カミナリ AS3935 使用 I²C-Bus インタフェース 雷センサーモジュール

Franklin Lightning Sensor Module

◆特長

AS3935(AMS 社) は、落雷や雲間放電で発生した信号を小型バーアンテナで受信し、独自のアルゴリズムによって雷雲までの距離やエネルギーを判定します。雷の発生を検知すると、内部のレジスタにデータが記録されます (レジスタの記録はイベントごとに上書き)。同時に割り込み信号 (IRQ) が出力されます。IRQ をトリガとして、マイコンからレジスタデータを呼び出すことによって、雷雲の発生や動きを知ることができます。このモジュールは、使いやすい 2.54mm ピッチの 5 ピン SIP 基板に AS3935 と専用バーアンテナ等を実装し、I²C と IRQ によってマイコンとのインタフェースを実現しています。

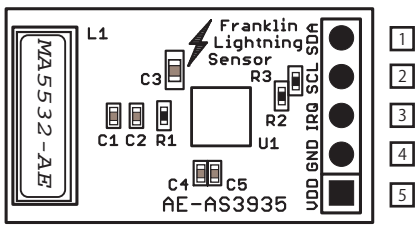
主な仕様

- 電源電圧：2.4V ～ 5.5V　・消費電流 *(V_{DD}=5V)：70μA(待機時)、350μA(信号検出時)　・I²C インタフェース
- 検出項目：雷雲までの距離 (40km ～直上)、雷のエネルギー
- 設定可能パラメータ：AFE ゲイン (32 ステップ)、NF レベル (8 ステップ)、WDTH**(16 ステップ) 等

(* I²C のプルアップ電流は除く、** ウォッチドッグ閾値)

◆ピン番号と機能

[部品面]



ピン番号	信号名	入出力	機　能
1	SDA	双方向	I2C-Bus 通信用の双方向データ入出力端子 プルアップ抵抗 10kΩ[R3]
2	SCL	入力	I2C-Bus 通信用のシリアルクロック入力端子 プルアップ抵抗 10kΩ[R2]
3	IRQ	出力	イベント発生時の割り込み信号として出力 (出力はイベント発生時に H レベル)
4	GND	ー	電源グランド端子 / I²C バスグランド端子
5	VDD	ー	電源入力端子 (2.4V ～ 5.5V)

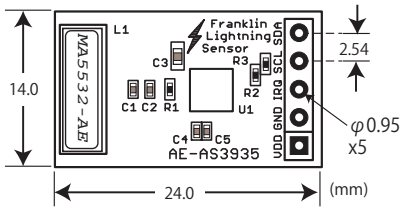
※ AS3935 の I²C スレーブアドレス：**0000000(00h、0x00)**

◆部品表

すべての部品は、基板に実装済みです。(ピンヘッダを除く)

