have also made the upgrade to 135A. The alternator receives its drive from an 8 groove serpentine which also powers the power steering pump, water pump, cooling fan, and air conditioning pump. The factory pulley is 69mm (3.1:1 drive ratio) that I have changed to a 58mm, ‘overdrive’ pulley (3.7:1 ratio) . With all of this, I believe the belt to already be pretty heavily loaded and adding a significantly increased capacity alternator seems likely to overstress the belt system, potentially reducing reliability.

Ford offers a second alternator option with a 120A '3G' alternator (needs to be smaller to fit into the only space available). The second alternator produces power into the same 12V system as the primary and is turned on or off by the ECU (triggered on system voltage level). As an efficiency and fuel mileage improving method, it is normally idle unless the system has high power demand. Some blog posts I have read of owners operating in this configuration, report that they feel it rarely, if ever, comes on. There is also no way of knowing if or when it does come on , or how much power it provides. In all, it sounds like a marginally effective 'upgrade' in the factory configuration. It is driven by a second, 6 groove serpentine using a second balancer pulley with 3 idlers and its own tensioner, driving no other devices. I should also note that the addition of the second alternator kit, requires a change in belt routing of the primary serpentine, causing it to have a belt 3" longer than the single (only) alternator drive. This rerouting of the belt changes the arc of contact on the primary alternator from ~120 degrees to over 180 degrees. The second alternator mounting option seems ideal to me as long as I control it separately. A 220A alternator in the same compact case, is also readily available through the aftermarket sources.

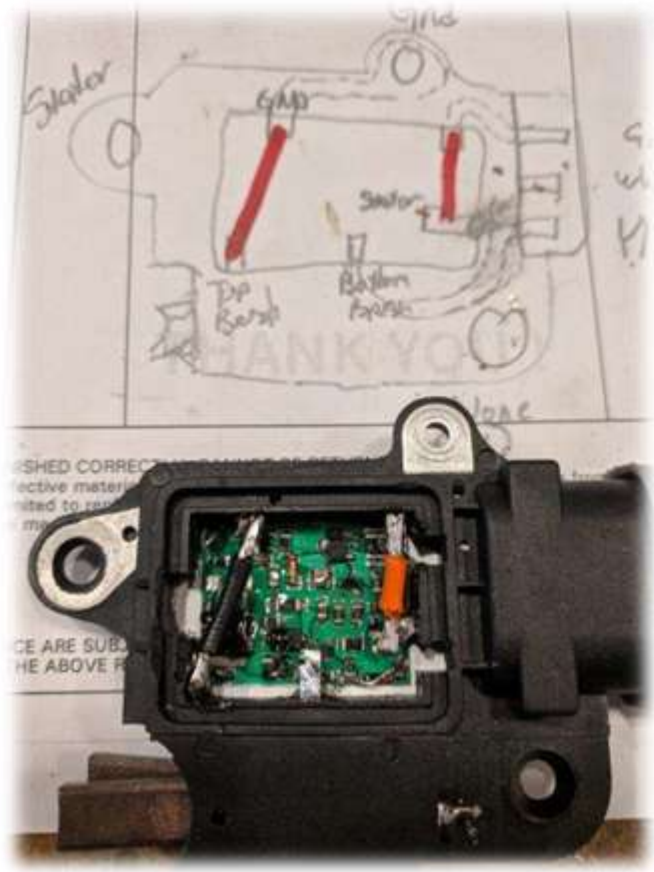
I purchased the entire set of parts as a 'kit' that was a takeoff from a junkyard truck and sold on eBay for $175. I imagine that searching eBay for 'dual alternator' and your vehicle model will produce any number of vehicle listings that are being parted out that you could ask them to sell you the parts to make your own conversion. Mine was complete (except for the longer primary alternator belt that I did not yet know about) and bolted up with only a little modification to the fan shroud to route the second belt. I replaced all of the bearings in the idler pulleys as a precaution. See my installation below (without fan or shroud). Primary alternator is at the top left, secondary at the bottom left.

