

Learning Cycle Procedure

- Discharge battery to empty
 - On the initial discharge, if IT is enabled, make sure to send a reset to the gauge so that the [RUP_DIS] bit is set and resistance updates do not occur.
- Relax for 5 hours
 - This relaxation time allows for a valid OCV reading to be taken and stored for the Qmax update. The valid OCV reading will occur when the dV/dt of the battery is $< 1 \mu V/s$.
 - The [VOK] and [RUP_DIS] bits in the Control() register will clear once the gauge has taken an OCV reading and qualified it for a Qmax update.
 - The 5 hour wait time is a recommendation, the most accurate time will be looking to see when the [VOK] and [RUP_DIS] bits are clear.
- Charge battery to full
 - We typically recommend a C/2 charge rate
 - Make sure IT is enabled at this point (the [QEN] bit in the Control() register should be set).
 - At the start of charge, the [VOK] bit in the Control() register should set.
 - At the end of charge the [FC] bit in the Flags() register should be set.
- Relax for 2 hours
 - This relaxation time allows for a valid OCV reading to be taken and stored for the Qmax update. The valid OCV reading will occur when the dV/dt of the battery is $< 1 \mu V/s$.
 - The [VOK] bit in the Control() register will clear once the gauge has taken an OCV reading and qualified it for a Qmax update.
 - The 2 hour wait time is a recommendation, the most accurate time will be looking to see when the [VOK] and [RUP_DIS] bits are clear.
 - At this point the first Qmax update should have occurred. Update Status should be at 0x01 for system-side gauges of 0x05 for pack-side gauges.
 - Note that it takes less time for a battery to relax once it is fully charged than it does when it is discharged.
 - Initial Qmax Update criteria:
 - OCV point ($dV/dt < 1 \mu V/s$)
 - At least 90 % passed charge
 - OCV point ($dV/dt < 1 \mu V/s$)
- Discharge battery to empty
 - We typically recommend a C/5 rate, but the rate can be as low as C/10. If using a C/10 load, make sure the gauge sees that the current is at least C/10, if the current is any lower, resistance updates will not occur.
 - During the discharge, the resistance table will be updated as each grid point is reached (the resistance table is stored in 15 grid points along the discharge curve).
- Relax for 5 hours
 - This relaxation time allows for a valid OCV reading to be taken and stored for the Qmax update. The valid OCV reading will occur when the dV/dt of the battery is $< 1 \mu V/s$.
 - The [VOK] bit in the Control() register will clear once the gauge has taken an OCV reading and qualified it for a Qmax update.
 - The 5 hour wait time is a recommendation, the most accurate time will be looking to see when the [VOK] bit are clears.
 - There is another Qmax update at this point because of the OCV reading taken in step 4 and then in step 5 there was at least 90 % passed charge and then during this step another OCV reading was taken.
 - At this point Update Status should be at 0x02 for system-side gauges of 0x06 for pack-side gauges.

Learning Cycle Setup

- Review app note: Achieving the Successful Learning Cycle
 - <http://www.ti.com/litv/pdf/slua597>
- Log and autoexport everything
 - Log DataRAM: In the DataRAM screen, set your logging interval under the Options menu. 4 seconds is the fastest you want, but 10 seconds or longer is probably fine. Then click the Start Logging button and enter the filename. Click OK and it will start saving the DataRAM values to that file.
 - Log DataFlash: In the Data Flash screen, under the Options menu, configure the interval and filename. About 10 minutes should be a sufficient interval. Then select AutoExport from the Options menu and it will read and dump the Data Flash contents shown on the screen into a new file. Each interval will create a new file and increment the filename.
- Import to spreadsheet and analyze the log to see what went wrong
 - check current, voltage, Flags, Control Status, etc.

Common problems during a learning cycle

- Battery not detected (BAT_DET = 0)
- IT not enabled (IT Enable = 0 for host-side gauges, Update Status = 04 for pack-side)
- Not reaching full charge (confirm FC bit was set before charger stopped)
- Not relaxing long enough (make sure VOK bit cleared)
- Discontinuous discharge
- Discharging too far (pack protector opens or gauge goes into POR)
- Not relaxing at all
- Too much current during “relaxation” causing voltage to steadily drop
- Not at room temperature (10C-40C)
- FET doesn't cut off discharge properly (relays are more reliable)
- Wrong chemID selected (RUP_DIS might get set during discharge)
- LiFePO4 needs 5 hour relaxation after charge (instead of standard 2 hours)