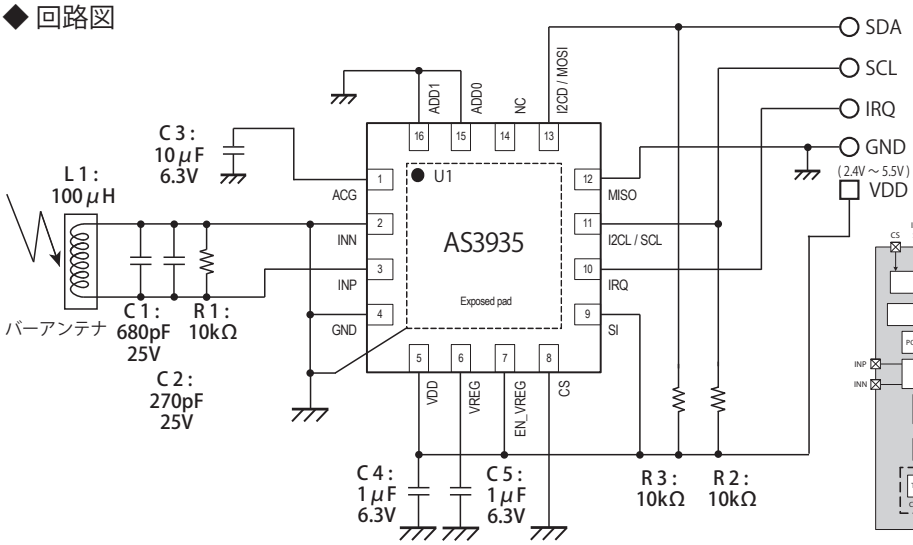
品番	部　品	備　考
U1	AS3935	Lightning Sensor (雷センサ)
L1	100μH	信号受信用小型バーアンテナ
C1	680pF (定格 25V 以上)	共振用コンデンサ
C2	270pF(定格 25V 以上)	共振用コンデンサ
C3	10μF (定格 6.3V 以上)	AGC 用バイパスコンデンサ
C4	1μF (定格 6.3V 以上)	電源用バイパスコンデンサ
C5	1μF (定格 6.3V 以上)	VREG 用バイパスコンデンサ
R1	10kΩ	整合用抵抗
R2	10kΩ	SCL 用プルアップ抵抗 (接続選択可)
R3	10kΩ	SDA 用プルアップ抵抗 (接続選択可)
ー	1×5 ピンヘッダ (細ピン)	基板にはんだ付けします

◆基板寸法図



アンテナ L1 の近くに電波受信の妨げとなるような金属や配線材等を配置しないでください。

◆回路図

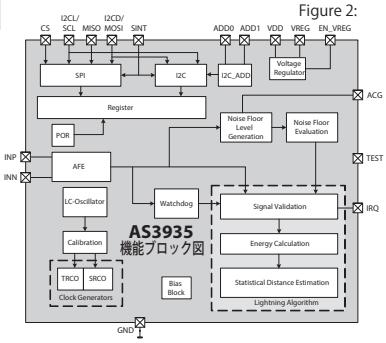


◆初期動作試験

Arduino 用のスケッチによるをデモソフトを秋月電子通商の商品ページに掲載しています。これを利用して動作試験をすることができます。

ご注意：雷センサーの検知結果の情報だけでなく、公機関の気象情報をご確認ください。

Figure 2:



Absolute Maximum Ratings 絶対最大定格 Figure 5:

Symbol	Parameter	Min	Max	Units	Comments
Electrical Parameters					
VDD	DC supply voltage	-0.5	7	V	
VIN	Input pin voltage	-0.5	5	V	
I_{scr}	Input current (latch up immunity)	-100	100	mA	Norm: Jedec 78
Electrostatic Discharge					
ESD	Electrostatic discharge	±2		kV	Norm: MIL 883 E method 3015 (Human Body Model)
Continuous Power Dissipation					
P_t	Total power dissipation (all supplies and outputs)		0.1	mW	
Temperature Ranges and Storage Conditions					
T_{strg}	Storage temperature	-65	150	°C	
T_{body}	Package body temperature		260	°C	Norm: IPC/JEDEC J-STD-020 The reflow peak soldering temperature (body temperature) is specified according IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices".
	Humidity non-condensing	5	85	%	
MSL	Moisture Sensitivity Level	3			Represents a maximum floor life time of 168h

Operating Conditions 動作条件 Figure 6:

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{DD}	Positive supply voltage	In case the voltage regulator is ON	2.4		5.5	V
		In case the voltage regulator is OFF	2.4		3.6	V
T_{AMB}	Ambient temperature		-40		85	°C

CMOS Input CMOS 入力仕様 Figure 7:

Symbol	Parameter	Min	Typ	Max	Units
V_{IH}	High level input voltage	0.6*VDD	0.7*VDD	0.9*VDD	V
V_{IL}	Low level input voltage	0.125*VDD	0.2*VDD	0.3*VDD	V

Note: On ALL outputs, use the cells with the smallest drive capability which will do the job, in order to prevent current/spikes problems.

