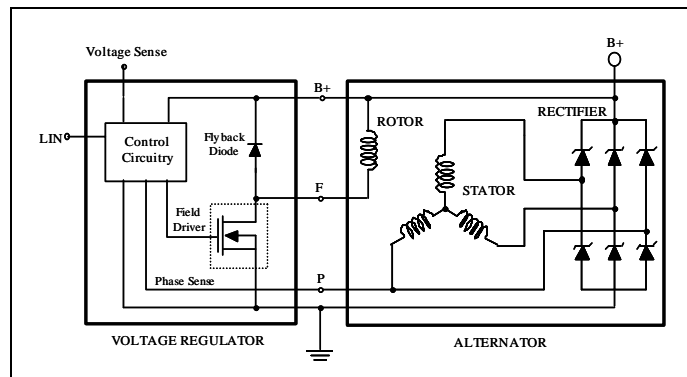


## LIN Controlled Alternator Voltage Regulator

### Features:

- 9600 Baud Rate
- 10.7 to 16.0V Setpoint Control
- Programmable Load Response Control
- Programmable Field Excitation
- Full Diagnostic Capability
- Self Excitation
- Short Circuit Protected
- EMI and ESD Immunity
- Field Excitation, Temperature, and Fault Status Feedback
- < 200uA Standby Current



### Description

The IRVR101 is an integral alternator voltage regulator that allows for external control of the setpoint voltage in an automotive charging system where optimized alternator output control is desired. The setpoint control is achieved using the Local Interconnect Network (LIN) serial communications protocol. Slew rate control and filtering of the interface lines provide electromagnetic compatibility. The regulator consists of a control ASIC, discrete low side power MOSFET (field driver), re-circulation diode, and passive components. The discrete circuitry allows for optimal flexibility with respect to the alternator rotor circuit and charging system requirements. The IRVR101 is characterized over the temperature range of  $-40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ .

### Design

The IRVR101 is manufactured using thick-film hybrid technology. The hybrid circuit can be customized for your application to optimize performance and reliability. The hybrid circuit can also be assembled in a custom housing with an insert-molded lead-frame specifically designed for flame-soldering or heavy wire bonding. Thick-film hybrid technology offers reliable high temperature operation with excellent parametric stability over the entire operating temperature range. Resistor values are trimmed within  $\pm 1\%$  using laser equipment that provides precise calibration of voltage and current sensing circuitry. The control IC is attached to the substrate using flip chip technology in order to optimize space and reliability. Bare die is also used for the low side field driver and re-circulation diode in order to optimize space and heat transfer.

