目次

第 1 章

はじめに

1.1　研究の背景

当研究室では, 毎年 NHK 高専ロボットコンテストに参加するためのロボット設計, 及び製作を行っている. 過去三年間全国大会に出場しており, 本校の名称が金沢工業高等専門学校である最後の年でもあり今年度は地区大会での優勝を目標にしてて取り組んだ.

私たちは, 目標達成のためには高速な移動ができるロボットが必要だと考え, ロボットの移動方法をタイヤの二輪駆動に決め, 使用する DC モータに高出力なものを使用した. そのため,30A でも問題ない高出力モータドライバが必要だった. そこで, 伊藤研究室で昨年作成された ITOLAB MOTORDRIVER を使用した. しかし, 多くの不具合が発生したので問題解決に向けて対策をとったものの, 目標とした移動速度を下回った状態で大会に挑むこととなった.

地区大会では, 初戦に一台のロボットの移動操作ができなくなるマシントラブルに遭い, 地区大会一回戦敗退という無念な結果となった.

その後, マシントラブルはモータドライバに異常があったのではという話になったが, 原因を見つけることはできなかった. 今年度の NHK 高専ロボットコンテストの結果から, 来年の当研究室のロボットが活躍するために, 扱いやすい高出力モーダードライバが有効だと考える.

今年度の NHK 高専ロボットコンテストロボットと, ロボットの足回り

のモータを図 1.1 と図 1.2 に示す.

図 1.1　ロボコンロボット

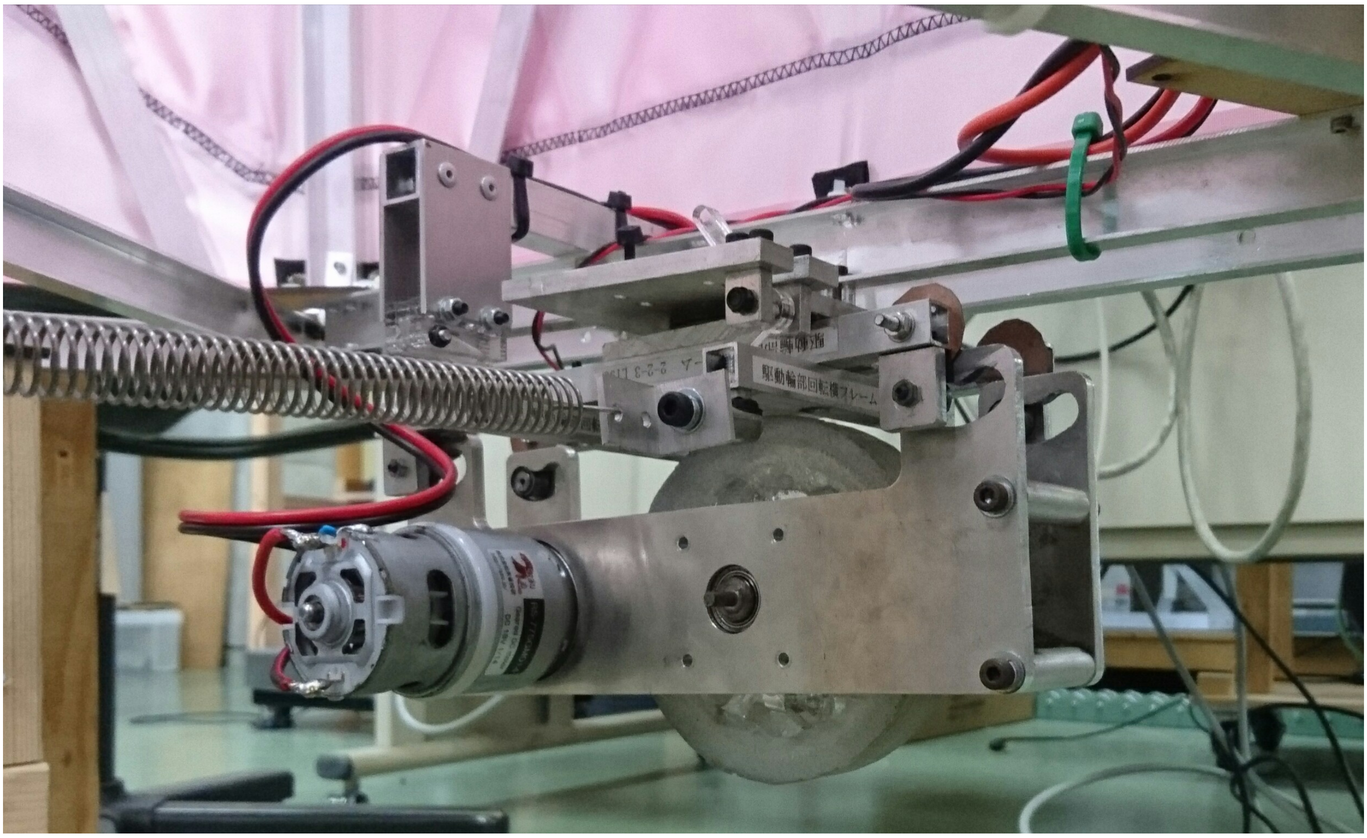


図 1.2　足回りのモータ

1.2　研究の目的

ITOLAB MOTORDRIVER を基に,当研究室で使用できる高出力モータードライバの設計,製作を行う.

1.3　本論文の構成

1 章では,本研究の背景と簡略化した概要を示す．2 章では,今年のロボコンで使用した ITOLAB MOTORDRIVER について述べる．3 章では,今回の研究で作成した高出力モータドライバについて述べる．4 章で,最後に本研究のまとめを述べる．

第 2 章

ITOLAB MOTORDRIVER

2.1 ドライバの特徴

ITOLAB MOTORDRIVER を図 2.1 に, 回路図を図 2.2 に示す. また, ITOLAB MOTORDRIVER の仕様を表 2.1 に示す. ロボコンでは, ロボットに使用できる部品の上限価格が設定されている. 今年度の上限は 30 万円でロボットを三台作製しなければならなかった. また, 作製するロボットに自動走行させたかったので, フィードバック制御が必要だった.

