Technical Bulletin

The Power of WAI

COM & Multifunction Regulator Interface and Terminology 2020

Valeo, Bosch, Denso, Mitsubishi, and Hitachi to name a few of the top voltage regulator manufacturers in the world, produce today's voltage regulators. As vehicles and their charging system evolve from the most basic of charging systems to advanced charging systems such as starter/generator and Kinetic charging system the regulator and I/O interface to the regulator has evolved. Furthermore the management has become an integral part of the interaction between the voltage regulator and the ECU of the vehicle. Thus, the day of the basic analog regulator for many vehicles is gone. Today regulators are more complex. They are capable communication with the ECU and making decisions based operating conditions. These regulators fall into the categories of COM (LIN/BSS) and Multifunction regulators. With these regulators comes a host of signals, terms and functions that require understanding. This is what drives many questions from automotive technicians when trouble shooting, testing, and installing these regulators. It is the intent of this article to clear up some of this confusion.

LIN/BSS COM Regulators…..

There are many communication protocols used in the automotive industry for example TTP/A and CAN. Although in today's charging systems the most common network protocols used are LIN (Local Interconnect Network) and BSS (Bit Synchronous Signal wire). Unlike Multifunction regulators which are affective. The COM type interfaces only require a single wire and are more robust because of the ability to pass more detailed parameters/status between the regulator and the ECU for control and monitoring operation. The communication ability provides for further optimizing alternator performance and load management. Both LIN and BSS COM protocols are bidirectional hierarchal (master/slave) interfaces. As listed below the command structure of both interfaces has access to multiple control parameters and status information.

- Control:
  - Voltage set point, Current, Duty cycle, LRC(cutoff and rate)
- Status:
  - Voltage, Current, Duty cycle, RPM, Temperature, Communication errors, Regulator/Alternator errors. ID information.

As indicated above LIN and BSS protocols are both serial type protocols and both use a single wire bidirectional interface to pass data but that's where the similarity in the protocol stops. The command structure, data format, and data rates differ. Described below are the unique features of LIN and BSS.

LIN:

- LIN has evolved from early LIN 1.3 to LIN 2.2 which has affected Data rate, Data integrity checking etc….
- LIN communication speeds are from 2.4 to 19.2 K Baud. In LIN 2.x devices the regulator may be auto rate.
- LIN Command ID's vary amongst the regulator manufacturers.
- The individual data byte format is 8 bit with start and stop bits.

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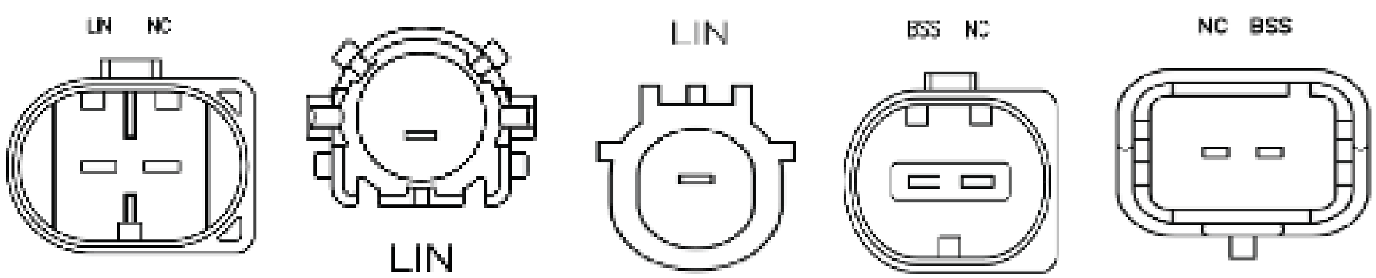
- The command structure is as follows.
  Break character which alerts the slave there is data coming
    - o Sync character which is used by the slave to align the data rate.
    - o Command ID to instruct the slave of the action to be performed
    - o Data bytes to or from the slave. The number of bytes varies based on the command.
    - o Check sum byte which determines the integrity of the data. The Check sum type differs based on the version of LIN.

