

**APPLICATION NOTE NUMBER 16, Revision A**  
**BEST BATTERY SELECTOR IN ENGINE STARTING APPLICATIONS**

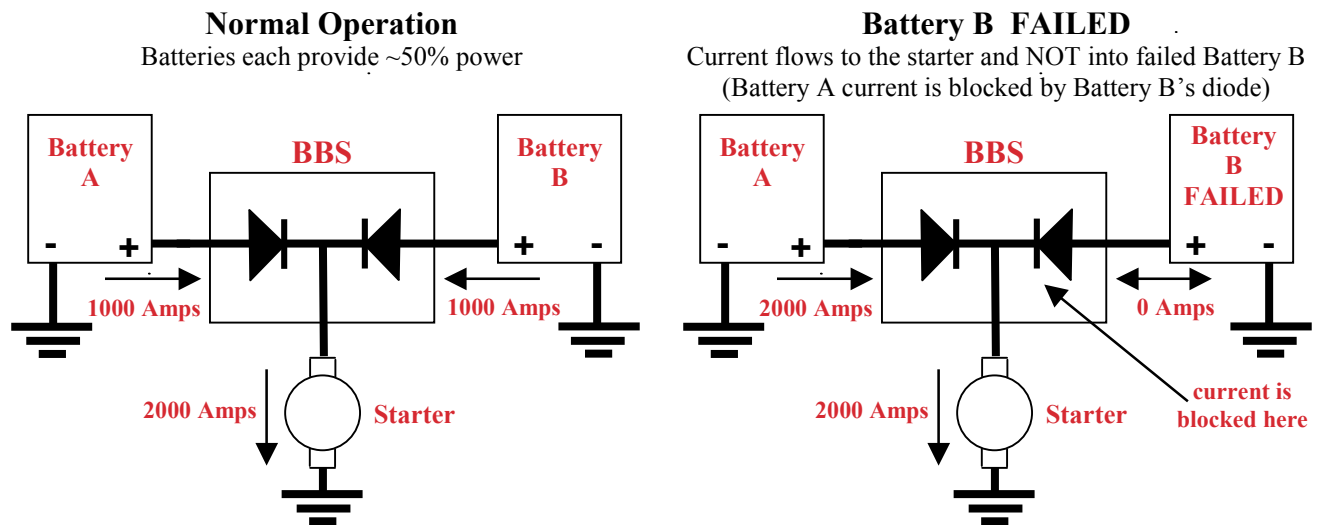
**Introduction**

This Application Note describes the function and usage of a Best Battery Selector (“BBS”) used in engine starting systems that use two batteries to increase system reliability. In this case the term “battery” means multiple cells connected in series. The reasons for using a BBS and two separate batteries, we’ll call “Battery A” and “Battery B”:

- 1) So the engine may be started even if one battery fails (dead, short, or low voltage)
- 2) So the failed battery is automatically isolated from the good battery, preventing a discharge path from the good battery into the failed battery

**What is a Best Battery Selector?**

A properly engineered Best Battery Selector (“BBS”) consists of two large diodes, specialized heat sinks, voltage surge protection and high current terminals assembled and mounted in a metal housing. Each diode allows starter motor cranking current to flow in the forward direction, but blocks current from flowing in the reverse direction. The BBS got its name because the “best battery” is the one that provides the majority of the power to the starter. Since a BBS is a passive device, it does not perform any switching or control functions, so the best battery is “selected” in a passive manner based on the principle that current flows from the source of the highest voltage. In a system that has well-matched batteries and cabling, under normal operating conditions two good batteries will each provide about 50% of the total power delivered to the starter. In the case of a partial battery failure, the battery with the highest voltage will supply the majority of the starter current. In the case of a total battery failure, the remaining battery becomes the “best battery” and provides 100% of the power delivered to the starter.