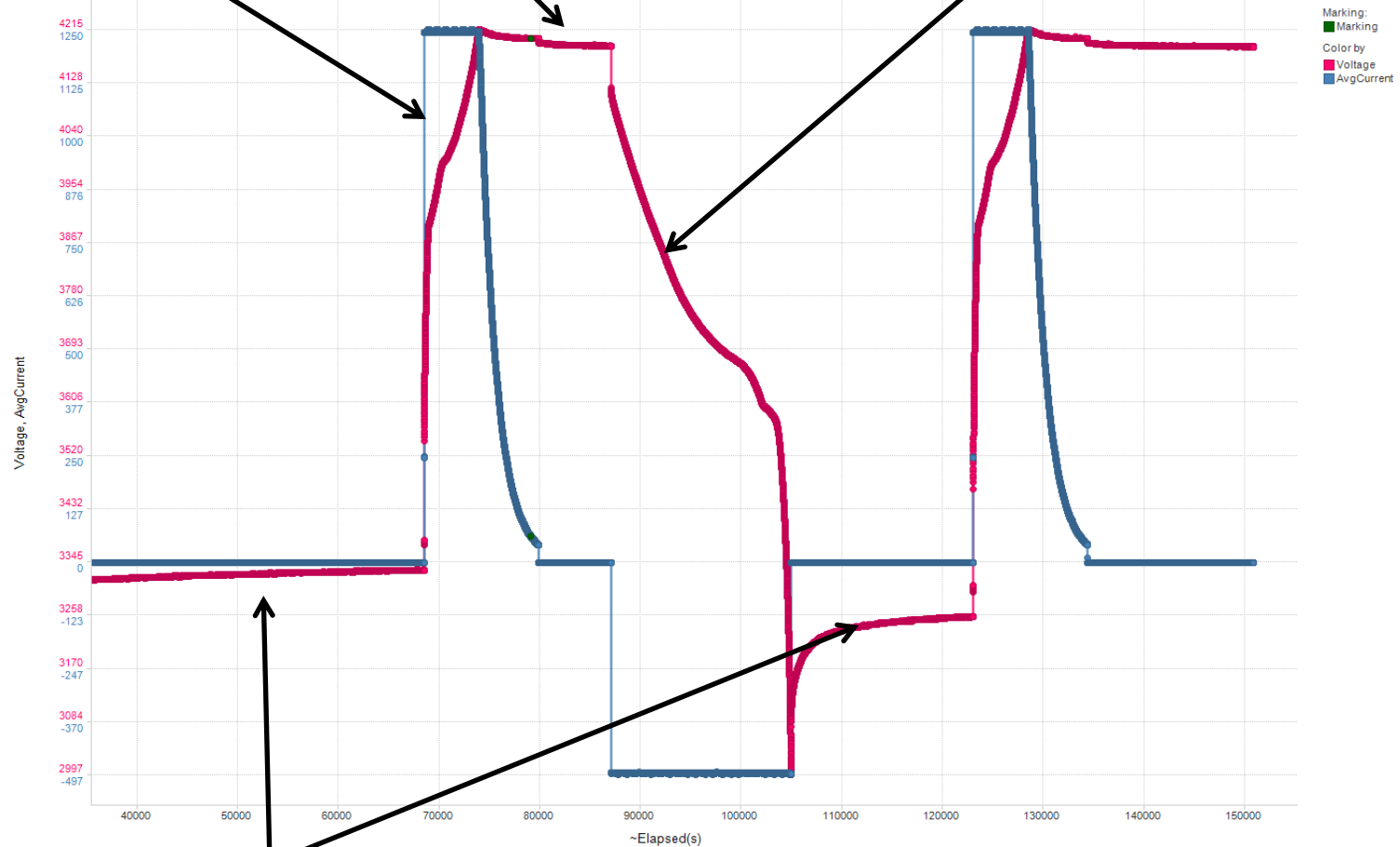
Learning Cycle Overview

Charge to full at C/2 rate

Relax for at least 2 hours

Discharge to full at C/5 – C/10 rate

Line Chart



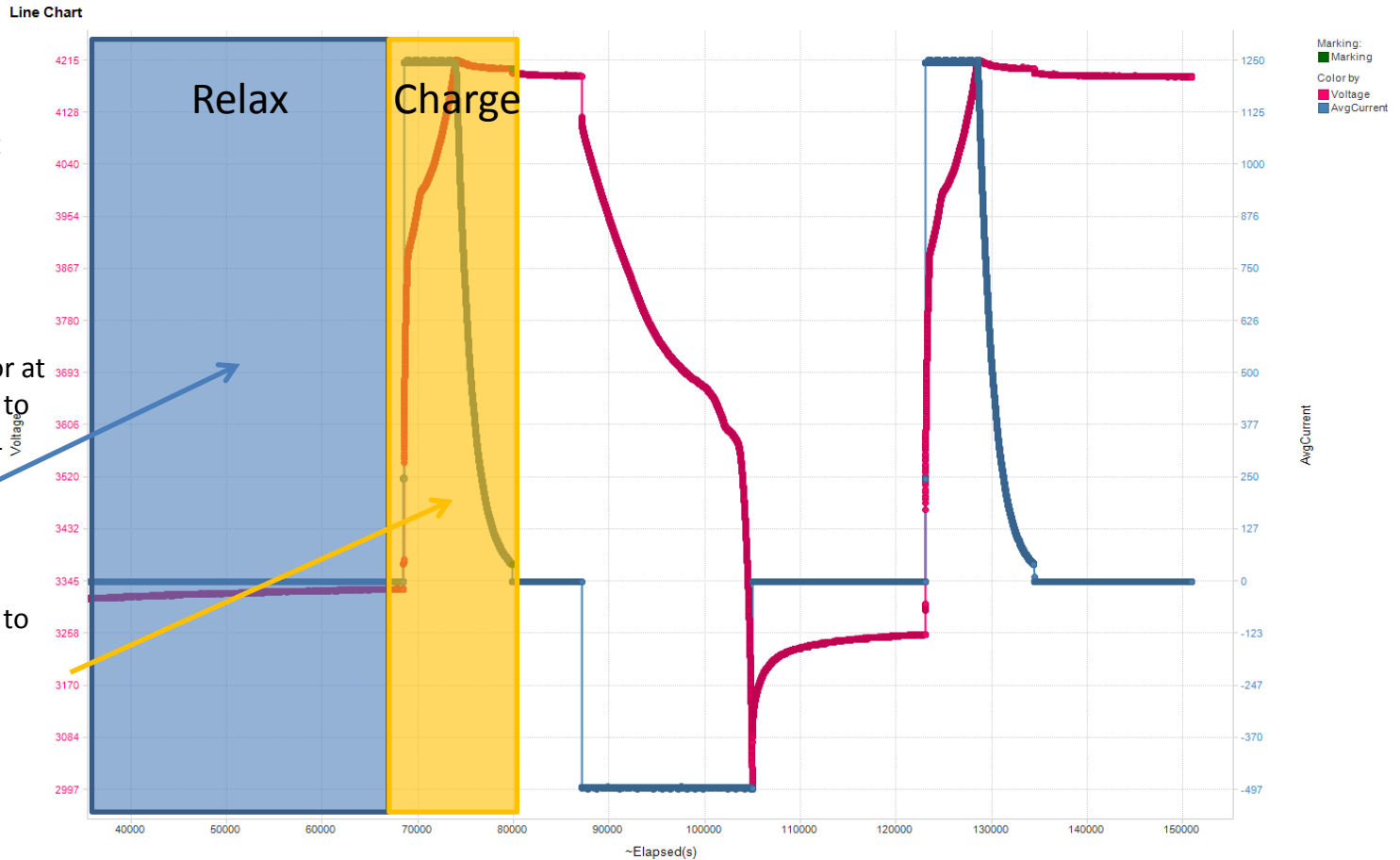
Relax for at least 5 hours

Learning Cycle Break Down

Send the `IT_ENABLE` command at the beginning of the test. The [QEN] bit in the Control Status register will set at that point.

Relaxation of a depleted battery for at least 5 hrs in order to reach the $dV/dt < 1$ $\mu V/s$ condition