そこで, エンコーダが使用でき, 製作コストが安い ITOLAB MOTORDRIVER を使用することにした。

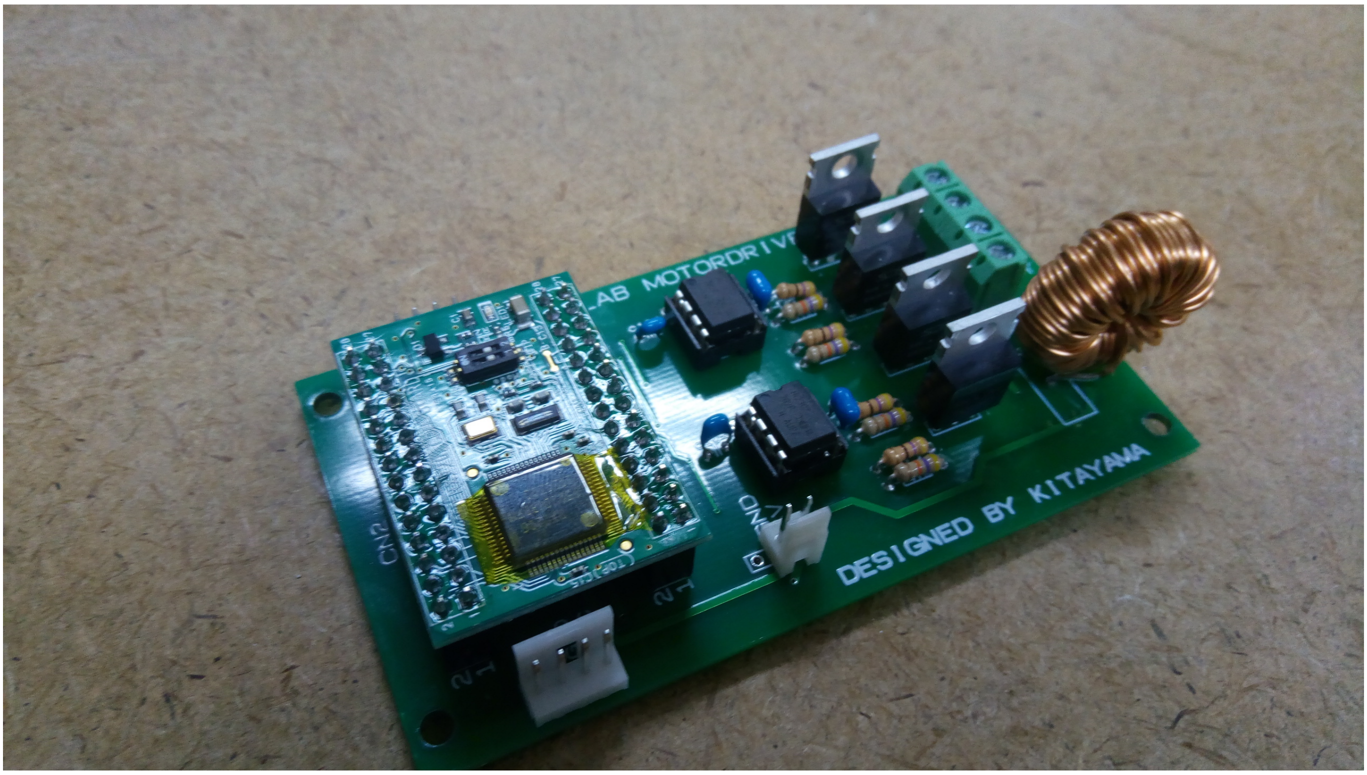


図 2.1　ITOLAB MOTORDRIVER

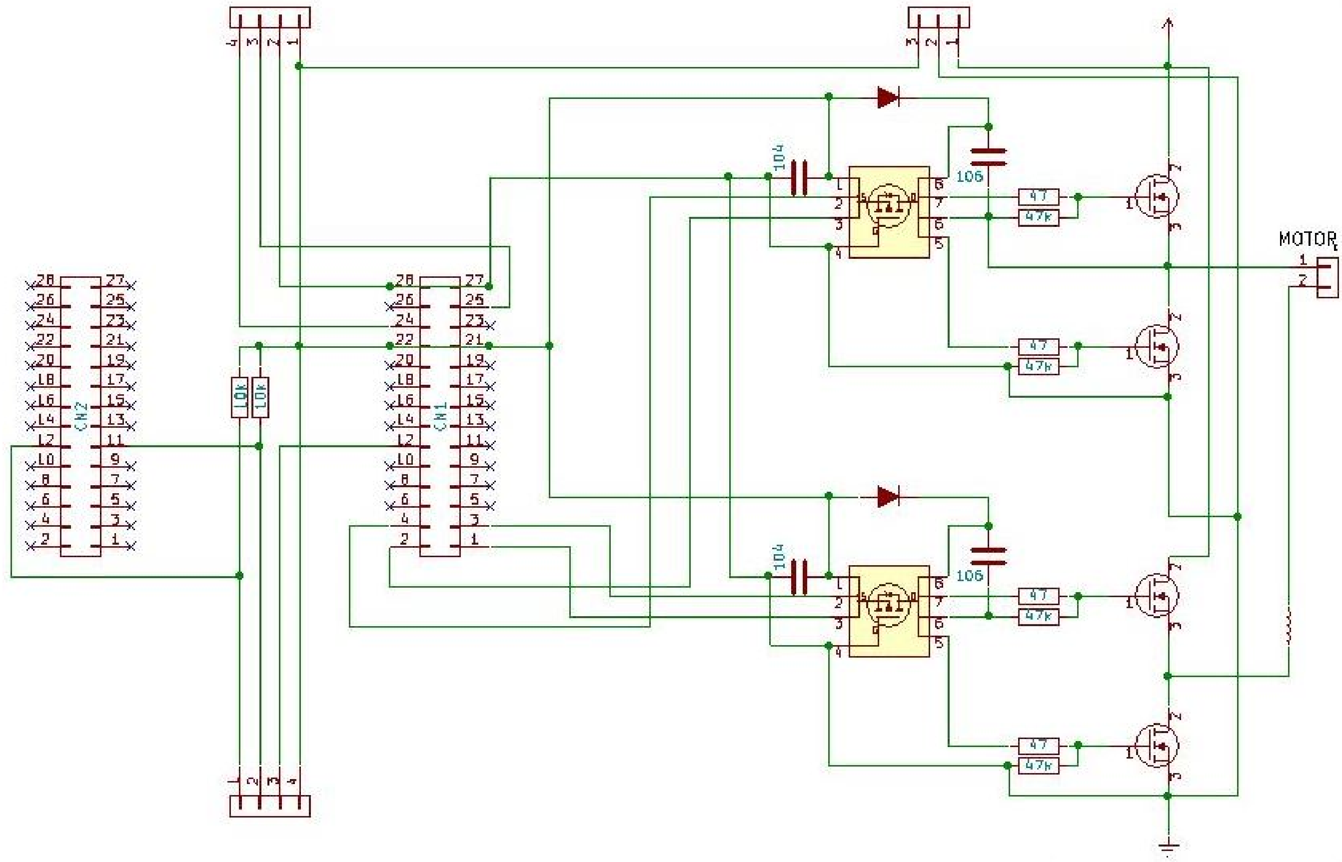


図 2.2　ITOLAB MOTORDRIVER 回路図

表 2.1　ITOLAB MOTORDRIVER の仕様

使用マイコン	RX220 マイコン
シリアル通信	RS232C
FET	V_{DS} 40V I_D 80A

2.2　改善点

2.2.1　発生した問題

ロボットの動作実験を行うと,ITOLAB MOTORDRIVER に以下の問題が発生した.

- 急加減速時にパターンの焼損
- 回生電流によるノイズの発生
- FET トランジスタの高温化
- 通信エラー

パターンの焼損

ロボットの走行実験中, ロボットを急加減速させた結果ロボット足回りから煙が上がり, 図 2.3 のようにモータドライバのパターンが焼損した. 再現実験によりパターンを焼損させた状態を図 2.4 に示す.

