Vanner 80-kJ Bus Ultra Capacitor for Starting Assist and Dead Battery Start

1.   Introduction

Regular vehicle starting system contains an engine, a starter motor, and an alternator (or a starter/alternator combination). The starter takes the starting command from multiplexing (MUX) system and starts the engine. When engine is on, the alternator charges the battery, which powers the MUX system and the starter. During starting, the starter takes very high cranking current from the battery. This affects the performance and life of the battery. And when battery is dead (with too low voltage), starting may not be possible. The ultra capacitor system is implemented to assist vehicle starting and support dead battery start.

2.   Theory of Operation

A block diagram of the 80-kJ ultra capacitor system is shown in Figure 1.
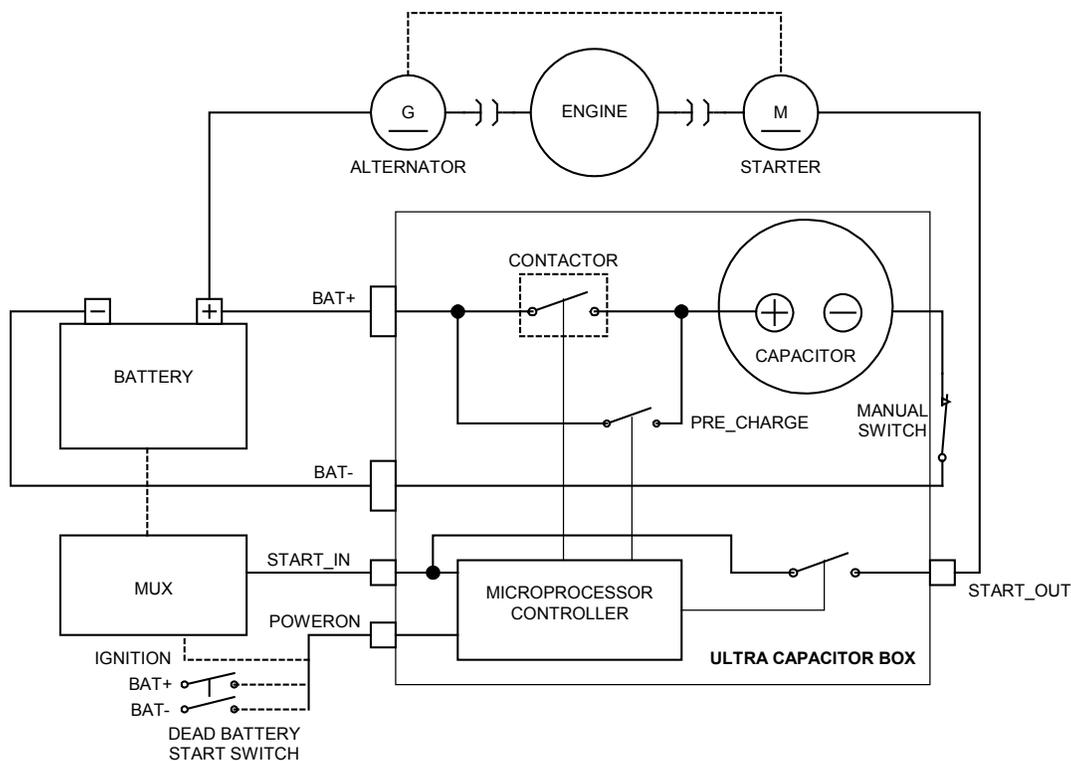

Figure 1.   Block diagram of 80-kJ bus ultra capacitor system

The ultra capacitor box has five terminals. Two of them are connected to the positive and negative battery terminals (BAT+ and BAT-). The ultra-cap intercepts the starting command from MUX system (START_IN) and generates a new starting command (START_OUT) for the starter. A POWERON signal is used to turn on the power supply of the control circuitry for the ultra-cap. It can take several different signals, which are detailed in following sections.

According to the state of battery and ultra capacitor, there are several different operating modes for the ultra-cap system. In the following sections, the battery voltage will be denoted as Vb and the ultra capacitor voltage denoted as Vc.

2.1 Normal Operation - both battery and ultra-cap are fully charged

When 20V < Vb < 30V and Vc > (Vb-2), the ultra-cap works in normal mode. The starting process is as follows,

a) The driver turns the ignition key, which powers up the MUX system and the ultra-cap controller.

b) The ultra-cap controller detects that 20V < Vb < 30V and Vc > (Vb-2), and closes the contactor.

c) The driver pushes the starter button, a starting command is sent by MUX system.

d) The ultra-cap controller detects the starting command, and sends out a new starting command after 50 milliseconds delay. The ultra-cap will provide major cranking current for the starter.

e) The engine will be started, and the alternator starts charging the battery and ultra-cap.

f) After 20 minutes, or when Vc reaches 30V, the ultra-cap controller opens the contactor. This prevents discharging of the capacitor when engine is off but accessory is still on. The ultra-cap is ready for next starting.

g) After 1 minute, the ultra-cap controller enters sleep mode to save power.

