

# LIN Alternator Regulator Devices

## 1 Overview

Basic functionality for Freescale's family of LIN alternator regulators is provided along with a detailed description for practical applications. Parameters are available by fuse providing product alignment with your application profile.

## 2 Introduction

The LIN alternator regulator family of devices is specially designed to work in adverse environments. It supplies a current through a high side MOSFET to the excitation coil of the alternator and provides an internal freewheeling diode. It's main functionality is to keep the battery at its nominal value, whatever the vehicle demand. The protection and diagnosis may be programmed using OTP (non-volatile Memory).

Additionally, these devices have a fail-safe mode for continuous battery charging in the event LIN is disconnected.

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## 2.1 Protection and Diagnostics

These devices incorporate the following protections and diagnostics, some of which are programmable and can be reported using LIN (version 1.3) to the Engine Control Unit (ECU). For more information please refer the device's data sheet. ([www.freescale.com](http://www.freescale.com))

- Thermal protection
- Thermal compensation
- Over-current detection (LIN and EXC)
- Over-voltage
- Resistive short-circuit detection (excitation to ground)
- High phase level missing
- LIN protocol errors (checksum, slave not responding, sync break error, parity)
- LIN bus time-out

## 2.2 Operational Modes

The LIN alternator regulator family has four operating modes: Standby mode (car parking), Pre-excitation mode (with LIN and no phase activity), Default mode (without LIN communication and with phases) and Normal mode.

These devices change its current consumption and capabilities depending on the operational mode. Detailed information for each of the modes can be found in the device's data sheet.

## 3 Fuse Options

**Table 1. Version Determined Electrical Parameters**

Self-Start	Self-start Threshold (RPM)	Phase sensitivity (V)	Default regulation voltage (V)	Fstart (RPM)	Fstop (RPM)	LRC Rates	LRC disable (RPM)	Crest Regulation	BUS inactivity	Thermal Fault Threshold	thermal compensation threshold (°C)	Special LIN Feature	Alternator Pole-Pair	Slave Address
Active/ Not Active	3000 / 4000	0.45/0.9/1.3 5/1.8	13.5 to 15 (100 mV steps)	800/1050/ 1300/1550/1 800/2050/23 00/2500	500/650/ 850/1000	0/3/ 6.4/ 12.3	2400/ 3000/ 4000/ never	Active / Not Active	1.3/3	135/145/ 150/160	135/145/ 150/160	Active/ Not active	6/8	A/B

### 3.1 Self-Start Option (Active / Not Active)

#### NOTE

If the LIN communication recovers during self-start operation, the LIN immediately takes the priority and new parameters coming from the Master (ID #29) will be considered.

Self-start option allows the product to start the regulation whereas there is no LIN communication between the master and the slave (LIN wire disconnection or ECU not functional). In that case the product takes internal default parameters programmed at Freescale production line as new reference and apply them as soon as the phase frequency reaches the self-start threshold.

### 3.2 Self-start Threshold (3000 / 4000 RPM)

Two selectable values are available in the product indicating at which rotation speed the device will start the regulation. Those values are the same whatever the number of poles of the alternator. This is present only when the self-start option has been activated by the fuse.

The signal used for speed measurement are coming from stator windings (Phase1 and Phase2). For more information, please refer to the application diagram in the device data sheet.

### 3.3 Phase Sensitivity (0.45 V / 0.9 V / 1.35 V / 1.8 V)

Phase sensitivity is linked to the phase signal voltage level coming from the stator windings. Phase signals are naturally out of phase by 120°. The device measures, in real time, the delta voltage between Phase 1 and Phase 2.

As soon as the voltage level difference between Phase 1 and Phase 2 reaches the desired phase sensitivity level AND if phase frequency is high enough (fstart), the product will start regulation.

### 3.4 Default Regulation Voltage (From 13.5 V to 15 V with 100m V Steps)

The default regulation voltage is used only if the LIN communication between the master and slave (LIN wire disconnection or ECU not functional) is lost during operation. In that case, the target regulation voltage becomes the one programmed in the default regulation voltage (in normal operation). The target regulation voltage is the one present in LIN MID#29 coming from the master.