**A BBS performs the valuable functions of coupling good batteries, and isolating a failed battery**

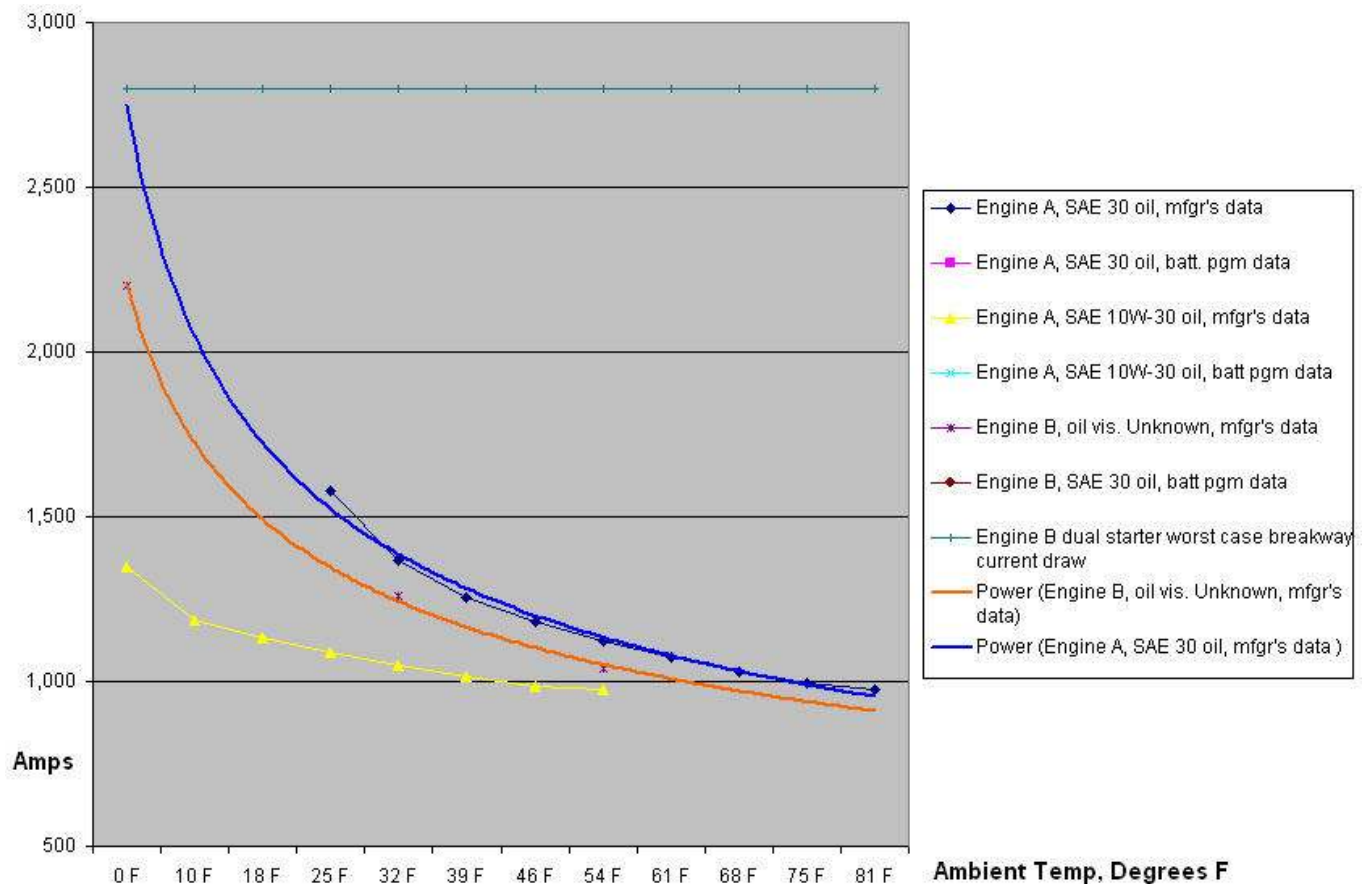
**Primary considerations for using a BBS in an engine starting system**

- 1) Diodes must be large enough to carry 100% of the worst case starter cranking current.
- 2) Larger batteries must be used to compensate for power loss in the Best Battery Selector.
- 3) Do not connect a single engine-driven alternator to both batteries, even through diodes. If an alternator is absolutely necessary, connect it to only one battery.

**Importance of selecting a BBS with sufficiently high diode ampere rating**

If a BBS diode is not large enough to carry 100% of the worst case starter cranking current, the diode could fail catastrophically. For example, from the chart below the starter rolling current for Engine A current with SAE 30 oil is about 1,600 amps at 25F. The break-away current for this engine can be up to 2,800 amps. The BBS therefore must be rated for 2,800 amps break-away current AND 1,600 amps rolling current for the full starting cycle when operated with SAE 30 oil at 25F. Note that these limits are always lower than the rated current of the diode device itself. This is because the diode must be derated for safe operation in a Best Battery Selector due to waste heat generated during the cranking cycle.