BSS:

- BSS has not evolved much. Furthermore there really is only one version of BSS. Although depending on the tester manufacturer. It may be broken into 3 versions based on the alternator error report.
  - o BSS 1: only Electrical error reported
  - o BSS 2: only Mechanical error reported.
  - o BSS 3: Mechanical and Electrical error reported.
- Data Rate is fixed at 1200Bps
- BSS is a bit synchronous and the bit states are pulse width modulated.
- Each command/data frame is 19 bits preceded by 3 sync pulses minimum.
- BSS command structure is a register driven interface.
  - o The master addresses the desired register and the purpose.
  - o The master or slave fills in the register value depending on the purpose of the access to the register.
  - o Parity testing is used to determine the validity of the data and acknowledge is provided.
- LIN/BSS vs. Manufacturer Connectors:
- Valeo, Bosch, Denso, Mitsubishi, Hitachi etc… LIN and BSS regulator connector interface varies based on the connector used by the manufacturer or the vehicle manufacturer using the regulator. But no matter the number of terminals in the connector. Only one pin is required to support the interface the rest of the terminals have no function. Shown below are a few of the typical connector interfaces.



Multifunction Function regulators…

Unlike LIN and BSS COM regulators which have a minimal terminal interface, Multifunction regulators are made up of multiple wire/terminal interfaces. The terminals are responsible for a number of functions as listed below

- Controlling set point
- Load/Field status
- Feedback for Soft Start and LRC
- Overcoming losses in the battery charging circuit
- Enabling/turning on the regulator operation
- Reporting error conditions (ie Loss of stator, Sense etc….)
- Active output to power some auxiliary function (ie Choke)

There are a number of terminal names/functions for these signals that support multifunction regulators. Also in many cases there is more than one name for a terminal that performs the same function. The names are abbreviated to acronyms or single letter indicators which in many cases can be cryptic. Leading to confusion and misunderstanding there function. Common terminal names are PCM, RCV, RC, C, RLO, P-D, IGN/PWM, IGN, Lamp, L, Li, K, F, FR, DF, DFM, M, S, Sta etc….The next section is meant to help remove the confusion and define the terminal/functions.

Voltage Set Point Control terminals:

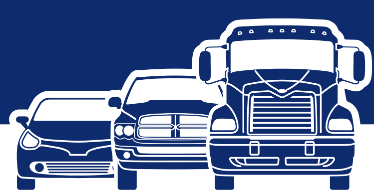
This group of terminals can be grouped into voltage set point control terminals. These terminals control the set point of the regulator through PWM (pulse width modulation) or Voltage level. Common names for these terminals are RCV, SIG, RC, RLO, P-D, IGN/PWM, and C.
Most of the set point controlled multifunction regulators fall into the category of PWM controlled regulators.
Car manufacturers such as Ford, GM, Hyundai, Toyota etc…. have adopted these various PWM schemes described below.

PWM:

- RC/SIG (Remote Control) is 125Hz PWM signal. The controllable range is from 5 to 95% Duty Cycle. Outside of the controllable range the regulator turns off or returns to the default set point. Ford's PCM interface uses RC/SIG.
- RVC (Remote Voltage Control) is a 125Hz PWM signal. The controllable range is from 10 to 90% Duty Cycle. Outside controllable range the regulator returns to default set point. The RVC interface also has the ability report fault condition. If no Stator/no rotation is detected the regulator pull the RVC Line to ground. GM adopted/developed this PWM interface.
- Reverse RVC uses the same 125Hz PWM signal as standard RVC. The big difference with reverse RVC is the set point control. Reverse RVC reduces the set point as the PWM Duty Cycle increase. Car manufacturers such as Hyundai use this PWM interface.
- RLO is the slowest PWM interfaces of the PWM type interfaces. RLO center PWM frequency is 8Hz. RLO is also a reverse PWM interface, 1% (15V) to 82% (12.6V) Duty Cycle. Duty Cycle greater the 82%DC result in 12.6V set point. Toyota adopted this PWM interface.
- P-D regulators use what is considered a ½ regulator circuit topology. Unlike the classic regulator circuit the vehicle PCM is responsible for the field control. The PCM PWM field control output drives the D terminal (Driver circuit) of the regulator. The P terminal (Phase) is connected to the Stator. The PCM uses the stator signal from the P terminal as an indication of field load. These P-D type regulators are produced be Mitsubishi/Hitachiand used in Mazda and Kia Cars.
- IGN/PWM 28V regulator IGN interface serves two purposes. The input can be used as a standard ignition line or PWM input. The PWM input center frequency is 200Hz. The PWM range is 8% to 96% Duty Cycle. Duty Cycle = or > than 96% results in the default set point. Mitsubishi produces these truck regulators.

Level Controlled:

C, G (computer controlled) terminal regulators are controlled by a voltage level. Grounding the C terminal reduce the voltage to a known set point. Opening or connecting the terminal to B+ raises the voltage to a known set point.