### 3.5 Fstart (800, 1050, 1300, 1550, 1800, 2050, 2300, 2500 RPM)

Engine speed is reflected on the phase signals. The phase frequency depends on both engine speed and the number of poles in the alternator. The regulator uses this information to start the regulation voltage.

This Fstart value is used only if LIN communication is valid otherwise the self-start speed threshold is considered.

### 3.6 Fstop (500, 650, 850, 1000 RPM)

This parameter indicates to the regulator at which alternator rotation speed it must stop the battery regulation function. This value corresponds usual to vehicle stops.

### 3.7 LRC Rate (0, 3, 6.4, 12.3s)

Load Response Control (LRC) function is very useful when there is a high vehicle load demand combined with a low engine speed. The LRC function controls the rotor current increase at the specified rate up to the LRC disable frequency. This function is only active for duty cycle increases: if there is a load unballasting, the excitation duty cycle is instantly reduced to the duty cycle corresponding to the new battery charge state. The alternator responds to loads commutation in the vehicle, slowly increasing the current in the rotor (EXC duty cycle). The LRC is mainly present at idle speed to avoid stalling the car.

### 3.8 LRC Disable (2400, 3000, 4000, Never RPM)

This specifies the rotation speed the LRC function is disabled. Above this rotation speed the changes in the duty cycle will be instantly done.

### 3.9 BUS inactivity (1.3, 3 s)

The regulator is checking continuously the activity on the BUS. If there is no LIN activity during the specified period, the regulator takes the following actions:

- If there is phase activity coming from stator, the regulator loads the internal default parameter and acts accordingly
- If there is no phase activity, the regulator goes back in Standby mode.

### 3.10 Default LIN Readout (T°, Current)

The regulator, under the MID#11 LIN command from master, can send back to the ECU junction temperature (Tj) OR rotor current (not both). The choice must be specified through this option and programmed at Freescale.

MID #11							
Byte 1							
7	6	5	4	3	2	1	0
EXC Duty Cycle					F_EL	F_MEC	F_HT
Byte 2							
7	6	5	4	3	2	1	0
LIN Bus Time-Out	Com Error	Measured Current <u>OR</u> Temperature					

Figure 1. Temperature or Current Data Location in MID#11

### 3.11 Thermal Fault Threshold (135, 145, 150, 160 °C)

This option is important for the ECU and indicates if the system reaches a certain level of temperature. In that case, the ECU can take appropriate actions and decide, for example, to reduce current in the rotor and by consequence, duty cycle on the EXCitation pin. The global system temperature should decrease slowly.

The information is available in the MID#11 (see below). This thermal fault threshold is independent of the thermal shutdown specified, which stays active at the same level (185 °C +/- 10 °C).

MID #11							
Byte 1							
7	6	5	4	3	2	1	0
EXC Duty Cycle					F_EL	F_MEC	F_HT
Byte 2							
7	6	5	4	3	2	1	0
LIN Bus Time-Out	Com Error	Measured Current <u>OR</u> Temperature					

Figure 2. Flag High Temperature Data Location in MID#11

### 3.12 Thermal Compensation Threshold (135, 145, 150, and 160 °C)

The thermal compensation feature reduces the target regulation voltage when the system temperature increases. This compensation is activated according to threshold programmed in the circuit.

- Four main slew rates have been defined for this function which are: -50, -100, -200 and -400 mV/°C
- Thermal compensation starts when the temperature threshold is reached
- Four regulation target categories are defined: 10.6 - 12.1 V, 12.2 - 13.7 V, 13.8 - 15.3 V, and 15.4 - 16 V.
- Final slope choice for the thermal compensation is chosen according to the temperature threshold and the target regulation voltage.

Thermal compensation on the regulation voltage is clamped at 10.6V. The thermal flag is sent back by the regulator as soon as the thermal compensation is active.