**Example of Total Starter Current Demand - 2 MW Genset**



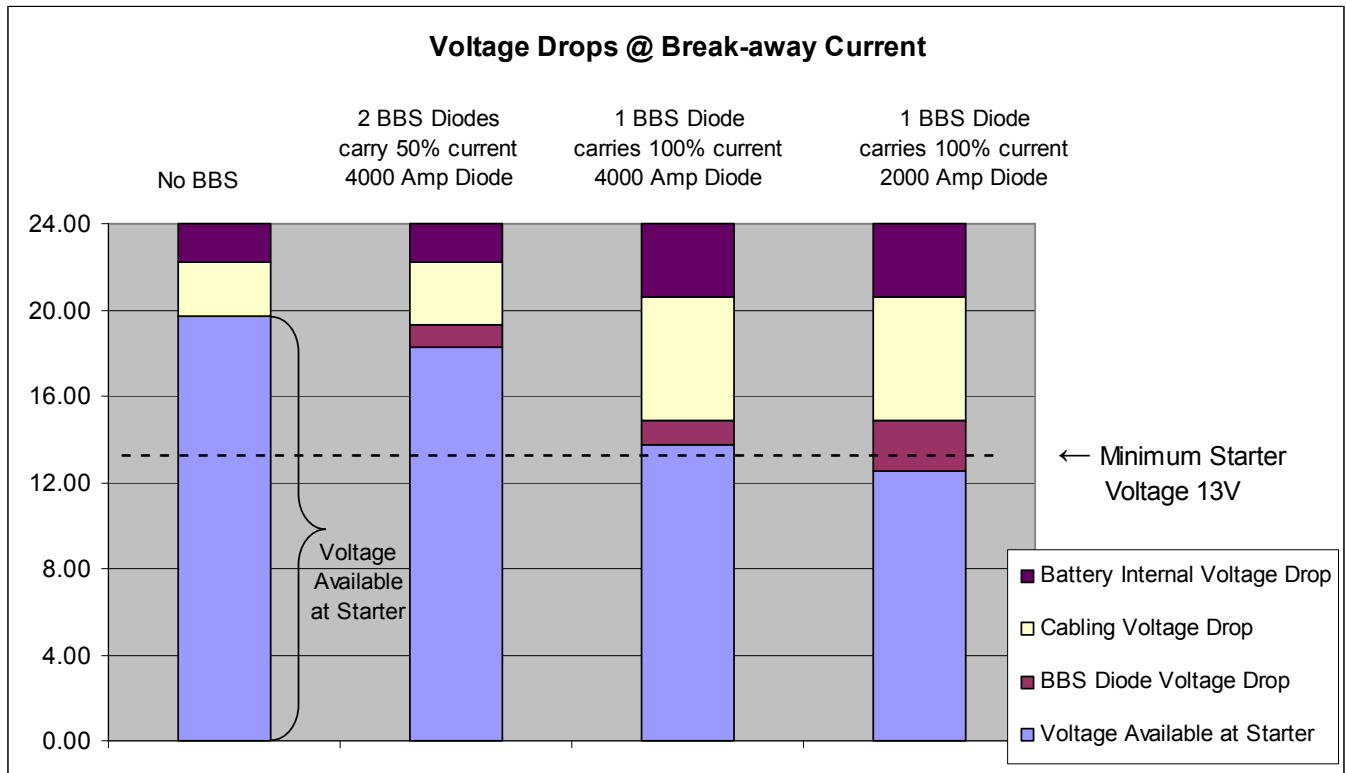
Besides more cranking current margin, there is another benefit of using larger diodes: Lower voltage drop while carrying full cranking current. Larger diodes reduce power loss, meaning that the battery has to be upsized less than it would with a higher loss diode.