CMOS Output CMOS 出力仕様 Figure 8:

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{OH}	High level output voltage	With a load current of 1mA	VDD-0.4			V
V_{OL}	Low level output voltage				VSS+0.4	V
CL	Capacitive load	For a clock frequency of 1MHz			400	pF

Tristate CMOS Output 3 ステート CMOS 出力仕様 Figure 9:

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{OH}	High level output voltage	With a load current of 1mA	VDD-0.4			V
V_{OL}	Low level output voltage				VSS+0.4	V
IOZ	Tristate leakage current	To V_{DD} and V_{SS}			400	nA

Register Table レジスタテーブル Figure 22:

Register #	7	6	5	4	3	2	1	0
0x00	Reserved		AFE_GB					PWD
0x01	Reserved	NF_LEV				WDTH		
0x02	Reserved	CL_STAT	MIN_NUM_LIGH			SREJ		
0x03	LCO_FDIV		MASK_DIST	Reserved		INT		
0x04	S_LIG_L							
0x05	S_LIG_M							
0x06	Reserved			S_LIG_MM				
0x07	Reserved		DISTANCE					
0x08	DISP_LCO	DISP_SRCO	DISP_TRCO	Reserved	TUN_CAP			
0x3A	TRCO_CALIB_DONE	TRCO_CALIB_NOK	Reserved					
0x3B	SRCO_CALIB_DONE	SRCO_CALIB_NOK	Reserved					

詳細な資料は秋月電子通商の商品ページ
http://akizukidenshi.com/catalog/g/gK-08685/ にございます。
なお、本資料内の Figure xx: は ams Datasheet, Confidential: 2014-Jan[1-03] の
図番号を示しています。

Electrical System Specifications 電気的仕様 Figure 10:

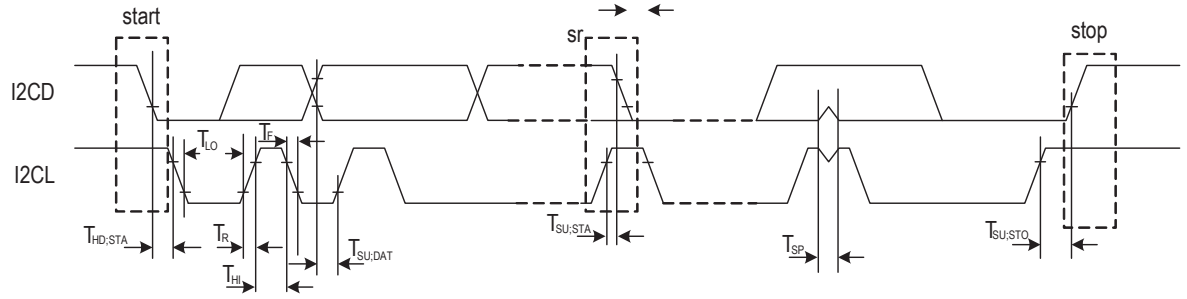
Symbol	Parameter	Min	Typ	Max	Units	Note
Input Characteristic						
R_{IN}	Input AC impedance		200		kΩ	
Current Consumption						
$I_{PWDROFF}$	Power-down current when VREG is OFF		1	2	µA	
I_{PWDRON}	Power-down current when VREG is ON		8	15	µA	
$I_{LSMROFF}$	Current consumption in listening mode when VREG is OFF		60	80	µA	
I_{LSMRON}	Current consumption in listening mode when VREG is ON		70		µA	
I_{SVM}	Current Consumption in signal verification mode		350		µA	
Timing						
$T_{lightning}$	Duration in signal verification mode once lightning is detected		1		s	
$T_{disturber}$	Duration in signal verification mode once disturber is detected		1.5		s	
Oscillators						
LCO_{SUT}	LCO Start-up Time			2	ms	Time needed by the LCO to start-up
T_{SRCO}	SRCO frequency after calibration	1.065	1.125	1.19	MHz	Assuming FLCO = 500 kHz
T_{TRCO}	TRCO frequency after calibration	30.5	32.26	34.0	kHz	
TRCOCAL	Calibration time for the RC oscillators			2	ms	The calibration of the RC oscillators starts after the LCO settles
Voltage Regulator						
VR_{OUT}	Voltage regulator output voltage	2.7	3.0	3.3	V	