A note on control of alternators; I take it for granted that 'you' will know how an alternator works, but I have found that is presumptuous. Some basics; Electricity is created when there is motion between a coil and a magnetic field. In the alternator , the coil is stationary. It is wound around a metal core just inside the casing and called the stator. The moving magnetic field is created by an electromagnet wound around the shaft and surrounded by 2 halves of 5-fingered, interlaced cores to concentrate the field into 5 pole magnet. This is called the rotor. The strength of the magnetic field and the speed of the alternator, determine the output (voltage). Since the speed is always varying with highway conditions, the only way to control the output is to vary the strength of the magnetic field. To do that, a 'regulator' measures the output voltage against the target voltage and increases or decreases pulses of electricity to the rotor (making the magnet stronger or weaker) to maintain a steady output voltage.

Since this is to be a 24V system and I have a 12v alternator with fixed internal regulator, I need to change the regulator. I want control over the voltage produced, so I necessarily need a 24V, external regulator with adjustable output. This led me to an aftermarket external product; 'Transpo V2400' from 'MotorCityReman.com' but can also be found on Amazon for $65. I later found they have a similar model with the adjustment potentiometer on a cable that could be brought into the cab which I would have preferred. I set the alternator output to 29.4V and my BMS end of charge at 28.0 volts (4.0VPC will reduce battery fatigue and since I have a large battery, the loss of capacity is not a problem).

A note on types of regulators; there are two types of regulators for automotive style alternators, only one of which you have probably know about. The far most common type, is a 'voltage regulator'. It is a simple device designed to deliver a constant voltage output from an alternator with varying speed and load. The reason it is used is that the vehicle's systems need a steady voltage to work properly, not because it is the best at battery charging,(because it is not). The second type is a 'charging regulator'. It's primary purpose is to charge batteries as rapidly as possible, according to the battery type and state of charge. While the 'voltage' regulator can do both, the 'charging' regulator practically cannot. It is more sophisticated but not intended to operate electrical equipment and batteries together. Doing so will 'confuse' the control algorithm. Sailboats generally operate in this fashion so this is where these regulators are found. Often sail boat engines have a small alternator with a voltage regulator for engine and control operation and a large alternator with a charging regulator. There are several manufacturers but Balmar is most common. A charging regulator manipulates both battery voltage and current to tailor its output to meet the needs of the battery. It operates in 'stages' just like an external battery charger. They are programmed to specific battery parameters, delivering varying voltage and current through the phases of charging. Since they are initially operating at the maximum amperage possible, they also monitor alternator temperature, and slow charging if overheating occurs. I have no doubt they are better at charging BUT, lithium batteries are easier to charge than lead-acid. Charging regulators are VERY expensive (often paired with special alternators designed for higher duty cycles than most land vehicle alternators. Like external chargers, many are not equipped to charge lithium types….theoretically they are the best solution but I am opting for the $65 suboptimal solution over the $400 one.

Connecting the external regulator is not difficult. Since the existing internal regulator operates by controlling the ground side of the brush and is an assembly that also holds the brushes, it cannot be removed, just bypassed. I removed the cover to the electronics and broke all existing connections to the internal regulation circuit. With an ohmmeter, found that the 3 external leads to the connector and the 2 brush leads. The Transpo regulator works by controlling the positive excitation to the rotor. To make the regulator work, it needs to sense the output from the alternator (stator) to assess output voltage, and to provide excitation to the rotor through the + brush (the other brush needs to be grounded). The two brush leads are the bottom left and bottom center terminals. As such, you can see how I jumpered the regulator using 2 - 16ga wires. One connects on brush to ground, the other connects the + brush to the top output contact on the regulator plug. Wires need to be large enough to carry up to 8A. I purchased a plug pigtail that fit the regulator and added wires to reach the regulator ~ 2 feet away (on the passenger side inner fender). To be clear, output power does not run THROUGH either regulator. Only 2 wires run from the alternator to the regulator, 'S' (stator connected) provides output voltage sense and 'I' (also called IG for ignition connected to a brush lead) provides excitation to the rotor.