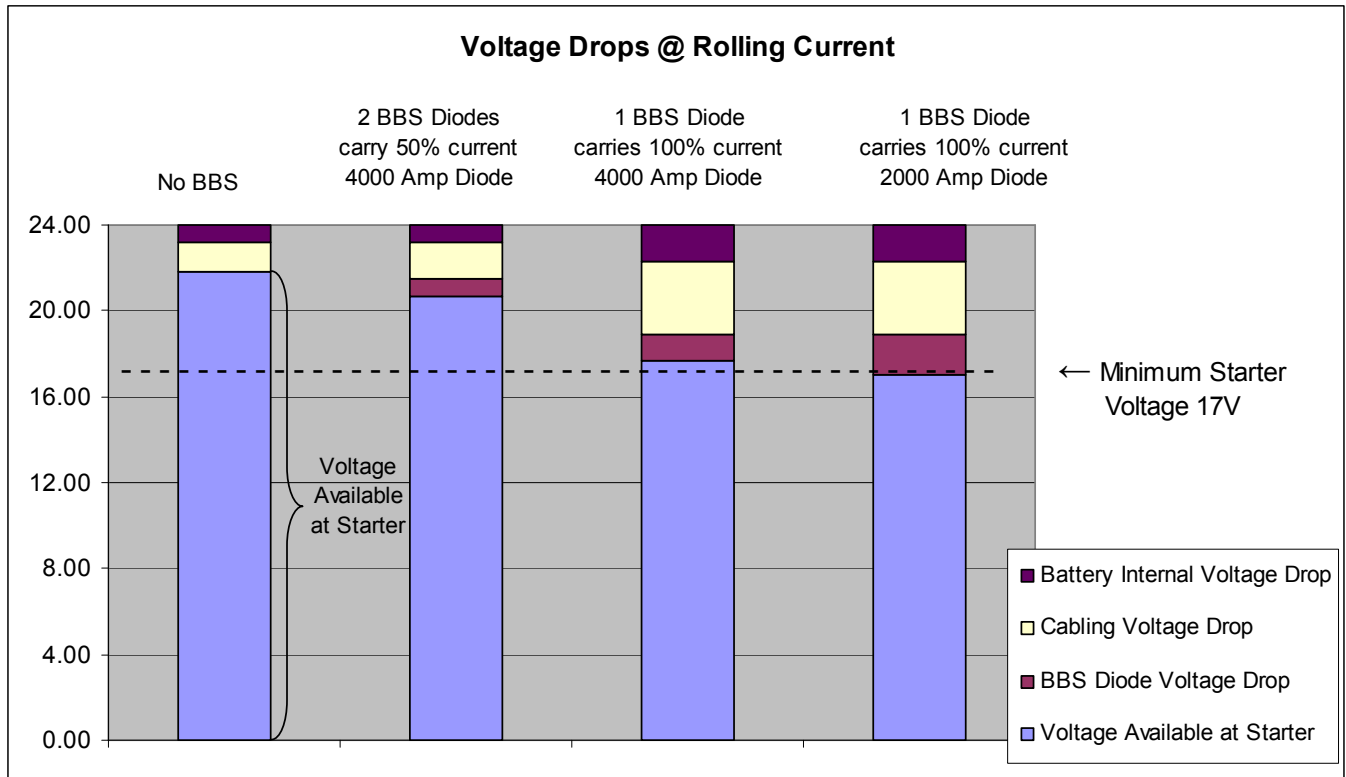
Diodes must be firmly attached to large masses of thermally conductive metal (the heatsinks) to insure the diode junction temperatures remain well below the diode manufacturer’s specified maximum under worst case conditions. The SENS BBS-1600 and BBS-4800 products contain large diodes on oversized heatsinks to assure reliable operation under worst case operating conditions. Even though normal cranking cycles may be short in duration, less than 45 seconds typical, SENS designs to the worst case specified cranking duration of 90 seconds (two consecutive cranking periods of 45 seconds each) as defined in NFPA 110 “Standard for Emergency and Standby Power Systems”, section 5.6.4.4. Undersized diodes run hotter in normal operation – risking catastrophic failure – and due to excessive voltage drop may not deliver sufficient voltage to the starter to start the engine.

**An engine starting system with a BBS requires larger batteries**

When a BBS is used, the additional voltage drops in the system create a need to increase the size of the batteries so they deliver the specified and expected starting performance at a considerably higher end voltage (i.e. more shallow discharge) than is normally assumed for engine start.