図 2.3　パターンの焼損

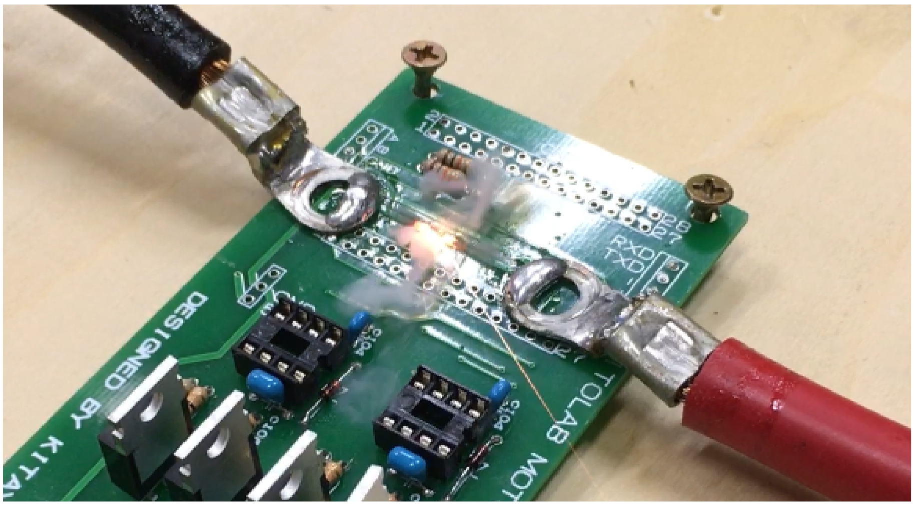


図 2.4　実験によるパターンの焼損直後

回生電流によるノイズの発生

ロボットの走行実験中,ロボットを急加減速させた結果モータから回生電流が発生し,ノイズとなった.

FET トランジスタの高熱化

移動速度が早いために,ロボットの前進,後進を繰り返した際電気エネルギが熱エネルギとなり,FET トランジスタから高熱が発生された.

通信エラー

回生電流で発生したノイズによって,RS232C 通信にノイズが乗り急停止時にロボットが暴走した.

2.2.2　問題に対しての改善

これらを解決するために,以下の対策を講じた.改善後の ITOLAB MOTORDRIVER を図 2.8 に,ロボットに取り付けた ITOLAB MOTORDRIVER を図 2.9 に示す.

- 電流制限プログラムの作成
- 回生ダイオードの取り付け

- FETトランジスタにヒートシンクの取り付け
- 通信エラー確認用のLEDの取り付け

電流制限プログラムの作成

急加減速をするとパターンの焼損するので, プログラムで加減速を緩やかにして最高速度を下げた.

回生ダイオードの取り付け

図2.5の回生ダイオードを取り付けることで, モータから発生する回生電流から基板を守り, ノイズを防ぐ.

図 2.5　回生ダイオード

FET トランジスタにヒートシンクの取り付け

ロボット操作によってFETで発生した熱を, 図2.6のヒートシンクで放熱, 冷却する.

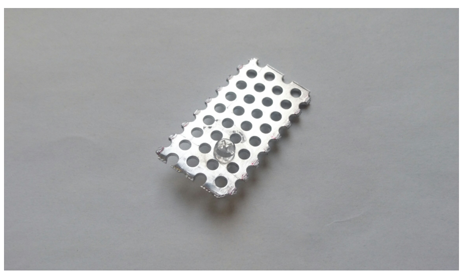


図 2.6　ヒートシンク

通信エラー確認用の LED の取り付け

RX220 マイコンに図 2.7 の LED を取り付け, 通信エラーが発生した時に光るようにプログラムした.