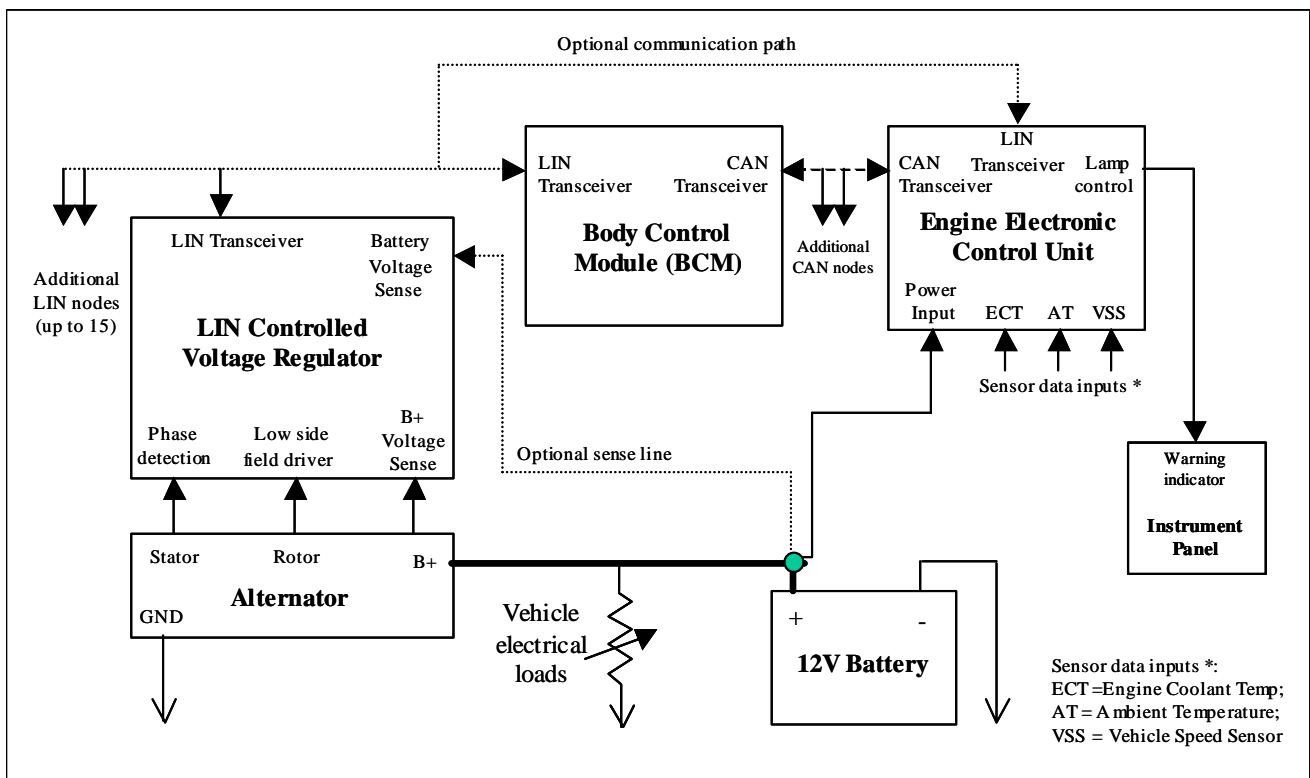


**Introduction**

The IRVR101 is designed for use in a 12V automotive charging system where optimized battery charging and dynamic alternator control are desired. The Block Diagram illustrates the main components and potential system configuration of the LIN controlled charging system. The regulator is shown separate from the alternator assembly but it is typically integrated into the machine. The interface between the Engine Control Unit (ECU) and the regulator requires one bi-directional line with a transceiver at each end for serial communication. Alternatively, communication may be achieved between the regulator and Body Control Module (BCM) as illustrated in below.

The signals to the regulator (received from the ECU or BCM) include the voltage setpoint, load response control ramp, load response control ramp cut-off speed, and the field excitation limit. The voltage setpoint command also allows for disabling of the field driver to achieve a momentary no output condition. Signals from the regulator (transmitted to the ECU or BCM) include the field excitation duty cycle, the field excitation current OR temperature (customer defined), and the fault status. Transmitted fault codes provide unique indication for mechanical, electrical, temperature, communication, and timeout errors.

**Block Diagram**



## Interface Design

The interface design is based on the LIN communication protocol. Detailed information regarding this communication protocol can be found in the latest revision of the LIN Specification Package. This package can be obtained from the LIN Website located at [www.lin-subbus.org](http://www.lin-subbus.org).

## Activation and De-activation

The voltage regulator is activated by a wake up signal that consists of the character '0x80'. The regulator is also capable of waking up with the presence of any normal bus activity. Once the regulator has been activated, the regulator will wait until a valid message is received prior to turning on the field driver. The regulator will then hold the field duty cycle at 18.75% until a cut-in phase signal is recognized at which time the regulator will soft start ramp to normal regulation. The cut-in phase voltage and frequency must be greater than 2V and 1200 Generator RPM (GRPM) respectively. De-activation requires a bus timeout in combination with a phase signal timeout. Bus timeout occurs 2s after the last valid message is received. Phase signal timeout occurs 500mS after the phase voltage and frequency have fallen below 0.6V AND 600 GRPM, respectively.

## Self-excitation

In the event of a LIN bus fault, the voltage regulator is capable of self-excitation if a phase voltage and frequency of greater than 0.6V AND 1200 Generator RPM is detected. This signal is only possible if the residual magnetism in the alternator rotor core is sufficient enough to generate a magnetic field capable of inducing the voltage signal in the stator windings. If this signal is detected, the regulator will apply an 18.75% duty cycle until the cut-in phase signal is recognized at which time the regulator will soft start ramp to default regulation. The regulator will return to sleep mode at any time when the phase signal has timed out as described above.

## Voltage Sensing

System voltage sensing can be achieved via the dedicated battery sense input or through machine sensing from the rectifier B+ output via the F+ input to the regulator. The battery sense input is optional and can be deleted. If the battery sense option is exercised, an open or short circuit at this input will cause voltage sensing to transfer to the machine voltage sense input (an electrical fault can be indicated if the regulator is configured for this fault option). The machine voltage setpoint can be set to a different value than the battery sense voltage to compensate for system voltage variation between the alternator and the battery.