2.2 Low Capacitor Voltage Operation - battery is fully charged and capacitor is discharged

When 20V < Vb < 30V and Vc < (Vb-2), the ultra-cap works in low capacitor voltage mode. The starting process is as follows,

a) The driver turns the ignition key, which powers up the MUX system and the ultra-cap controller.

b) The ultra-cap controller detects that $20V < Vb < 30V$ and $Vc < (Vb-2)$. It turns on the pre-charge circuit to charge the ultra capacitor from the battery. During pre-charging, any starting command sent by the MUX system will be ignored. Pre-charging is done when $Vc > (Vb-2)$. Now the ultra-cap is ready for starting.

c) The driver pushes the starter button, a starting command is sent by MUX system.

d) The ultra-cap controller detects the starting command, and sends out a new starting command after 50 milliseconds delay. The ultra-cap will provide major cranking current for the starter.

e) The engine will be started, and the alternator starts charging the battery and ultra-cap.

f) After 20 minutes, or when Vc reaches 30V, the ultra-cap controller opens the contactor. This prevents discharging of the capacitor when engine is off but accessory is still on. The ultra-cap is ready for next starting.

g) After 1 minute, the ultra-cap controller enters sleep mode to save power.

2.3 Dead Battery Start Operation - battery is discharged and ultra-cap is fully charged

When engine is off and accessory is left on, the battery will be discharged. Sometimes the battery voltage may drop to a level that too low to start the MUX system, which makes vehicle starting impossible. If the ultra-cap is charged, it can be used to start the vehicle from this dead battery. Since the IGNITION signal is not available from the MUX system, the POWERON terminal of the ultra-cap box needs to be connected to a dead battery start switch. The switch can be connected to either terminal of the battery (if BAT+ is used, the battery voltage needs to be at least 6V). The starting process is as follows,

a) The driver pushes the dead battery switch, which powers up the ultra-cap controller.

b) The ultra-cap controller detects that $Vb < 20V$ and $Vc > 20V$. It closes the contactor to charge the battery from the ultra capacitor. When Vb reaches above 18V, the MUX system can be powered up.

c) The driver pushes the starter button, a starting command is sent by MUX system.

d) The ultra-cap controller detects the starting command, and sends out a new starting command after 50 milliseconds delay. The ultra-cap will provide major cranking current for the starter.

e) The engine will be started, and the alternator starts charging the battery and ultra-cap.

f) After 20 minutes, or when Vc reaches 30V, the ultra-cap controller opens the contactor. This prevents discharging of the capacitor when engine is off but accessory is still on. The ultra-cap is ready for next starting.

g) After 1 minute, the ultra-cap controller enters sleep mode to save power.

2.4 Sleep Mode Operation

When IGNITION is connected to the POWERUP terminal of the ultra-cap controller, the controller will always be powered up when IGNITION is on. However, to save power, the ultra-cap controller will enter sleep mode if it has been idle (no starting command coming in) for one minute. It can automatically wake up on starting command and resume starting operation.

When dead battery switch (momentary pushbutton) is used and switching to BAT+ or BAT- is connected to the POWERUP terminal of the ultra-cap controller, the controller is powered by the ultra-cap upon receiving the switch signal. It will then generate a signal to keep the power on when the dead battery start switch is released. To prevent the ultra-cap from being depleted by powering the controller for a long time, the controller will power itself off when being idle for one minute. Under this situation, the ultra-cap controller can NOT wake up on starting command. The driver has to push the dead battery start switch again, and push the starter button within one minute to start the bus.

3. Fault Conditions and Signals

Several situations may lead the ultra capacitor into fault conditions. A red LED on the ultra-cap box will show the fault signal for such cases.

♦ In low capacitor voltage operating mode, THE LED will blink once per second during pre-charging of the ultra capacitor. If the pre-charging circuit can NOT charge the capacitor up correctly, or if the pre-charging can NOT be completed (when Vc > Vb-2) within 50 minutes, the LED will stay on and starting is not allowed. If the driver is sure that the battery is fully charged and the ultra-cap is bad, he can turn off the manual switch on the ultra-cap box to bypass the ultra capacitor and start the bus directly with battery. The LED will be turned off when the controller enters sleep or off mode.

♦ In dead battery start operating mode, THE LED will blink once per second during pre-charging of the battery. If the pre-charging can NOT bring the battery voltage

up to 20V within one minute, the contactor will be opened and the LED will stay on. The LED will be turned off when the controller enters sleep or off mode.

♦ In dead battery start operating mode, when the battery is charged up and the MUX is powered on, the starting command needs to be sent within one minute. Otherwise the ultra-cap controller will power off and the dead battery switch needs to be pushed again to re-energize the ultra-cap controller.

♦ When engine is started and the capacitor voltage can NOT be charged above 30V within 20 minutes, the LED will stay on. The LED will be turned off when the controller enters sleep or off mode.

4.   **Characteristics of Vanner 80-kJ Ultra Capacitor System:**

✓ It supports both starting assist and dead battery start.

✓ It pre-charges the capacitor before closing the contactor when capacitor voltage is low. This prevents the huge inrush current from the battery to the capacitor.

✓ The start signal is intercepted by the ultra-cap, and a new start signal is generated according to the operating conditions of the battery and ultra-cap. This gives a much safer start of the vehicle.