図 2.7　5mm 砲弾型 LED

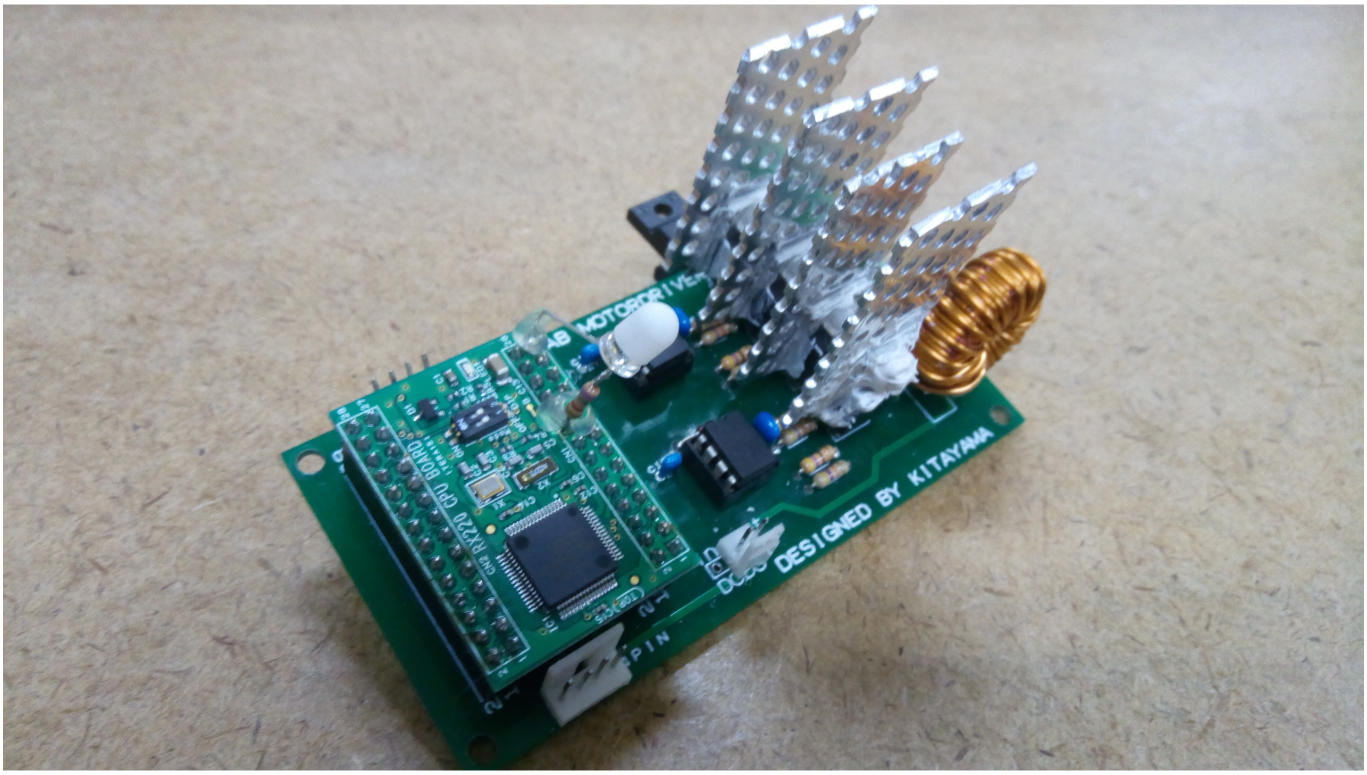


図 2.8　改善後の ITOLAB MOTORDRIVER

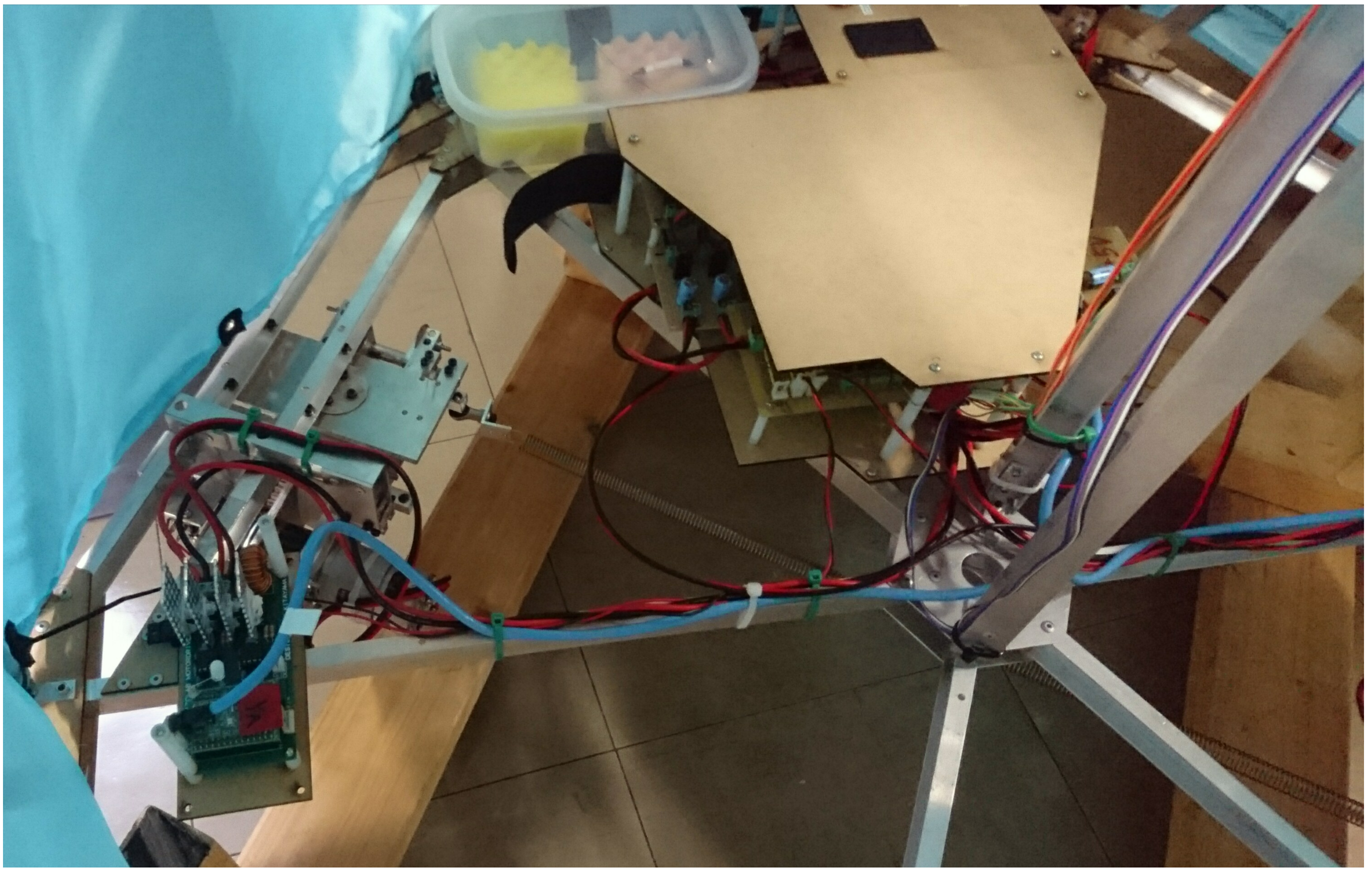


図 2.9　ロボットに取り付けた ITOLAB MOTORDRIVER

2.3　ITOLAB MOTORDRIVER 使用結果

ロボットの最大移動速度を 5.83m/s にするために, 回転数を 1114rpm に設定した. しかし,電流制限プログラムを入れたために, 目標の 1114rpm に達せず,700rpm までとなった.

また, 地区大会時に図 2.10 のように 1 台のロボットのモータが動作しなくなった. 試合後には動作したので, 原因を調べたが原因を発見できず, モータドライバの不具合も発見できなかった.

図 2.10　停止したロボット

第3章

新高出力モータドライバ

3.1　要求機能

ロボコンで使用するバッテリーは,最大電圧14.8V,最大電流178Aで,モータは最大電流130Aである.このことから,ITOLAB MOTORDRIVERでバッテリー,モータの性能を最大まで発揮できていないことが分かる.これを考慮した上で,先に述べた不具合箇所を修正,改良した高出力モータドライバを製作した.

- 大電流が流れるパターン幅の拡張,GNDのベタ化
- FETヒートシンク,回生ダイオードの標準搭載
- FET用温度センサの取り付け
- モータに流れる電流を確認するための電流センサの取り付け
- エラー,通信を確認するための汎用LEDの取り付け
- 制御用マイコンのリセットスイッチ,実験などに使用できる汎用スイッチの搭載
- ノイズの影響を受けやすいRS232通信から,影響の受けにくい作動伝送を用いたRS485通信への変更

3.2　構成

新高出力モーターードライバのシステムブロック図を図 3.1 に示す. また, 新モータドライバの仕様書を表 3.1 に示す. 付録 C に RX マイコンと各部品との接続を示した.