Slew Rate (mV/°C)		Temperature threshold (degree Celsius)			
		135°C	145°C	150°C	160°C
Regulation Voltage (V)	10.6 V to 12.1 V	-50	-50	-50	-100
	12.2 V to 13.7 V	-100	-100	-100	-200
	13.8 V to 15.3 V	-100	-200	-200	-400
	15.4 V to 16.0 V	-200	-200	-200	-400

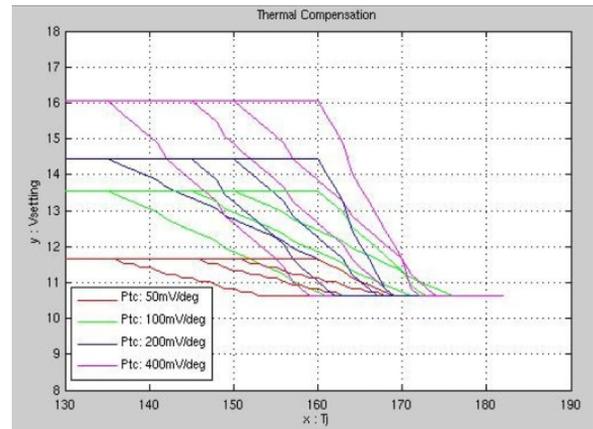


Figure 3. Thermal Compensation Curves

### 3.13 Special LIN feature (Active / Not Active)

This function, when activated by fuse, allows the master (ECU) to command the regulator to not charge the rotor (no current) whatever the conditions are in the vehicle (load, speed, battery charge level). Sending a 10.6 V target regulation voltage in MID#29, enables this feature. If another target regulation voltage is asked by the ECU, the product will regulate the battery at the required voltage then, if a new 10.6 V command is sent, the EXC will be switched off.

It is important to note that if this command is programmed not active, the 10.6 V command (EXC=0) is available only one-time after a cranking and if the ECU did not change the target regulation from 10.6 V to other ones (up to 16 V). Once the product started a regulation cycle, the 10.6 V command is then no more available and 10.6 V becomes a target regulation voltage like others.

MID #29							
Byte 1							
7	6	5	4	3	2	1	0
X	X	Target Regulation Voltage					
Byte 2							
7	6	5	4	3	2	1	0
Ramp Cutoff				Ramp Rate			
Byte 3							
7	6	5	4	3	2	1	0
X	X	X	X	Current Limitation			
Byte 4							
7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	X

Figure 4. Target Regulation Voltage Data Location in MID#29

### 3.14 Alternator Pole Pair (6, 7, 8, 9 Poles)

Depending on the machine type, and to adapt the frequency conversion on the phase signal compared to real RPM, the alternator pole pair number must be programmed.

### 3.15 Crest Regulation (Active, Not Active)

Crest regulation fuse not active: in the case of a load dump, EXC is stopped when the internal filter reaches the load dump detection threshold (~21 V typ.). The delay is given by the internal filter (~1.0 ms).

Crest regulation fuse active: in the case of a load dump, EXC is stopped immediately when the internal ADC reaches 21 V typical. The delay is given by the ADC conversion (~16  $\mu$ s).

# 4 LIN Protocol

The version of LIN protocol used in our product is REV 1.3 (available on demand on the Web)

## 4.1 Message Frame

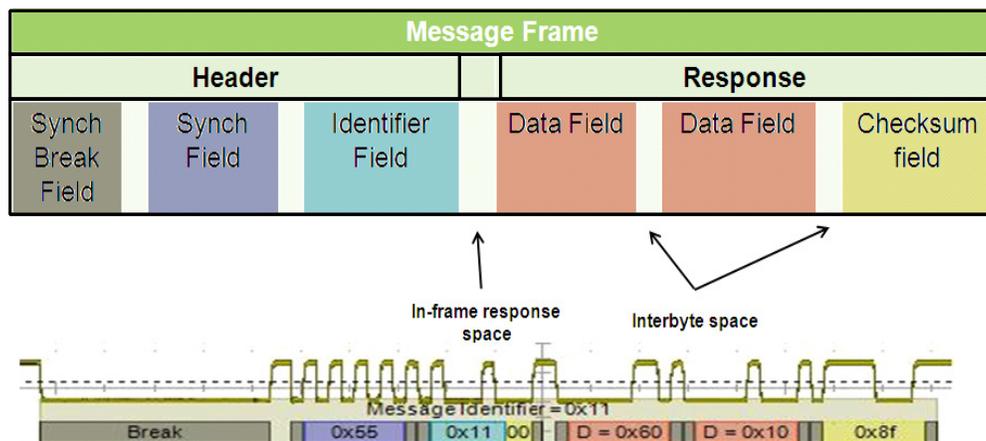


Figure 5. LIN standard Message Frame

Three identifier field are recognized by the product which are MID#29, MID #11, MID #12. MID#29 is a writing command (4 bytes) then MID#11 and MID#12 are read commands (2 bytes). the data in the MID are fixed and must be respected and are organized in the following way.