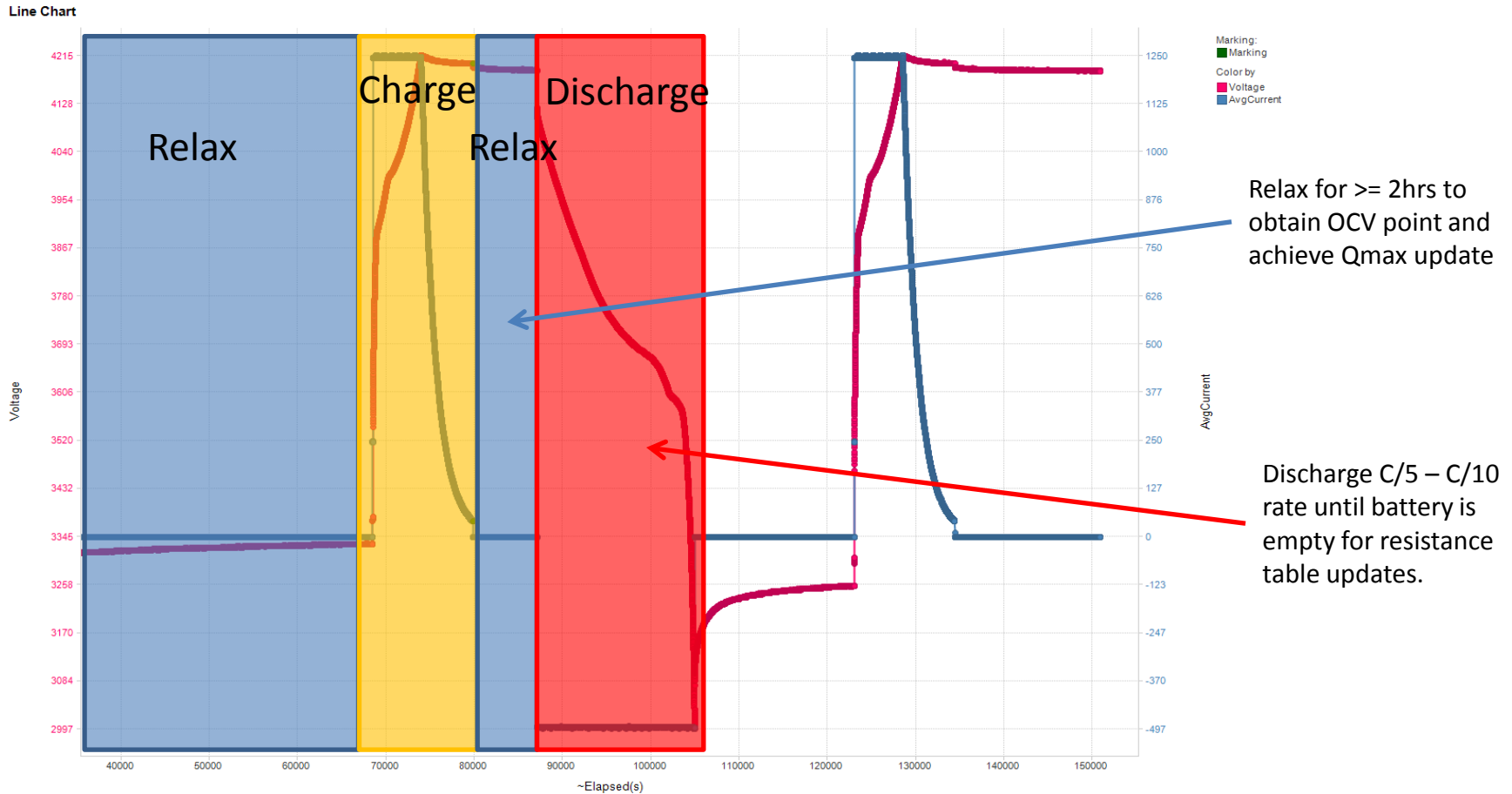
Charge the battery to full (typically C/2 constant current charge)



The Learning cycle should start with a depleted battery (typically **Voltage()** < 3200 mV). The learning cycle should also start out with the battery being in the relaxed state. The fuel gauge will recognize a relaxed battery when $dV/dt < 1$ $\mu V/s$

After the dV/dt condition is reached, the fuel gauge will take an open circuit voltage (OCV) reading and store the value for a future Qmax update. An indication of this would be the [RUP_DIS] bit in the Control Status register should be clear and the [VOK] bit in the Control Status register should clear. The battery can now be charged to full.