Detailed Register Map レジスタ詳細マップ Figure 23:

Address	Register Name	Bit	Type	Default Value	Description
0x00	Reserved	[7:6]	R/W	0	Reserved
	AFE_GB	[5:1]		10010	AFE Gain Boost
	PWD	[0]		0	Power-down
0x01	NF_LEV	[6:4]	R/W	010	Noise Floor Level
	WDTH	[3:0]		0010	Watchdog threshold
0x02	Reserved	[7]	R/W	1	Reserved
	CL_STAT	[6]		1	Clear statistics
	MIN_NUM_LIGH	[5:4]		00	Minimum number of lightning
	SREJ	[3:0]		0010	Spike rejection
0x03	LCO_FDIV	[7:6]	R/W	00	Frequency division ration for antenna tuning
	MASK_DIST	[5]		0	Mask Disturber
	Reserved	[4]		0	Reserved
	INT	[3:0]	R	0000	Interrupt (see Figure 43)
0x04	S_LIG_L	[7:0]	R	00000000	Energy of the Single Lightning LSBYTE
0x05	S_LIG_M	[7:0]	R	00000000	Energy of the Single Lightning MSBYTE
0x06	Reserved	[7:5]			Reserved
	S_LIG_MM	[4:0]	R	00000	Energy of the Single Lightning MMSBYTE
0x07	Reserved	[7:6]			Reserved
	DISTANCE	[5:0]	R	000000	Distance estimation
0x08	DISP_LCO	[7]	R/W	0	Display LCO on IRQ pin
	DISP_SRCO	[6]		0	Display SRCO on IRQ pin
	DISP_TRCO	[5]		0	Display TRCO on IRQ pin
	TUN_CAP	[3:0]		0000	Internal Tuning Capacitors (from 0 to 120pF in steps of 8pF)
0x3A	TRCO_CALIB_DONE	[7]	R	0	Calibration of TRCO done (1=successful)
	TRCO_CALIB_NOK	[6]	R	0	Calibration of TRCO unsuccessful (1=not successful)
	Reserved	[5:0]	R	000000	Reserved
0x3B	SRCO_CALIB_DONE	[7]	R	0	Calibration of SRCO done (1=successful)
	SRCO_CALIB_NOK	[6]	R	0	Calibration of SRCO unsuccessful (1=not successful)
	Reserved	[5:0]	R	000000	Reserved

I²C Timing Diagram

Figure 31:



I²C Parameters I²C パラメータ

Figure 32:

Symbol	Parameter	Conditions	Min	Typ	Max	Units
T_{SP}	Spike intensity		50	100		ns
T_{HI}	High Clock Time	400 kHz Clock speed	330			ns
T_{LO}	Low Clock Time		660			ns
T_{SU}		I2CD has to change Tsetup before rising edge I2CL	30			ns
T_{HD}		No hold time needed for I2CD relative to rising edge of I2CL	-40			ns
$T_{HD;STA}$	Within start condition, after low going I2CD, I2CL has to stay constant for specified hold time		300			ns
$T_{SU;STO}$	After high going edge of I2CL, I2CD has to stay constant for the specified setup time before STOP or repeated start condition is applied		100			ns
$T_{SU;STA}$			100			ns

I²C Abbreviations I²C 関連の略語と意味

Figure 35:

Symbol	Description
S	START condition after STOP
Sr	Repeated START
DW	Device Address for write
DR	Device Address for read
WA	Word address
A	Acknowledge
N	No acknowledge
P	STOP condition
WA++	Internal address increment