MID #29							
Byte 1							
7	6	5	4	3	2	1	0
X	X	Target Regulation Voltage					
Byte 2							
7	6	5	4	3	2	1	0
Ramp Cutoff				Ramp Rate			
Byte 3							
7	6	5	4	3	2	1	0
X	X	X	X	Current Limitation			
Byte 4							
7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	X

Figure 6. LIN MID#29 Writing Command

MID #11							
Byte 1							
7	6	5	4	3	2	1	0
EXC Duty Cycle					F_EL	F_MEC	F_HT
Byte 2							
7	6	5	4	3	2	1	0
LIN Bus Time-Out	Com Error	Measured Current <u>OR</u> Temperature					

Figure 7. LIN MID#11 Reading Command

MID #12							
Byte 1							
7	6	5	4	3	2	1	0
Alternator Class					Manufacturer ID		
Byte 2							
7	6	5	4	3	2	1	0
0	0	0	0	Slave not responding	Checksum	ID Parity Fault	Sync Break Fault

Figure 8. LIN MID#12 Reading Command

## 4.2 Bit Rate

The maximum bit rate is 20 kbit/s. the minimum bit rate is 1.0 kbits/s.

Bit Rate		
Slow	Medium	Fast
2400 bit/sec	9600 bit/sec	19200 bit/sec

Figure 9. LIN Bit Rate Recommendation

For more details regarding LIN protocol, please refer to the LIN Specification Package, Revision 1.3 ([www.lin-subbus.de/](http://www.lin-subbus.de/)). The physical layer parameter of the LIN, designed in the product, is also in line with the LIN Specification Package, Revision 1.3. Conformance reports are available upon request from the C&S group GmbH (<http://www.cs-group.de/>) which is an accredited testhouse by the LIN administration.