Learning Cycle Break Down

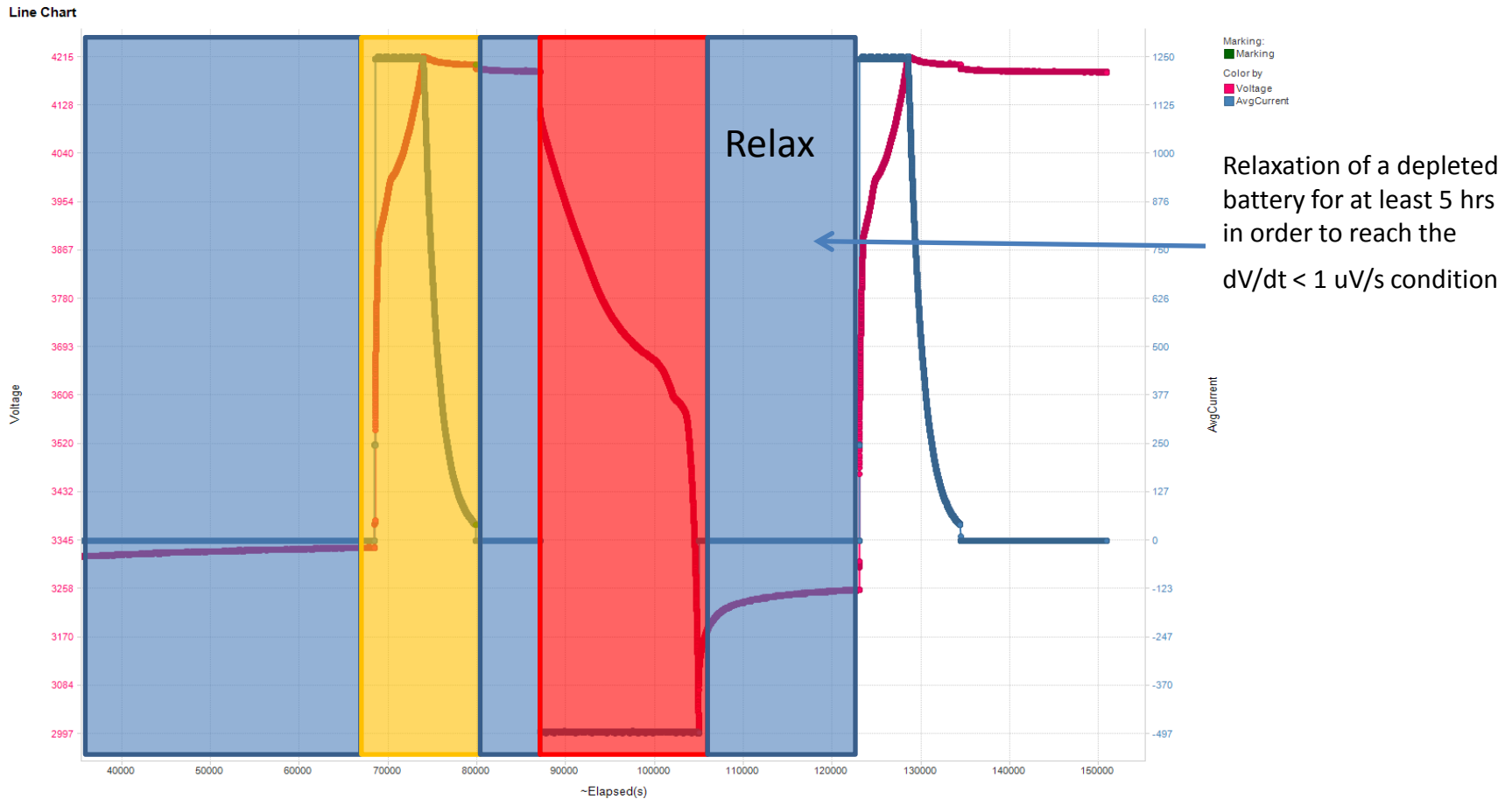


After the battery has charged to full. The [FC] bit in the Flags() register should set. The battery should now relax for at least 2 hours in order to meet the $dV/dt < 1 \mu V/s$ condition for another OCV measurement.

Once the $dV/dt < 1 \mu V/s$ condition has been met the fuel gauge will take another OCV measurement. At this point a Qmax update can be completed and Update Status should go to 0x01 for system side fuel gauges and 0x05 for pack side fuel gauges.

After the Qmax update has occurred, the battery can be discharged to empty in order to allow for resistance table updates. The discharge charge should be between C/5 – C/10.

Learning Cycle Break Down



During the discharge, the resistance table will update.

After the battery has been discharged to empty. The battery should be allowed to relax at least 5 hours in order to allow the fuel gauge to obtain another OCV point. After the OCV point is taken another Qmax update will occur. At this point Update Status will go to 0x02 for system side fuel gauges and 0x06 for pack side fuel gauges.

Learning Cycle

Line Chart