Load status feedback (F, Fr, DF, DFM, M, Li, K):

This next group of terminals is meant to provide feedback to the ECU of the Vehicle in order to assist in the management/ optimization of the alternators operation. In some cases the feedback also reports an error condition. F/Fr (Field return), DF (Digital Field), DFM (Digital Field Monitor), M (Monitor), Li (Load Indicator) and K (Kinetic) have the same basic function which is to report load on the alternator. The signal is PWM (Pulse width modulation) reports the load condition of the alternator in percent Duty Cycle (DC).

DF and DFM is typically the European label for F and FR. Depending on the output circuit a pull up resistor to B+ is required.

Li (Load indicator) functions the same as the feedback signals described above up to about 95%. The full on state is for reporting error conditions such as Loss of Sense, Stator or RC. Li is used by the Ford PCM interface.

Stator (Sta, P, AC, W):

The stator terminal on the regulator is taken from one of the phase of the Stator. The stator is monitored by the regulator for a number of reasons.

- Stator starting the regulator. In many regulators the regulator relies on the feedback from the stator to activate the regulator.
- Soft start exit/return
- Monitored for LRC (Load remote control) cutoff frequency. In order to determine LRC no longer needs to be applied because the engine RPM is now high enough to avoid the affect of electrical loading.
- Tach (RPM) report to ECU
- The Stator voltage can also be monitored by the regulator for stator regulation. If the voltage goes low enough the regulator will enter stator regulation mode to maintain the voltage. This feature is not found in all regulators. Mitsubishi is one of the regulator manufacturers that apply stator regulation in there regulation scheme.

Sense (S):

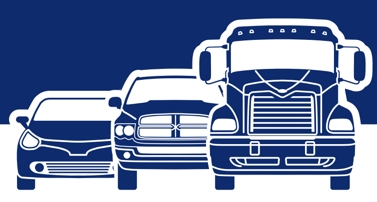
The Sense terminal is used by the regulator to measure the output voltage at a remote location typically at the battery. This is done to determine the actual voltage at the battery. In a vehicle resistance between the alternator and battery can be high enough to cause enough of a drop in voltage between the alternator and battery so, that the battery is no longer charging at the optimum voltage. The resistance is caused by poor connections or faulty cables. So based on the voltage at the battery verse the alternator output it will cause the alternator to adjust the output to compensate for losses in the charging circuit.

Ignition (Ign, R):

Ignition as it is defined is provided to the regulator when the ignition of the vehicle is turned on. Regulators that do not rely on stator as the regulator activation mechanism, rely on the voltage provided to the regulator by the ignition line to **activate the regulator.**

Lamp (L, I, D+):

The Lamp terminal has a primary function of pulling the line low with the use of MOSFET/Bi polar Transistor to turn on a lamp on the dash of the vehicle as a warning indicator of a fault conditions such as loss of stator. The Lamp terminal is also used to activate the regulator when Ignition is not supplied.



The Lamp also comes in Active and Inactive circuit configuration.

- The inactive lamp only pulls the line low to generate a fault by turning on a dash indicator.

A Lamp terminal with an active lamp has the ability to power a relay, small load or electronic choke in the days of carbureted vehicles. The active lamp feature is powered by a MOSFET/Bi polar transistor which when powered provides B+ to the Lamp terminal. If a fault condition occurs the Active function MOSFET/Bipolar transistor is turned off and the Fault pull down MOSFET/Bipolar Transistor is turned on to cause the dash lamp to turn on.

Common Regulator Terminology….

There are a number of regulator terms that need to be understood when discussing the operation of regulators. This next section breaks down the functions and explains their purpose. Terms such as A/B Circuit, Leakage Current, Rotor Poles, Tach (RPM), PWM, Duty cycle, LRC, and SS (Soft Start) are explained in the following section of this article.

A vs. B Circuit:

Voltage regulator field drive circuits come in two circuit variations. The two drive circuit topologies are referred to as A (low side switched) and B (high side switched).

- "A" circuit regulators are defined as low side switched because one side of the field circuit is switched to ground through a MOSFET/Bipolar Transistor when it is modulated for a desired set point. The other side of the field is pulled to B+.
- "B" circuit regulators are defined as high side switched because one side of the field circuit is switched to B+ through a MOSFET/Bipolar Transistor when it is modulated for a desired set point. The other side of the field is pulled to ground.

Leakage Current:

In the Alternator world Leakage current is a bad word. High leakage current can be the cause of a dead battery. The components are the source of the leakage current in the regulators and rectifiers. All regulators today have Solid state electronics such as Transistors, MOSFETs, and Diodes that are made up of semiconductor materials. Furthermore the components are made up of PN junctions (P type and N type semiconductor material). When these junctions are forward biased the current flows as it is expected during normal operation. When they are reversed biased theoretically they turn off. Although in actuality a very small amount of back current flows. This current is referred to as leakage. Now if quality components are chose with low leakage currents and good design technique. The leakage current will be small enough to be of no concern.