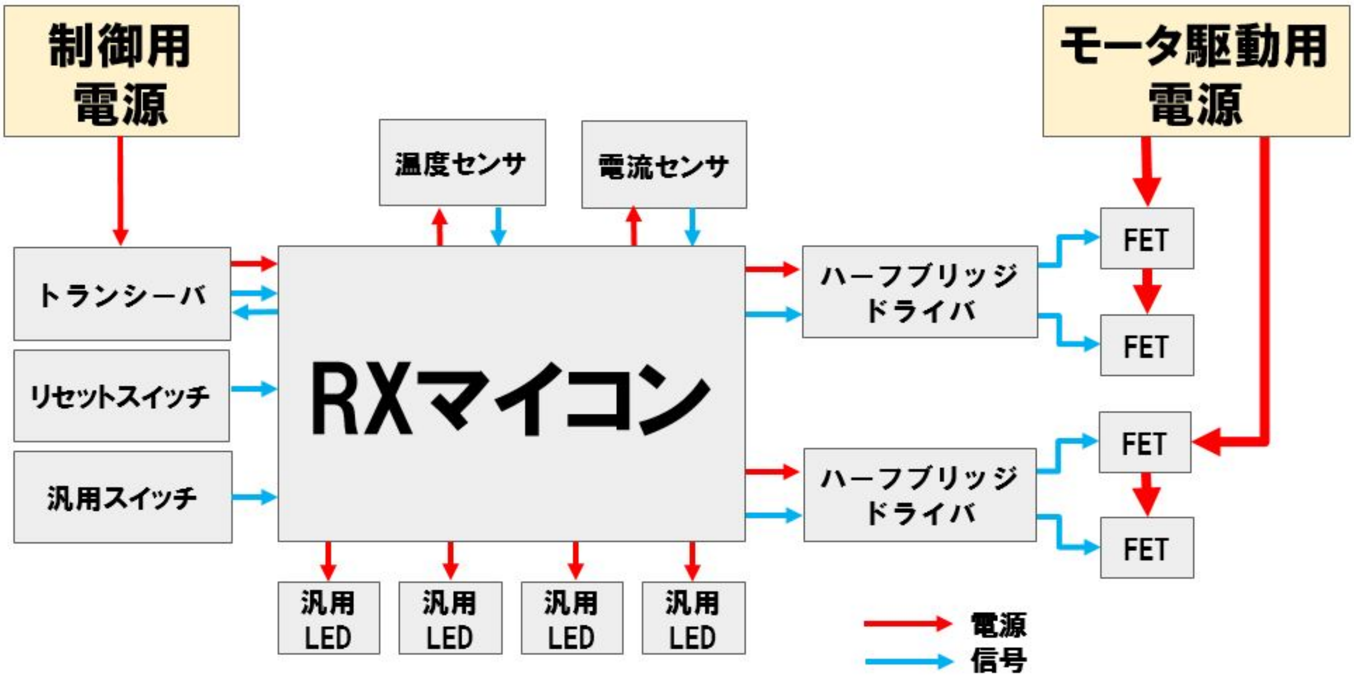


図 3.1　システムブロック図

表 3.1　新モータドライバの仕様書

使用マイコン	RX220 マイコン
シリアル通信	RS485
FET	V_{DS} 40V I_D 80A
温度センサ	動作温度 -40～125 ℃ 動作電圧 3.1～5.5V
電流センサ	動作温度 -40～150 ℃ 作動電圧 3.3～5.5V 検出電流 0～100A
最大定格電圧	40V
最大定格電流	80A

3.3　回路図・アートワーク図

ロボコン用高出力モータードライバの回路図, アートワーク図をそれぞれ図 3.2 , 図 3.3 に示す. また, 基板の 3D ビューアを図 3.4 に示す. 回路図, アートワークの作成は, 回路図とアートワークが連動している KiCad を用いた. 回路図は,ITOLAB MOTORDRIVER の回路図を作成した後に, 新たな部品を接続した.

アートワークは, 大電流の流れる可能性のあるパターン幅を,1.0mm から 5.0mm に変更した. パターン幅と電流許容量は比例しているので, 電流の許容量は 5 倍になる. また, 裏面は GND のベタ化を行った.