## 5 Operational Mode Examples

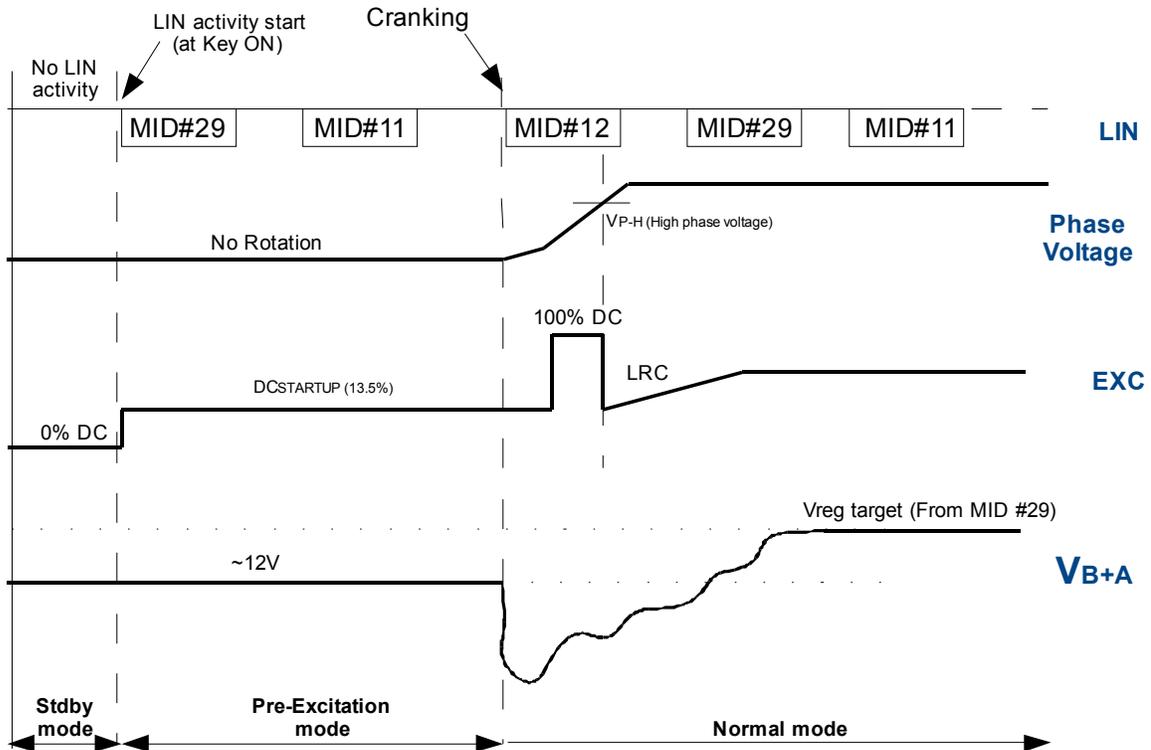
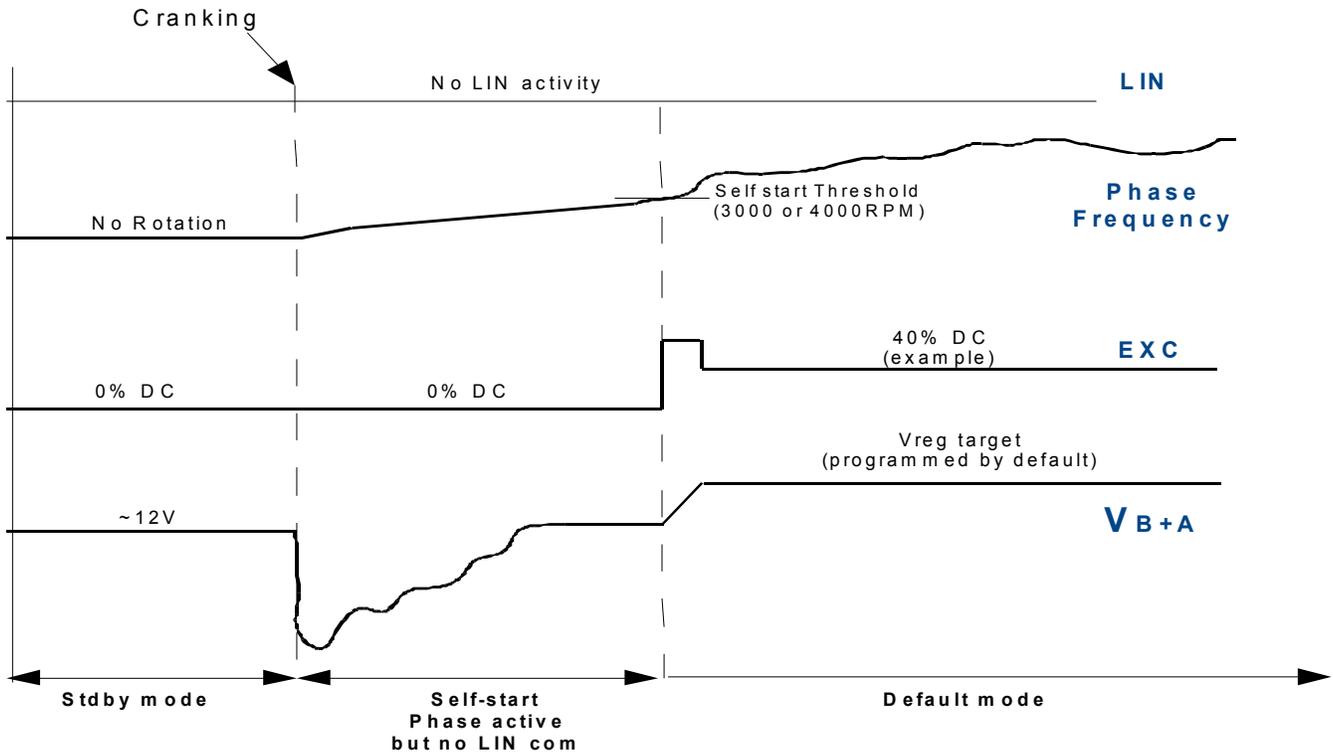


Figure 10. Standard Operation at Vehicle Cranking

1. Standby mode: no activity on phase (no alternator rotation) and no LIN communication enabled (car parking).
2. As soon as the ignition key is ON, LIN commands are sent by the master to the regulator. As a consequence, state machine is switching from Standby mode to Pre-excitation Operational mode by sending 13.5% duty cycle on EXC (Rotor).
3. Finally, the cranking appears leading a battery voltage drop down to few volts. Phase voltage appears when alternator rotation and EXC duty cycle is at 100% during 100 ms max, to increase phase voltage level and reach high phase voltage (~8.0 V). The product starts the regulation of the battery with LRC if programmed.