Rotor Pole Pairs:

The rotor of an alternator is made up of a number of pole pairs. The pole count is the number of pole pairs x2. Typical pole counts are 12, 14, and 16 poles. This information is import when converting between Stator frequency and RPM. Understanding the relationship of poles vs. stator frequency and RPM is important when dealing with the TACH and LRC measurement.

TACH:

The Tachometer output is the alternator RPM report to the ECU of the vehicle. The RPM is derived from the frequency of a stator phase of the alternator. The RPM is directly proportional to the stator frequency and the number of rotor pole count. See the below equation

$$RPM = Stator\ Freq\left(\frac{120}{Rotor\ poles}\right)$$

The RPM report is important to the ECU of the vehicle as it assists in the control of the transmission. Some of the common terminal names on a regulator when this feature is offered are: Sta, P, AC, and W.

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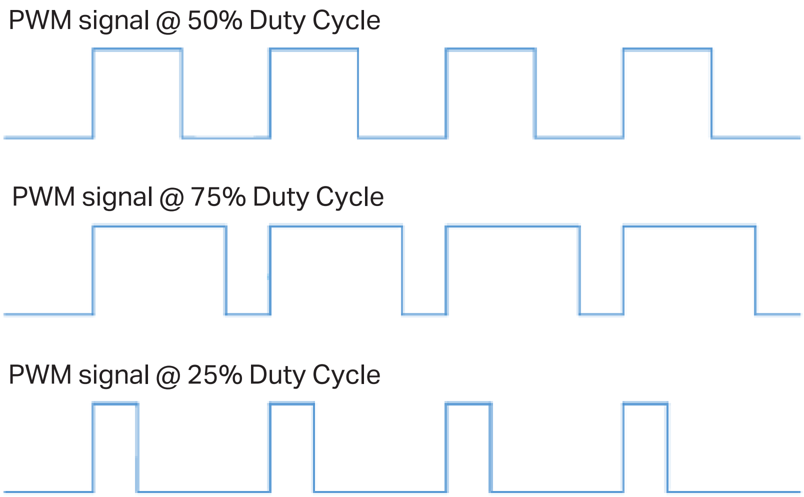
PWM:

PWM is one of the most common terms that will be mentioned when discussing regulators. This acronym stands for Pulse Width Modulation. The method of Pulse Width Modulation discussed in this article is the modulating of known frequencies duty cycle. In voltage regulators PWM is used for a number of functions

- Representing a command to PCM, RCV, RC, RLO, IGN/PWM type multifunction regulators.
- Reporting regulator load, Error conditions, Current etc…. to the ECU of the vehicle. Common signal names are F, Fr, DF, DFM, M, Li, K etc…..
- Modulation of the alternator rotor field to produce a desired alternator output.

A basic concept of the modulation would be to vary the positive portion (on time) of a signal for a known frequencies period in time. The ON time in reference to OFF time is known as Duty Cycle. See the below figure for an examples of PWM.



Duty Cycle:

This term is in reference to Pulse Width Modulation for voltage regulators. Duty Cycle is a measurement of the positive or negative portion of frequencies period in time in relationship to the full period. The measurement is in percent ranging from 0 to 100% of the period. This percentage for example can represent a voltage set point command to the RCV regulator. See the above figure.

LRC:

LRC is an acronym that stands for Load Response Control. This feature controls the rate at which the alternator output ramps up its output to meet a new load demand such as the vehicles AC. The ramp up smoothes the load applied to the engine. The LRC ramp rate can be as long as 15 seconds. Multifunction regulators typically have a fixed LRC rate whereas a COM regulator LRC rate is programmable and ranges from about .2 to 15 seconds. LRC is applied when the engine RPM is low making the engine more susceptible to a load changes that could cause engine fluctuation, vibration, or stalling. The LRC cutoff frequency is the point at which the LRC feature is disabled because the engine RPM is high enough to overcome the load up. COM regulators have a programmable selection of LRC cutoff frequencies.

SS/SSD:

Soft Start (SS) or Soft Start Delay (SSD) is a mechanism that keeps the alternator from producing full output until the engine is started, in order to keep the load off the starter while starting. During starting the battery is low and the alternator wants to charge the battery. So until the stator SS frequency or Frequency and Delay are exceeded the Alternator remains in Soft start to reduce the output. The typical SS exit RPM is about 2500 RPM.

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