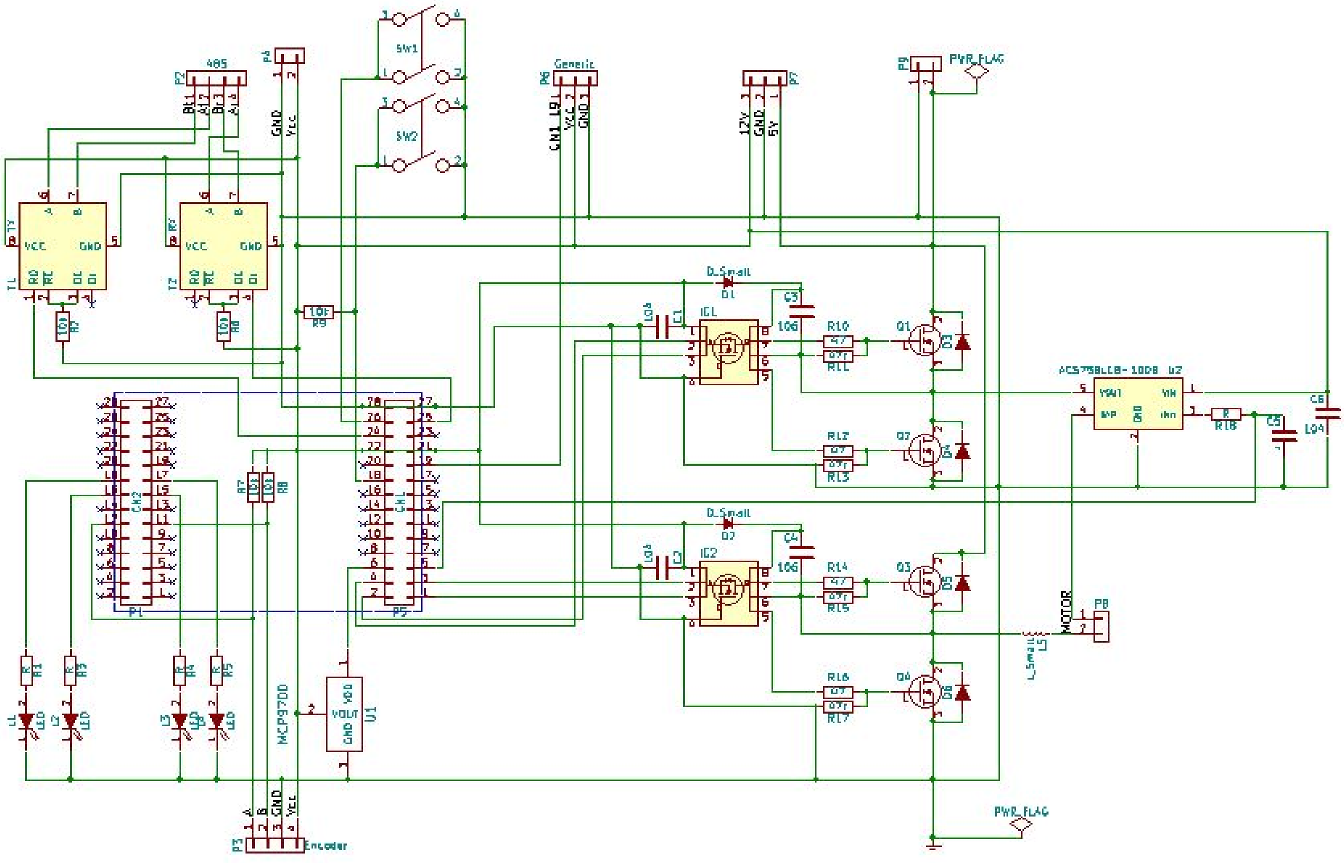


図 3.2　回路図

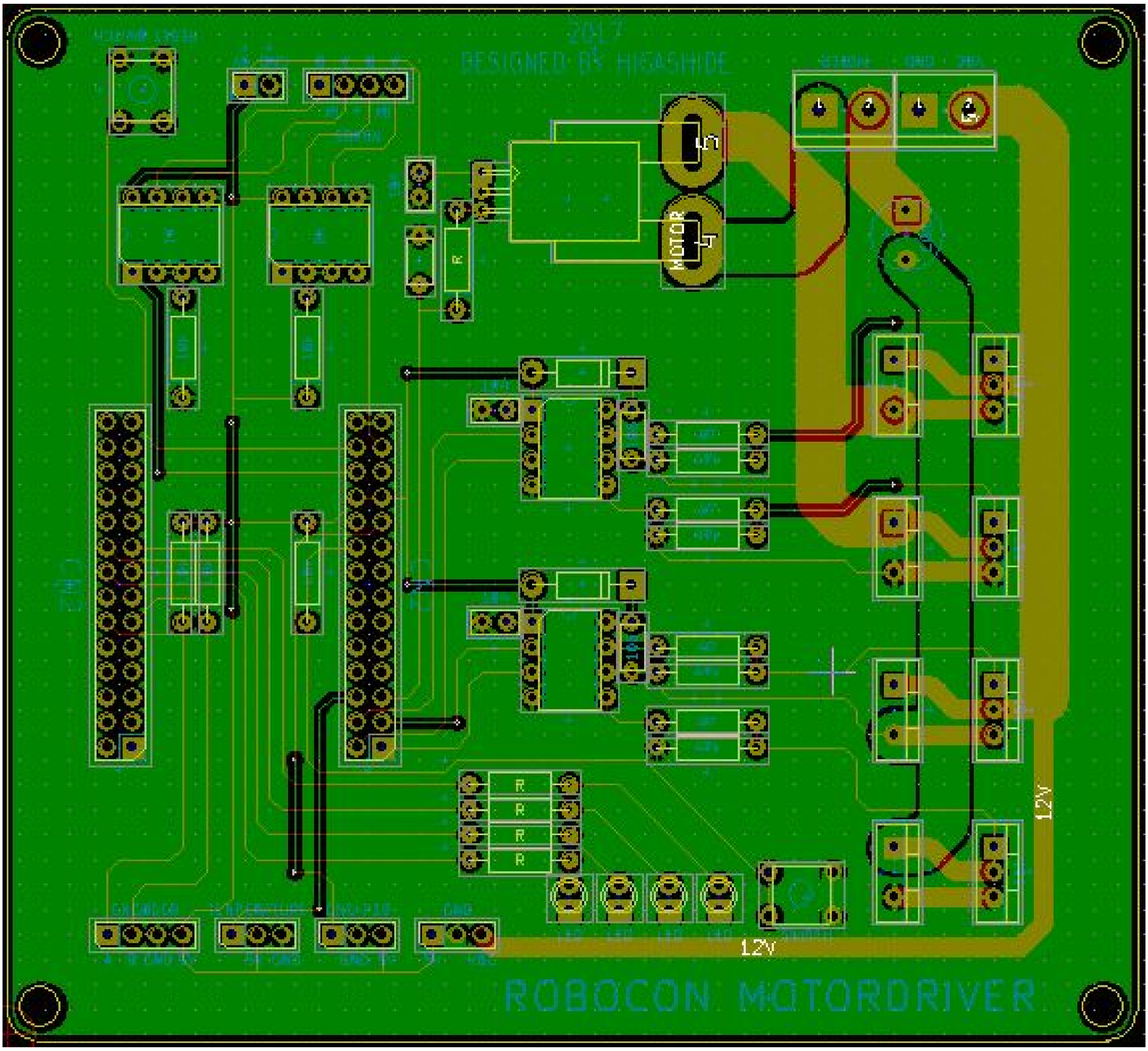

2017
DESIGNED BY HIGASHIDE
MOTOR
12V
12V
ROBOCON MOTORDRIVER

図 3.3　アートワーク図

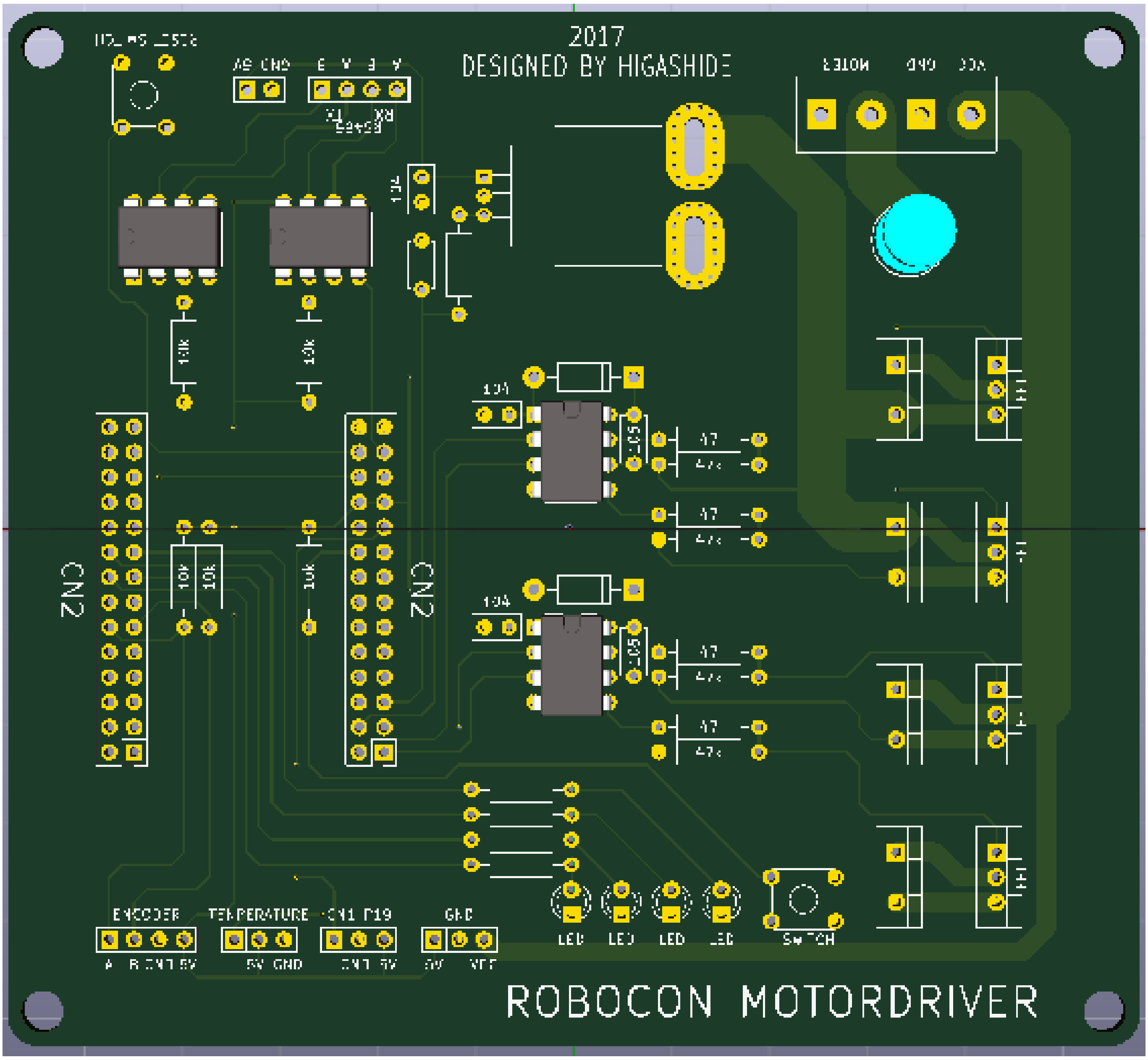


図 3.4　3D ビューア

3.4　完成品

ロボコン用高出力モータドライバの完成品を図 3.5 に, 組み付けたものを図 3.6 に示す. 基板の製作は,Fusion PCB に依頼した.