The Electrical Generating Systems Association standard, EGSA 100B, 2000 “Performance Standard for Engine Starting and Control Batteries”, contains specific recommendations for minimum allowable battery voltages at two levels of cranking current: break-away current (first second of any cranking period) and rolling current. For break-away current, NiCad batteries should have no less than 0.65 volts/cell [13 volts in a “24V” system], and lead-acid batteries should have no less than 1.00 volts/cell. For rolling current, NiCad batteries should have no less than 0.85 volts/cell [17 volts in a “24V” system], and lead-acid batteries should have no less than 1.50 volts/cell. This is the voltage as measured at the battery terminals and does not include the voltage drops in the cabling and BBS diodes. The charts below show the end voltages required for different BBS operating points. The worst case operating point must be used to size the battery in case one battery fails completely.





This data shows that minimizing voltage drops in the BBS is critical to reliable engine starting. The installer must minimize cable lengths, use the largest possible wire, parallel two or three times if possible, and insure tight crimps and connections. In order to properly size batteries for an engine starting system with a BBS, the genset package supplier will need to obtain data on engine cranking amps from the engine manufacturer, and BBS diode voltage drops from the BBS manufacturer.

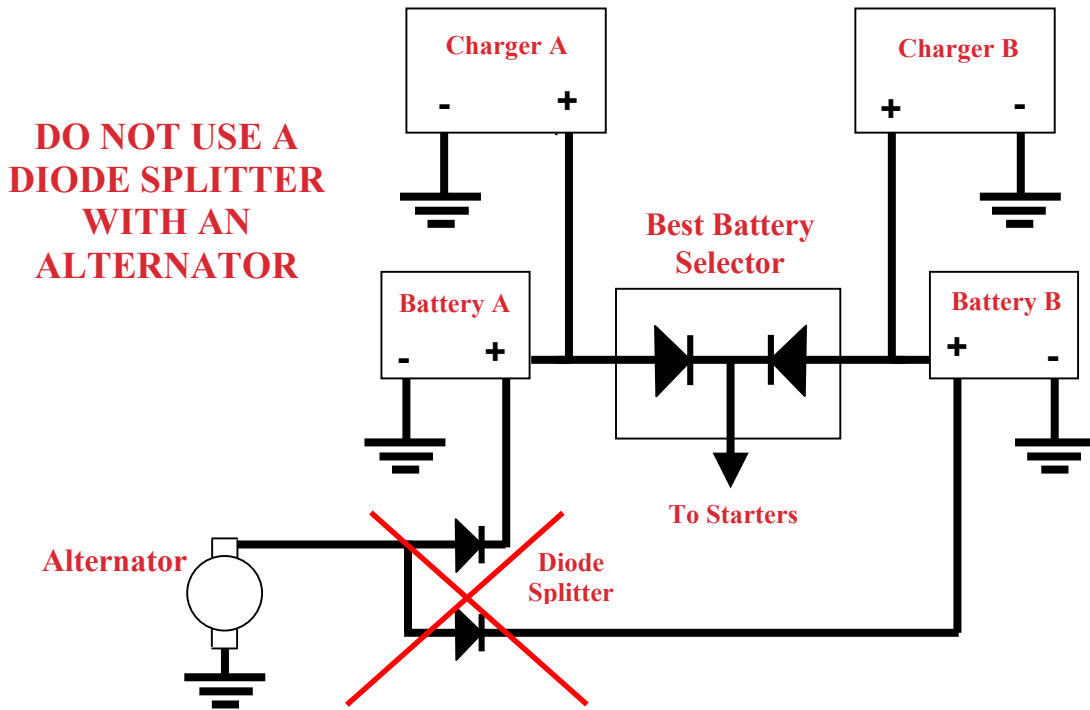
#### Interconnection of engine-driven alternator with systems using Best Battery Selector

System packagers providing Best Battery Selectors face a dilemma: What to do with their engine-driven alternator? Acceptable alternatives include the following:

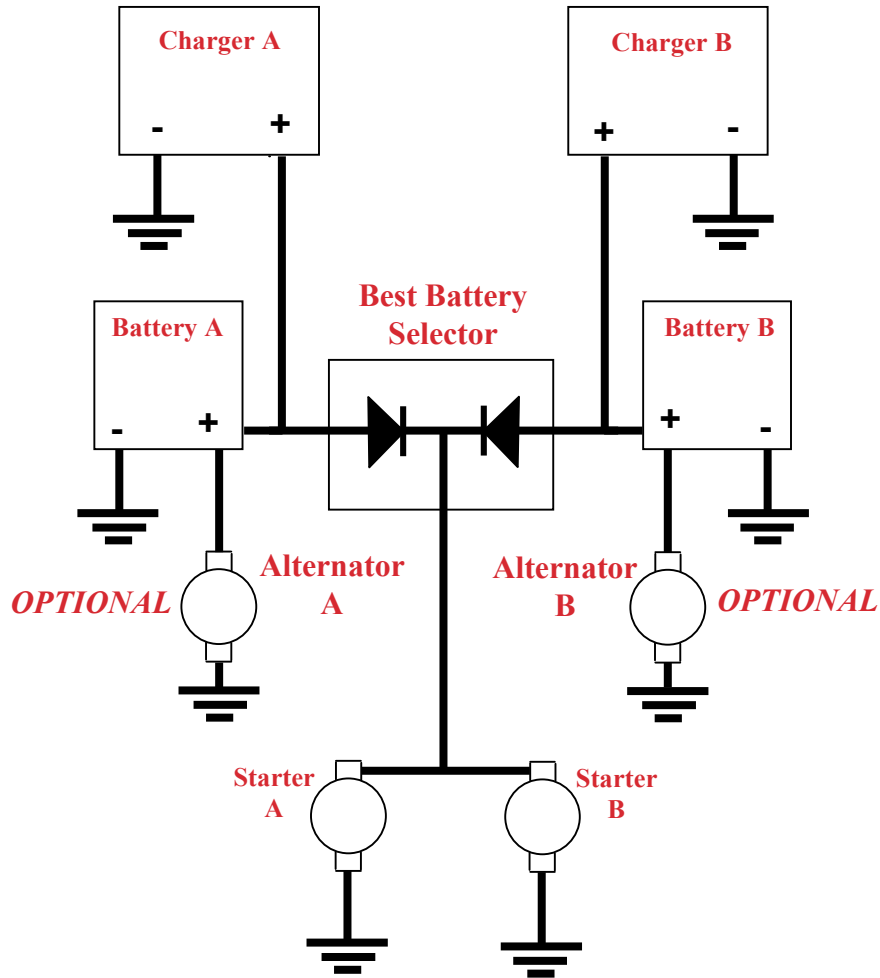
- 1) Do not use an alternator in the system. Each battery in the system will be charged by its dedicated battery charger.
- 2) Connect one alternator directly to one battery only (NOT BOTH BATTERIES).
- 3) Connect one alternator directly to Battery A, and an independent second alternator directly to Battery B.

A single alternator should NEVER be connected to both batteries, because it connects the two system batteries in parallel, defeating the isolation function of the BBS. A “diode splitter” in which a single alternator is connected through a diode to Battery A, and also connected through a second diode to Battery B, solves the isolation problem but creates two new problems:

- 1) The alternator was designed for direct connection to the battery directly with no intervening device. The alternator's performance is thus not characterized or guaranteed by its manufacturer for such operation. Installing an alternator diode splitter would require the BBS maker (or the genset packager) to guarantee compatibility between alternator and BBS.
- 2) Voltage drop (about one volt) across the splitter diode reduces the charging voltage available at the battery, making the alternator virtually useless for charging the battery. The only way to overcome the splitter voltage drop would be to increase the alternator's output voltage. This is not practical because voltage drop in the splitter varies depending on current flow.



If an alternator is required to be connected into the system, the alternator should be connected directly to the battery it is charging, not connected through a diode. If two alternators are used, Alternator A should be connected directly to Battery A, and Alternator B connected to directly to Battery B, with no diodes or cross connections used.



**Conclusion**

A BBS with sufficiently large diodes can provide significant value-added functions in an engine starting system: Coupling good batteries, and isolating a failed battery. Because there are no ideal diodes, there is always a “power penalty” in using a BBS. For engine starting systems that use a BBS, a BBS rated for worst-case starting conditions must be chosen (such as SENS BBS-1600 or BBS-4800), the installation must minimize voltage drops, and the alternator(s) must be connected to assure system integrity and correct battery recharge.