The other terminal that needs to be connected to the alternator is B terminal. It is the insulated stud on the back or side of the alternator case where the power is delivered. Ensure the lead on 'B' terminal is large enough to handle the max current you expect. My original wiring was 8ga. In my case, with a 120A alternator, I knew it was likely I would see current in excess of the rated capacity and possibly for an extended time, particularly if my thermostat cuts in and out when the battery is low. I anticipated at least 150A and installed 4 gauge welding cable on the output. It was pure luck that is, in fact, what I have seen. It is also important to note here that I am doubtlessly exceeding the rated ampacity of the diode bridge. This is the biggest reason for control with a thermostat. I am considering adding an external 3 phase bridge rectifier and can get a 150A one for $20 on Amazon or eBay (right). It must obviously be bolted to a heat sink and have good airflow, possibly with its own fan.

The on/off control of the regulator excitation is how alternator output is started and stopped. Cutting the output of the alternator directly,(with a heavy duty relay) especially under load, is a recipe for destroying your alternator. A number of controls are needed to safely operate this system. All operate in series on the wire that brings the 24V excitation from the battery to the regulator.

1) The BMS must be able to 'authorize' charging based on parameters I set in the BMS (Electrodacus SBMS120). The BMS has an internal solid state relays that outputs 24V but does not have the ampacity to directly control excitation. I use the SSR output to control an external

24V/10A coil relay. SSR is closed (on) when charging is 'OK' and in turn, closes the external relay, passing excitation power.

2) Next in line; the excitation should only be delivered when the engine is on. As with most other alternators, I have to settle for simply being able to determine when the key is 'on' so placed a typical automotive relay near the fuse panel (under the driver side dash) to be near the 12V 'ignition' (key on) circuit.

3) I want to have my own control of the alternator to charge only when I feel the need. I placed a manual toggle switch on my center console (in photo at right, the red covered switch to the upper right) to 'enable' charging. I find that most of the time, I get enough charge from my solar panels and don't need the alternator to supplement. Note: To the left of the enable switch is the thermostat (top row is actual temperature, bottom row is limit temp setting, see notes in para 4). To the left of the thermostat is a volt/amp gauge. Knowing operating conditions of both alternators is key to making good decisions on power use. The current sensor is by Hall effect (see blue ring sensor right) The top set is for the 24V system, the bottom set is for the 12V system. It is very easy for me to see the camper battery voltage and decide when/if I want to charge.

4) The 4th control of the excitation circuit, I believe is the most important. This is where my system departs from most norms. A thermostat in the console displays operating temperature and limit temperature to allow/disallow charging, automatically. My batteries have the ability to place a heavy demand on the charging system for hours. Automotive alternators are 'rated' (in amps) to deliver a maximum output but this is NOT a continuous duty capability. At most, it for a relatively short term (low tens of minutes). My battery is able to draw charge at 150A for hours if fully discharged. If unchecked, the alternator would burn up (possibly literally) if allowed to do so. IMHO, short of active current regulation based on temperature (what battery charging regulators do), the only means of actively controlling the alternator is with a thermostat. This effectively achieves what the charging regulator does by modulating (switching on an off) the alternator rather than reducing the load. With DIRECT control of alternator operation by temperature, I can compensate for both changes in load and

environmental conditions. The 10k thermistor sensor is mounted on the alternator case in an aluminum block (clamped to the case in a drilled and tapped hole, see picture above right) directly over the stator laminations. It allows excitation until the alternator case reaches 120C, then it cuts it off till it drops back to 110C. 120C (I feel) is a relatively safe temperature. I have not been able to find a reputable, accurate 'max temperature' rating of an alternator. What I have found is typically higher than 120C. OBTW, 120C is the max my thermostat will allow….so there's that… I have also done this for my 12V alternator so I can get a feel for how comparative the temperature runs. I never see over 80C on my 12V system. I note that the 12V alternator under normal (30-40A) load runs 10-20C hotter than the 24v alternator under no-load. Turning on and off the alternator to prevent overheating is something that would NOT WORK WITH A PRIMARY ALTERNATOR. I think it likely that vehicle systems would be severely affected by system voltage going from 13.5-14 with the alternator on to 12.2-12.4V (loaded battery) when off.

The alternator output is directly connected to the camper battery by 4 ga welding cable with only one disconnect, behind the cab. This connector is a 175A 'Anderson powerpole' clone. The insulated QD terminal on the left is the excitation power lead coming from the BMS relay….I have melted the 175A connector once when one of the contacts backed partially out….. This is a serious amount of power to be putting through any connector, especially for a long period of time, so make sure you have a good one that is rated for that much amperage continuously.