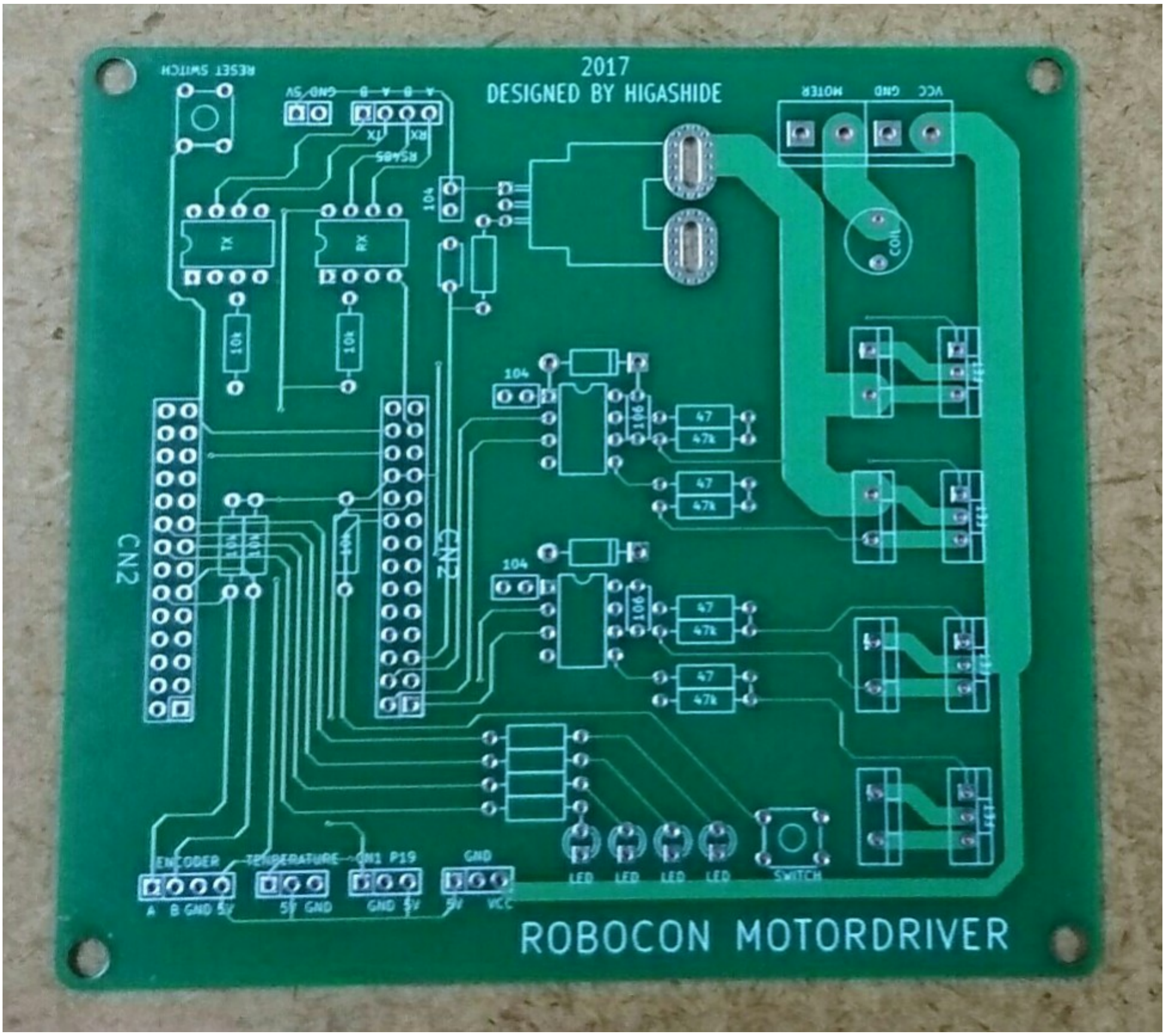

2017
DESIGNED BY HIGASHIDE
ROBOCON MOTORDRIVER
CN2
ENCODER
TEMPERATURE
SWITCH
LED

図 3.5　完成品

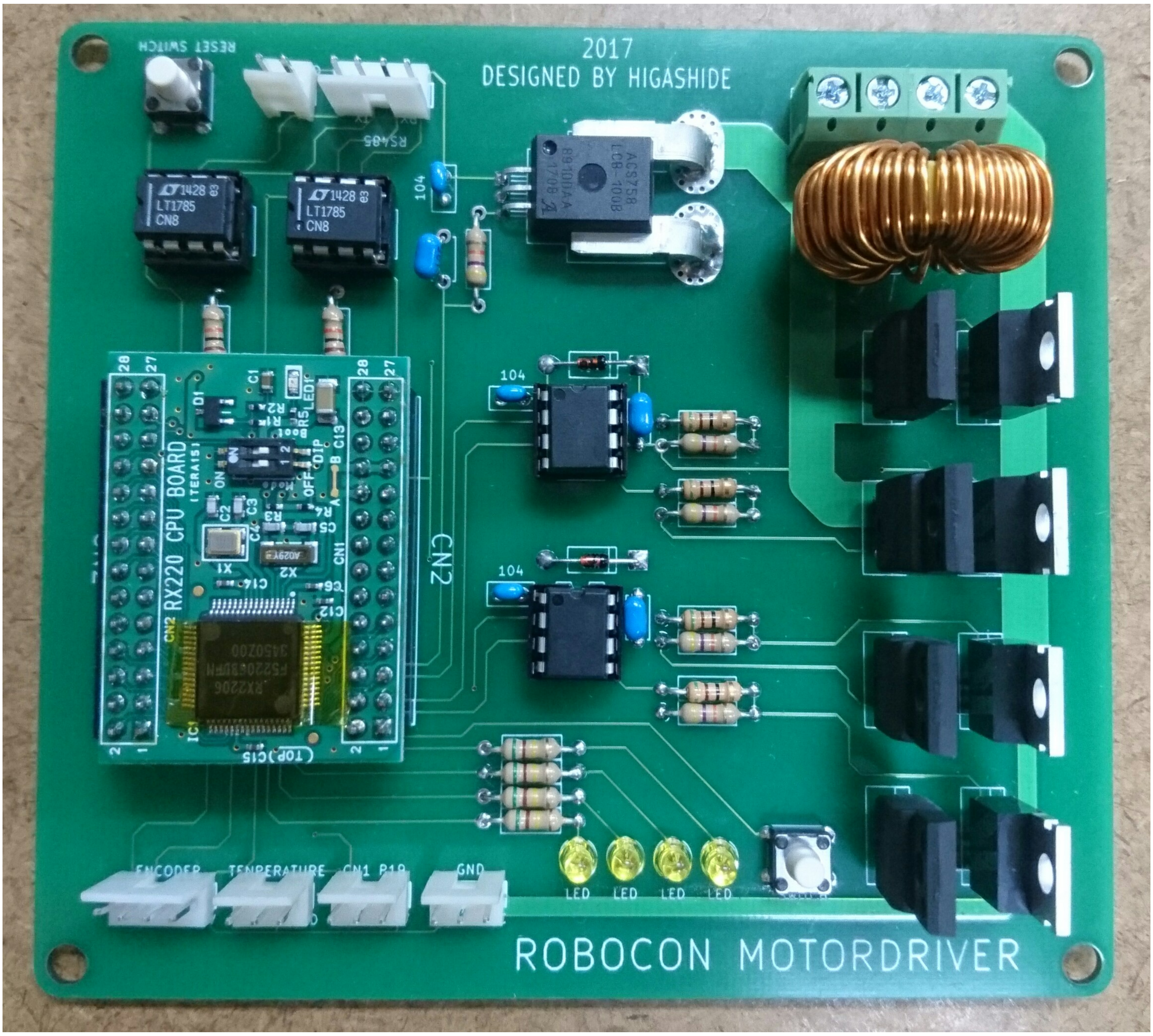


図 3.6　組み付け後

3.5　実機の動作実験

動作の確認として以下の実験を行った.