**Figure 11. Self-start Operation (No LIN Communication)**

1. Standby mode: no activity on phase (no alternator rotation) and no LIN communication enabled (car parking)
2. During cranking, the device detects phase signal, and the device is activated, but don't see any activity on LIN pin. It is taking as reference all default parameter programmed and is waiting phase frequency for witch it must start the regulation.
3. As soon as the self-start threshold speed is reached (3000 or 4000 RPM), the device starts the battery regulation.

# 6 Packaging

## 6.1 Die Dimensions

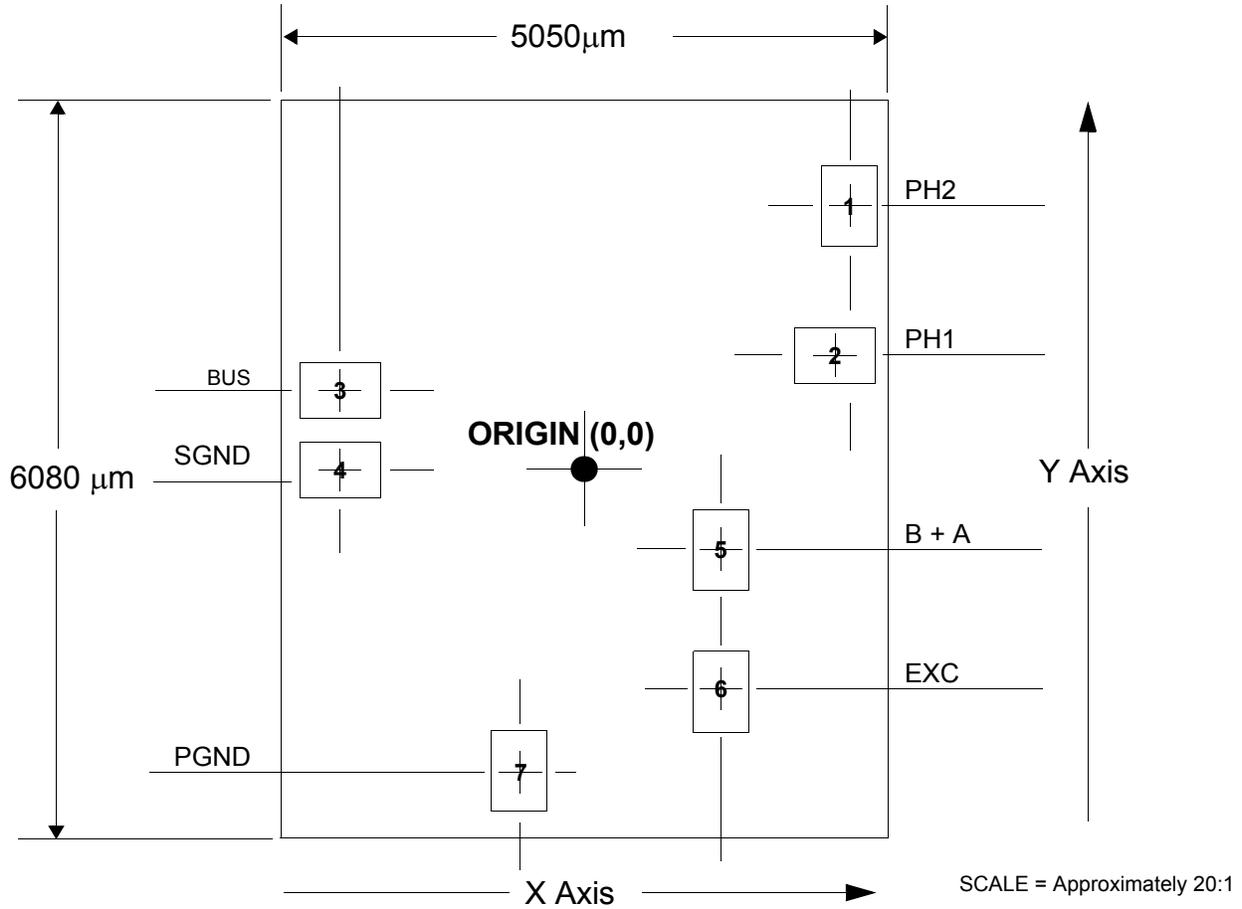


Figure 12. Die floor plan

Table 2. Pad Coordinates

Pad	Function	Die Coordinate (Origin at center of Die)	
		X/µm	Y/µm
1	PH2	2166	2158
2	PH1	2098	1217
3	BUS	-1989	834
4	SIGNAL GROUND <sup>(1)</sup>	-1989	0
5	B+A	1179	-840
6	EXC	1179	-1987
7	POWER GROUND <sup>(1)</sup>	-367	-2631

**Notes:**

1. Signal Ground, POWER ground, and die backside must be connected all together and must be bonded on the same pad on package lead frame to avoid any resistance path between grounds

## 6.2 Die Characteristics

The die is designed to be fitted into a customer designed package however, as so many wiring configurations exist, not all may be possible from the same die design. Due to thermal considerations, soldering is the preferred die attach method, but under some circumstances, conductive epoxy may be acceptable.