## Voltage Regulation

Voltage regulation is achieved using fixed frequency pulse width modulation. The base frequency is typically 150 Hz and the proportional control range for regulation is 100mV. This provides for very stable regulation over the entire speed and electrical load range.

## Load Response Control

Load response control is programmable and can be varied from 0.426 seconds to 13.2 seconds in 16 steps. Additionally, the load response control cut-off speed is programmable and can be set to "always active" or varied from 2400 to 8000 Generator RPM. The load response at startup is equal to the programmed value for the load response control. The load response will always be executed on the first ramp to full field after engine start regardless of frequency in order to assist in achieving a smooth engine start.

## Fault Detection

Respective fault codes are transmitted per the "Fault Detection" table. A 500mS delay is enforced prior to the transmission of any fault code. Mechanical faults are based on the frequency detection of the stator phase signal. Electrical faults are based on the voltage detection of the stator phase and system voltage sense inputs. A temperature fault is based on the regulator IC junction temperature. Communication errors are detected after a delay of 2s. Examples of sync communication errors are sync bit, checksum, and bit detect errors. A sync bit error is detected when the sync field does not = '0x55'. A checksum error is generated when the sum of the modulo-256 sum over all data bytes and the checksum byte do not equal '0xFF'. A bit error is detected when a transmitted bit does not correspond to the appropriate bus state due to another device forcing the bus to a

different state. Bus timeout errors are detected for any lack of a valid signal within a 2s time frame.

### Absolute Maximum Ratings

Absolute Maximum Ratings indicate sustained limits beyond which damage to the device may occur. All voltage parameters are referenced to GROUND pin. T Ambient = 25 °c unless otherwise specified.

Condition	Symbol	Rating	Unit
<b>Power Supply</b>			
Continuous DC Voltage	$V_{BATT}$	25	V
Transient Voltage (load dump)	$V_{MAX}$	40	V
Reverse Battery (connector/other terminals)	$V_{MIN}$	-12/-3	V
<b>Temperature</b>			
Operating baseplate temperature	$T_A$	-40 to +150	°C
Storage temperature	$T_{STG}$	-50 to +170	°C
<b>Field Current</b>			
Continuous @ -40 °C	$I_{FLD-40}$	11	A
Continuous @ 25 °C	$I_{FLD+25}$	8	A
Continuous @ 150 °C	$I_{FLD+150}$	5	A

### Signal Characteristics

SIGNAL	TYPE	FREQUENCY RANGE	NORMAL VOLTAGE RANGE	MAXIMUM VOLTAGE	QUIESCENT CURRENT DRAIN
S	DC	N/A	12.5 to 16.0V	100V	100uA
C	PCM	9600 Hz	0.2 to 15.0V	100V	N/A
F-	PWM	100-150 Hz	0.5 to 17.0V	100V	100uA
P	AC	0-2000 Hz	-1 to 17V	100V	N/A

### Terminal Functions

Pin Name	Symbol	Description
LIN	C	Serial communication input/output
B+ Voltage Sense	B+	Alternator rectifier output. Provides machine voltage sense input and power supply input to regulator. Also used as re-circulation diode cathode connection.
Battery Voltage Sense	S	Optional input for remote battery voltage sensing
Low Side Field Driver	F-	Low side of alternator field coil. Connected to the drain of the FET when using a low side drive.
Phase Detection	P	Stator phase input to the regulator. Used for self-excitation and fault detection.
Ground	G	Ground connection

Electrical Characteristics

Function	Symbol	Min	Typ	Max	Unit
Default regulation setpoint voltage	$V_{RDEF}$	13.6	13.8	14.0	V
Setpoint voltage range	-	10.7	-	16.0	V
Default Load Response Control	-		3.0		s
Load Response Control range		0.4	-	13.2	s
Default LRC cut-off speed			3000		GRPM
LRC cut-off speed range		2400	-	8000	GRPM
Field excitation current limit range		2	-	7.75	A
Field excitation duty cycle limit range		0	-	100	%
Field excitation current feedback		0	-	7.75	A
Field excitation duty cycle feedback		0	-	100	%
Temperature range feedback		-29	-	157	°C
Temperature feedback resolution			6		°C
High voltage threshold	$V_{HV}$	16.3	16.5	16.7	V
Battery sense line fault threshold	$V_{STh}$	5.0	6.0	7.0	V
Base switching frequency	f	135	150	165	Hz
Field minimum duty cycle	$DC_{MIN}$	-	3	-	%
Field maximum duty cycle	$DC_{MAX}$	-	100	-	%
High speed under-voltage warning (> 3000 GRPM)		10.0	10.5	11.00	V
Low speed under-voltage warning (< 3000 GRPM)		9.0	9.5	10.00	V