Registers 0x3C, 0x3D 直接コマンド

Figure 37:

Direct Command	Register
PRESET_DEFAULT	0x3C
CALIB_RCO	0x3D

Interrupts インターラプト

Figure 43:

Interrupt Name	REG0x03[3:0]	Description
INT_NH	0001	Noise level too high
INT_D	0100	Disturber detected
INT_L	1000	Lightning interrupt

Settings for the Noise Floor Threshold ノイズフロア閾値の設定

Figure 40:

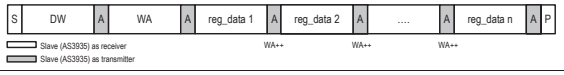
Continuous Input Noise Level [µVrms] (Outdoor)	Continuous Input Noise Level [µVrms] (Indoor)	REG0x01[6]	REG0x01[5]	REG0x01[4]
390	28	0	0	0
630	45	0	0	1
860	62	0	1	0
1100	78	0	1	1
1140	95	1	0	0
1570	112	1	0	1
1800	130	1	1	0
2000	146	1	1	1

I²C Byte Write

Figure 33:

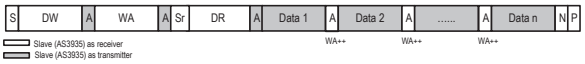
I²C Page Write

Figure 34:



I²C Page Read

Figure 36:



Distance Estimation 距離算定結果

Figure 42:

REG0x07[5:0]	Distance [km]
111111	Out of range
101000	40
100101	37
100010	34
011111	31
011011	27
011000	24
010100	20
010001	17
001110	14
001100	12
001010	10
001000	8
000110	6
000101	5
000001	Storm is Overhead

Minimum Number of Lightning Detection 雷検出の最低数

Figure 44:

Minimum Number of Lightning	REG0x02[5]	REG0x02[4]
1	0	0
5	0	1
9	1	0
16	1	1

AFE Setting, Outdoor vs. Indoor 屋外と屋内の AFE 設定

Figure 38:

AFE Setting	REG0x00[5:1]
Indoor	10010
Outdoor	01110

Analog Front-end (AFE) and Watchdog アナログフロントエンドとウォッチドッグ

The AFE amplifies and demodulates the AC-signal picked up by the antenna. The AS3935 is based on narrowband receiving techniques with a center frequency of 500 kHz and a bandwidth of about 33 kHz. The AFE gain can be considered as constant within the antenna's bandwidth. This is achieved by making the AFE bandwidth greater than the antenna bandwidth.

The AFE gain has been optimized for two operating environments as shown in Figure 38. By default the gain is set to Indoor. It is of paramount importance that the gain is set according to the surrounding environment, otherwise the sensor will not yield the desired results.

Frequency Division Ratio for the Antenna Tuning アンテナチューニングの周波数分割比

Division Ratio	REG0x03[7]	REG0x03[6]
16	0	0
32	0	1
64	1	0
128	1	1

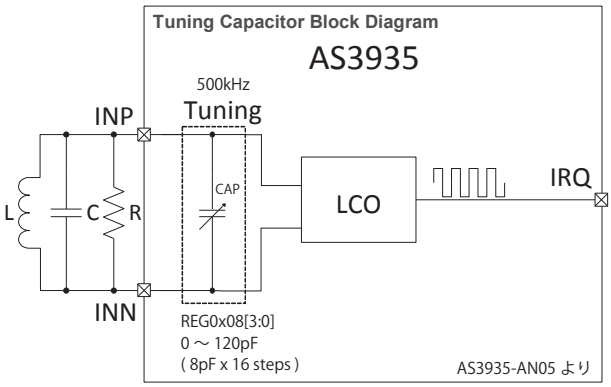
Figure 45:

The antenna tuning algorithm can be performed in the following way:
アンテナチューニングの実行方法：

1. Measure actual resonance frequency of the antenna on the IRQ pin.
2. Add additional internal capacitance in parallel to the external LC.
3. Repeat this sequence until the resonance frequency is tuned to 500 kHz.