**Table 3. Physical Die Characteristics**

Mechanical Data	Lenght	Width	Units
Bonding Pad Size	0.66	0.5	mm
Die Size (lenght x Width)	6.08	5.05	mm
Die Back Metal Composition	Cr/CrAg/Ag		
Die Back Metal Thickness, Typical	2.1		µm
Die Top Metal Thickness, Typical	2.0		µm
Die Top Metal Composition	99.5 Al	0.5Cu	%
Die Thickness	0.36		mm

## 6.3 Assembly Recommendations

Values below are for information only and are based on Freescale experiments. A complete characterization/validation by the customer is needed to fully qualify the assembly process. Freescale will not be responsible of the customer's assembly process.

**Table 4. Mechanical Data**

Mechanical Data	Description
Wire Bonding	Aluminum, 8 Mils Diameter
Assembly Process Type	Wedgebond Process
Maximum End Force to apply	320 Gr <sup>(2)</sup>
Minimum End Force to apply	180 Gr <sup>(3)</sup>

**Notes:**

2. To avoid any mechanical damage to the part, the end force pressure must be controlled ensuring the assembly process and should not exceed this value.
3. Lower value could degrade wire shear performance.

### 6.3.1 Ground Connections

Signal Ground, Power Ground, and Die Backside must be connected all together and must be bonded on the same pad on the package lead frame to avoid any resistance path between grounds

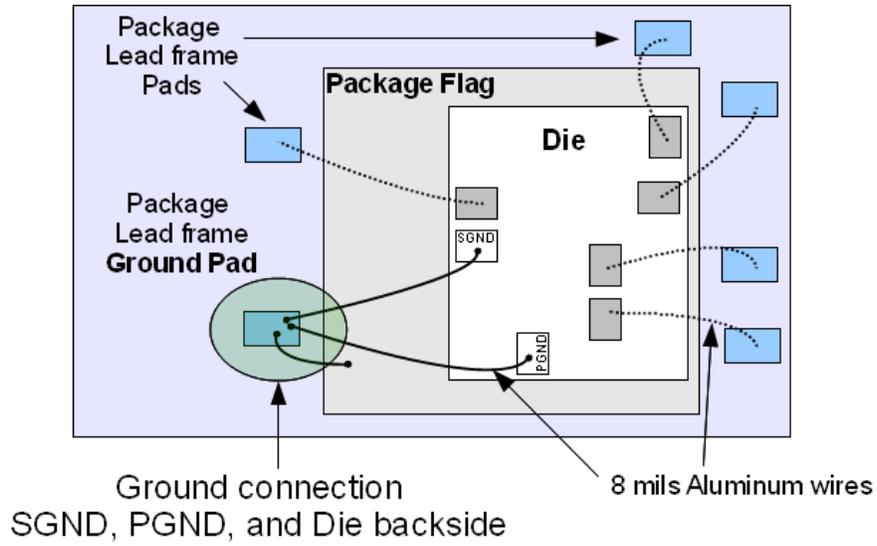


Figure 13. Ground Connections

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