## Fault Detection

Fault Condition	Detection	Type	Effect	Delay	Regulation Mode
Open phase terminal	P = 0V, 0 Hz	Mechanical	Normal or reduced alternator output	500mS	Attempted normal regulation
Broken belt	P = 0V, 0 Hz	Mechanical	No alternator output	500mS	Same as "Open phase terminal"
Open rotor circuit	P = 0V, 0 Hz	Mechanical	No alternator output	500mS	Same as "Open phase terminal"
Field driver open circuit	P = 0V, 0 Hz	Mechanical	No alternator output	500mS	Same as "Open phase terminal"
Shorted rotor circuit	P = 0V, 0 Hz	Mechanical	No alternator output	0mS	Short circuit mode
Field driver short circuit	F = "ON" with no gate drive; no recirculation current	Electrical	High system voltage	500mS	0% duty cycle field drive
Open circuit B+	Overvoltage	Electrical	System supplied by battery	500mS	B+ regulation at 17V or B+ > S +/-3.0V when using a remote battery sense.
Rectifier fault	P < 8V, P > 60 Hz	Electrical	Low system voltage	500mS	Full field
High RPM system under voltage	B+ < 10.5V, P > 300Hz Setpoint < 12.2V	Electrical	Battery drain	500mS	Full field
Low RPM system under voltage	B+ < 9.5V, P < 300Hz Setpoint < 11.4V	Electrical	Battery drain	500mS	Full field
High system voltage	B+ > 17.0,	Electrical	Battery drain	500mS	Attempt to turn off field driver
Loss of S (optional function)	S > 2.2V	Electrical (fault indication optional)	Battery voltage regulation inaccuracy	500mS	Voltage sensing from B+
Corrupted communication	Sync bit, checksum, or bit error	Comm error	Rx/Tx request ignored	2s	Maintain regulation based on last good communication
Loss of/corrupted communication	C open/shorted > 2s or Comm error > 2s	Comm and Timeout error	Pre-excitation until phase > 2V	2s	18.75% duty cycle or default regulation (based on stator signal)
High temperature	160 < T <sub>j</sub> < 190 °C	Thermal	Potential alternator damage	500mS	Attempt to maintain regulation

## Identifier Requirements

(Regulator IC mask option configured as either Regulator 1 or Regulator 2)

### **Write data:**

Regulator 1 ID for RX-frame - 100101 (ID0-5)  
ID0=1, ID1=0, ID2=0, ID3=1, ID4=0, ID5=1

Regulator 2 ID for RX-frame - 010101 (ID0-5)  
ID0=0, ID1=1, ID2=0, ID3=1, ID4=0, ID5=1

### **Read data:**

Regulator 1 ID for TX-frame - 100010 (ID0-5)  
ID0=1, ID1=0, ID2=0, ID3=0, ID4=1, ID5=0

Regulator 2 ID for TX-frame - 110010 (ID0-5)  
ID0=1, ID1=1, ID2=0, ID3=0, ID4=1, ID5=0

### **Read data for alternator identification:**

Regulator 1 ID for TX-frame\_2 - 010010 (ID0-5)  
ID0=0, ID1=1, ID2=0, ID3=0, ID4=1, ID5=0

Regulator 2 ID for TX-frame\_2 - 001010 (ID0-5)  
ID0=0, ID1=0, ID2=1, ID3=0, ID4=1, ID5=0



LIN Regulator Communication Protocol – Receive Frame (Write Data)

**Rx Frame:** (Signals sent TO the ACM)

- A. Voltage Setpoint, 6bit, bit-offset 0
- B. Load Resp Ramp, 4bit, bit-offset 8
- C. Cut Off Speed, 4bit, bit-offset 12
- D. Excitation Limitation, 5bit, bit-offset 16

A						B				C				D																	
1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7

LIN Regulator Communication Protocol – Transmit Frame (Read Data)

**Tx Frame:** (Signals sent FROM the ACM)

- E. Status bit 1, 1bit, Offset 0
- F. Status bit 2, 1bit, Offset 1
- G. Status bit 3, 1bit, Offset 2
- H. Excitation Duty cycle, 5bit, Offset 3
- I. ACM Excitation Current OR Regulator Temperature, 6bit, Offset 8
- J. Communication error, 1bit, offset 14
- K. Time Out, 1bit, offset 15