Measure LCO Frequency LCO 周波数の測定

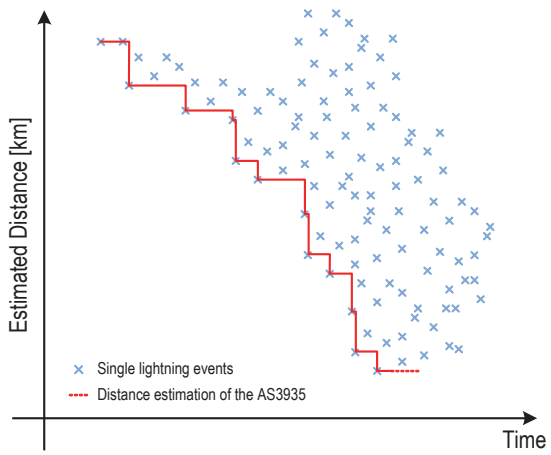
Connect the LCO to the IRQ pin setting register REG0x08[7] = 1. Select the division ratio of the LCO frequency defined in register REG0x03[7:6]. Based on the division ratio the theoretical period can be calculated. Wait 2ms for the LCO to start up and to be settled before measuring the frequency.



Detailed Description 詳細説明

The AS3935 can detect the presence of an approaching storm with lightning activities and provide an estimation of the distance to the leading edge of the storm, where the leading edge of the storm is defined as the minimum distance from the sensor to the closest edge of the storm. The embedded hardwired distance estimation algorithm of the AS3935 issues an interrupt on the IRQ pin (see Interrupt Management on page 34) every time a lightning is detected. The estimated distance which is displayed in the distance estimation register does not represent the distance to the single lightning but the estimated distance to the leading edge of the storm. A graphical representation is shown in the Figure 17.

Figure 17: Storm



Lightning Algorithm 雷検知アルゴリズム

The lightning algorithm consists of hardwired logic. False events (man-made disturbers) which might trigger the AS3935 are rejected, while lightning events initiate calculations to estimate the distance to the head of the storm.

The Lightning algorithm is broken up into three sub blocks:

1. **Signal validation:** Verification that the incoming signal can be classified as lightning.
2. **Energy calculation:** Calculation of the energy of the single event.
3. **Statistical distance estimation:** According to the number of stored events (lightning), a distance estimate is calculated.

In case the incoming signal does not have the shape characteristic to lightning, the signal validation fails and the event is classified as disturber. In that case the energy calculation and statistical distance estimation are not performed and the sensor automatically goes back to listening mode.

The shortest time span between two lightning strikes that the AS3935 can resolve is approximately one second.

Once a signal is classified as disturber the sensor is deactivated for a further 1.5s time period. As the duration of disturber signals can vary, this sensor down time will prevent the sensor from triggering repeatedly due to longer disturber events.

Signal Validation 信号評価

During the signal validation phase the shape of the incoming signal is analyzed. The sensor can differentiate between signals that show the pattern characteristic of lightning strikes and man-made disturbers such as random impulses. Besides the watchdog threshold the spike rejection settings SREJ in **REG0x02[3:0]** can be used to increase the robustness against false alarms from such disturbers. By default the value is set to **REG0x02[3:0]** = 0010. Larger values in **REG0x02[3:0]** correspond to more robust disturber rejection, yet with the drawback of a decrease in detection efficiency. In Figure 41 the detection efficiency is illustrated as function of distance for various settings of SREJ.

At the end of the signal verification, the AS3935 automatically returns to listening mode.

Energy Calculation 強度の演算

If the received signal is classified as lightning, the energy is calculated. The result of the energy calculation is then stored in the registers **REG0x06[4:0]**, **REG0x05[7:0]** and **REG0x04[7:0]**. This value is just a pure number and has no physical meaning.

Detection Efficiencies vs. Distance for Different Setting of SREJ, if WDTH=0001