E	F	G	H					I						J	K
1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7

LIN Regulator Communication Protocol – Transmit Frame (Read Alternator Identification Data)

**Tx Frame:** (Signals sent FROM the ACM)

- L. Supplier ID, 3bit, Offset 0
- M. Alternator ID, 5bit, Offset 3

L			M				
1	1	1	1	1	1	1	1
:	:	:	:	:	:	:	:
0	1	2	3	4	5	6	7

Voltage Setpoint Signal to the Regulator (A)

**Setpoint Voltage, 10.7-16.0V, 100mV resolution, 6 bits (1:0 – 1:5), 55 values.**

A setpoint voltage of "10.6V" shall mean: Field driver off. Default = 13.8 V

Voltage setpoint	Byte 1Bit: 543210
16.0	111111
:	:
:	:
16.0	110110
15.9	110101
15.8	110100
15.7	110011
15.6	110010
15.5	110001
15.4	110000
15.3	101111
15.2	101110
15.1	101101
15.0	101100
14.9	101011
14.8	101010
14.7	101001
14.6	101000
14.5	100111
14.4	100110
14.3	100101
14.2	100100
14.1	100011
14.0	100010
13.9	100001
13.8	100000
13.7	011111
13.6	011110
13.5	011101
13.4	011100

13.3	011011
13.2	011010
13.1	011001
13.0	011000
12.9	010111
12.8	010110
12.7	010101
12.6	010100
12.5	010011
12.4	010010
12.3	010001
12.2	010000
12.1	001111
12.0	001110
11.9	001101
11.8	001100
11.7	001011
11.6	001010
11.5	001001
11.4	001000
11.3	000111
11.2	000110
11.1	000101
11.0	000100
10.9	000011
10.8	000010
10.7	000001
10.6 = field driver off	000000

International  
**IR** Rectifier  
**IRVR101**

Load Response Control Signals to the Regulator (B and C)

**B. LRC Ramp time, 0.426-13.2s, 4 bits (2:0 – 2:3), 16 values.**

Time for excitation duty cycle to go from 0-100% during soft start and step up in electrical load. Default 3.0 s.

LRC Ramp Time	Byte 2 Bit: 3210
13.2s	1111
12.35s	1110
11.5s	1101
10.65s	1100
9.8s	1011
8.9s	1010
8.1s	1001
7.25s	1000
6.4s	0111
5.55s	0110
4.69s	0101
3.84s	0100
2.99s	0011
2.13s	0010
1.28s	0001
0.426s	0000

**C. LRC Ramp cut-off speed, 0- 8000 alternator rpm, 4 bits (2:4 – 2:7), 16 Values.**

Over this speed no ramp function is allowed except for the first ramp after start. Default 3000 rpm.

LRC Ramp cut-off speed (alternator RPM)	Byte 2 Bit: 7654
Always active	1111
8000	1110
6860	1101
6000	1100
5330	1011
4800	1010
4360	1001
4000	1000
3690	0111
3430	0110
3200	0101
3000	0100
2820	0011
2670	0010
2530	0001
2400	0000

# International **IR** Rectifier **IRVR101**

## Excitation Limitation (current or duty cycle) Signal to the Regulator (D)

### 2.0 - 7.75 amps, 5 bits (3:0 – 3:4), 32 values (bit select option: 3:5 = 0).

Limitation of the excitation current to the rotor. Default; max excitation current (100% duty cycle).

PWM Field Current Maximum Excitation	Byte 3 Bit: (5)43210
7.75	(0)11111
7.5	(0)11110
7.25	(0)11101
7.0	(0)11100
6.75	(0)11011
6.5	(0)11010
6.25	(0)11001
6.0	(0)11000
5.75	(0)10111
5.5	(0)10110
5.25	(0)10101
5.0	(0)10100
4.75	(0)10011
4.5	(0)10010
4.25	(0)10001

4.0	(0)10000
3.75	(0)01111
3.5	(0)01110
3.25	(0)01101
3.0	(0)01100
2.75	(0)01011
2.5	(0)01010
2.25	(0)01001
2.0	(0)01000
2.0	(0)00111
2.0	(0)00110
2.0	(0)00101
2.0	(0)00100
2.0	(0)00011
2.0	(0)00010
2.0	(0)00001
Full field	(0)00000

### 0-100%, 5 bits (3:0 – 3:4), 32 values (bit select option: 3:5 = 1).

Limitation of the excitation duty cycle to the rotor. Default 100%

PWM Field Duty Cycle Maximum Excitation	Byte 3 Bit: (5)43210
100%	(1)11111
93.75	(1)11110
90.625	(1)11101
87.5	(1)11100
84.375	(1)11011
81.25	(1)11010
78.125	(1)11001
75	(1)11000
71.875	(1)10111
68.75	(1)10110
65.625	(1)10101
62.5	(1)10100
59.375	(1)10011
56.25	(1)10010
53.125	(1)10001

50	(1)10000
46.875	(1)01111
43.75	(1)01110
40.625	(1)01101
37.5	(1)01100
34.375	(1)01011
31.25	(1)01010
28.125	(1)01001
25	(1)01000
21.875	(1)00111
18.75	(1)00110
15.625	(1)00101
12.5	(1)00100
9.375	(1)00011
6.25	(1)00010
3.125	(1)00001
0	(1)00000

# International Rectifier IRVR101

## Status Signals from the Regulator (E, F, and G)

3 bits used to indicate an electrical fault, mechanical fault, or high temperature.

**E. High Temperature, 1 bit (1:0)**

**F. Mechanical fault, 1 bit (1:1)**

**G. Electrical, 1 bit (1:2)**

Error indication	Byte 1 Bit: 210
High Temperature	001
Mechanical	010
Electrical	100
No fault present	000

## Excitation Duty Cycle Signal from the Regulator (H)

**5 bits (1:3-1:7), 32 values.** Information needed for calculation of alternator output current and torque.

PWM Field Excitation Duty Cycle	Byte 1 Bit: 76543
96.875 and 100%	11111
93.75	11110
90.625	11101
87.5	11100
84.375	11011
81.25	11010
78.125	11001
75	11000
71.875	10111
68.75	10110
65.625	10101
62.5	10100
59.375	10011
56.25	10010
53.125	10001

50	10000
46.875	01111
43.75	01110
40.625	01101
37.5	01100
34.375	01011
31.25	01010
28.125	01001
25	01000
21.875	00111
18.75	00110
15.625	00101
12.5	00100
9.375	00011
6.25	00010
3.125	00001
0	00000

# International Rectifier **IRVR101**

## Excitation Current or Temperature Signal from the Regulator (I)

**Excitation Current. 6 bits (2:0 – 2:5), 64 values.** Information needed for calculation of alternator output current and torque. Excitation current will be sent by 6 bits, the least significant bit will always be set to 0.

Excitation current	Byte 2 (I) Bit: 543210
≥7.750	11111x
≥7.500	11110x
≥7.250	11101x
≥7.000	11100x
≥6.750	11011x
≥6.500	11010x
≥6.250	11001x
≥6.000	11000x
≥5.750	10111x
≥5.500	10110x
≥5.250	10101x
≥5.000	10100x
≥4.750	10011x
≥4.500	10010x
≥4.250	10001x

≥4.000	10000x
≥3.750	01111x
≥3.500	01110x
≥3.250	01101x
≥3.000	01100x
≥2.750	01011x
≥2.500	01010x
≥2.250	01001x
≥2.000	01000x
≥1.750	00111x
≥1.500	00110x
≥1.250	00101x
≥1.000	00100x
≥0.750	00011x
≥0.500	00010x
≥0.250	00001x
≥0.000	00000x

**Regulator Temperature, 6 bits (2:0 – 2:5), 32 values (pin selectable option).** Information needed for calculation of alternator output current and torque. To be used in place of excitation current per customer specific requirements. Temperature will be sent by 6 bits, the least significant bit will always be set to 0.

Regulator baseplate temp	Byte 2 (I) Bit: 543210
-29	111110
-23	111100
-17	111010
-11	111000
-5	110110
1	110100
7	110010
13	110000
19	101110
25	101100
31	101010
37	101000
43	100110
49	100100
55	100010

61	100000
67	011110
73	011100
79	011010
85	011000
91	010110
97	010100
103	010010
109	010000
115	001110
121	001100
127	001010
133	001000
139	000110
145	000100
151	000010
157	000000

### Communication Fault Signals from the Regulator (J and K)

**J. Communication error, 1bit (2:6).** Set when the regulator recognizes a communication error. Reset after one correct read.

**K. Time Out flag, 1 bit (2:7).** Time out after 2s with no valid communication. Default values after time out. Reset after one correct read.

Error indication	Byte 2 (K,J) Bit: 76
Communication error	01
Time out flag	10
No communication error present	00

Data and specifications subject to change without notice.  
This product has been designed and qualified for the Automotive market.  
Qualification Standards can be found on IR's Web site.