- LED が点灯するか
- 汎用スイッチが動作するか
- リセットスイッチで RX マイコンのリセットが可能か
- RX マイコンから PWM 信号の出力が可能か

3.6 実験結果

実験の結果,以下のようになった.

- 図 3.7 のように,LED の点灯を確認
- 汎用スイッチ動作を確認
- リセットスイッチでリセット確認
- PWM 信号の出力により,モータが回転することを確認

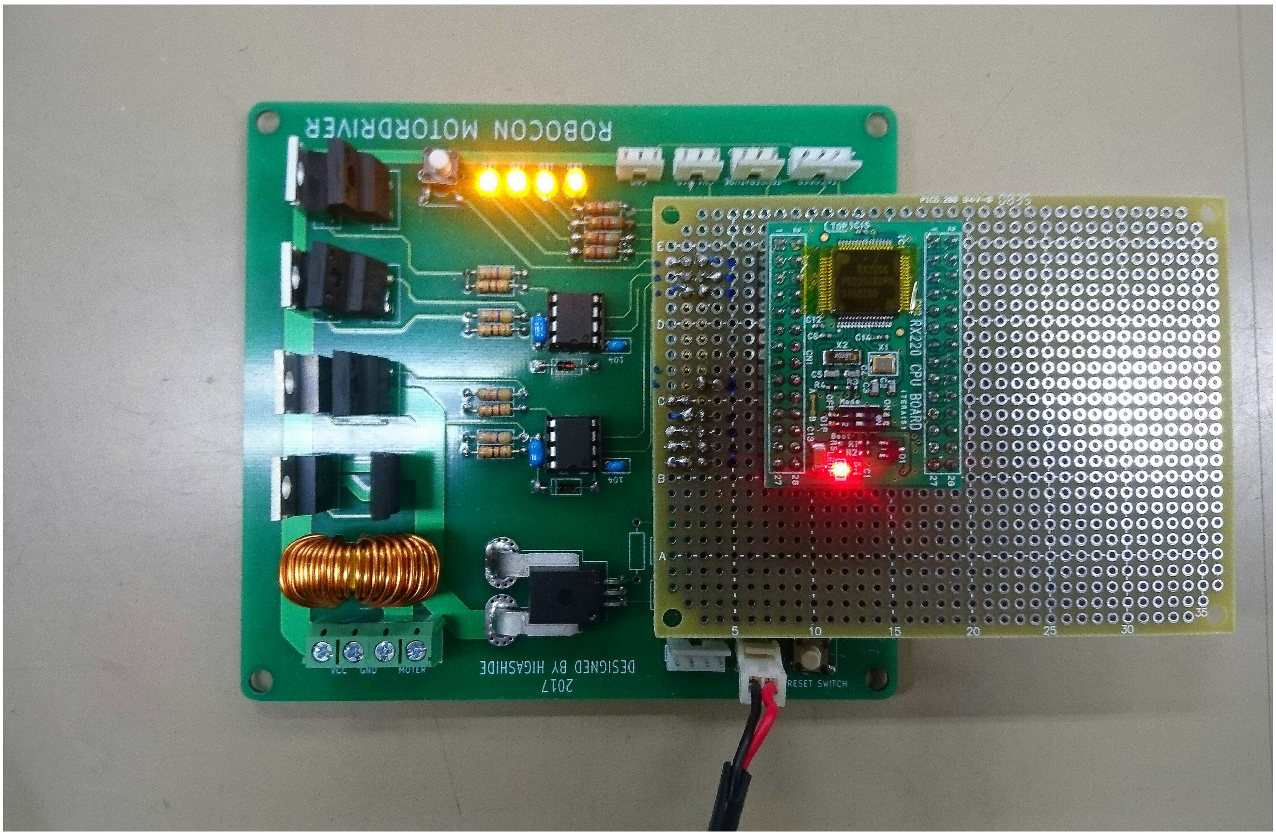


図 3.7 LED の点灯している高出力モータドライバ

3.7 考察

以上の結果から,配線の間違いはないことが分かる.また,モータが回転したことから,RX マイコンの PWM 信号でハーフブリッジドライバ,FET が問題なく機能していることが分かる.

第 4 章

おわりに

既存の ITOLAB MOTORDRIVER を基に改良することで, 短期間でモータドライバを製作することができた. また,KiCad を用いることで, 設計時間の短縮ができた.

今後, 電流センサ, 温度センサの検出値の確認,RX マイコンによるシリアル通信の確認が必要である.

謝辞

ロボット作成時に,知識の少ない電気分野を丁寧にご指導,サポートして下さった林道大教授,ロボット作成時に,予定が遅れていた時に喝を入れて下さったり本論文作成にあたり研究の考え方,方法のまとめ方などご指導,ご鞭撻していただいた伊藤恒平教授に厚く御礼申し上げます.

特に回路作成時に指導していただいたり,不得意なプログラムを助けて頂いた林道大教授に大変ご苦労をかけてしまいましたこと心よりお詫び申し上げます.

その他,助けていただいた多くの皆様に心から感謝しております.ありがとうございました.

参考文献

[1] 寺前裕司,1 人で始めるプリント基板作り [完全フリー Kicad 付き],CQ 出版株式会社,2014/7/1

[2] KiCAD で基本設計,http://www.kicad.xyz/

[3] KiCad で雑に基板を作るチュートリアル,https://www.slideshare.net/soburi/kicad-53622272

付録 A

ITOLABMOTORDRIVER 電子部品リスト

	部 品 名	型 番	PDF URL
1	4P,EI コネクタピンヘッダ	171825-4-50P	https://jp.misumi-ec.com/pdf/el/2015_H/0380.pdf
2	回生ダイオード	20ETS12FP	http://akizukidenshi.com/download/ds/vishay/vs20ets.pdf
3	ターミナルブロック	P-02333	http://akizukidenshi.com/download/ds/alphaplus/TB111-2-x-x-x-x.pdf
4	カーボン被膜抵抗 10k Ω	R-25103	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
5	カーボン被膜抵抗 47k Ω	R-25103	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
6	カーボン被膜抵抗 47 Ω	R-25470	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
7	汎用小信号高速 スイッチング・ダイオード	1N4148	http://akizukidenshi.com/download/1n4148.pdf
8	セラミックコンデンサ 0.1 μ	P-00090	http://akizukidenshi.com/download/ds/murata/RPEF11H104Z2P1A01B_a.pdf
9	セラミックコンデンサ 10 μ	P-03095	http://akizukidenshi.com/download/rd_series.pdf

10	ハーフブリッジドライバ 8-DIP	IR2302PBF	http://akizukidenshi.com/download/ds/ir/ir2302.pdf
11	ピンソケット 14 × 2P	c-03951	http://akizukidenshi.com/download/ds/kakusya/FH-2X00SG.pdf
12	RX200 マイコンボード	K-08769	http://akizukidenshi.com/download/ds/akizuki/RX220_CPU_Manual.pdf
13	トロイダルコイル 330 μ H9A	P-06731	http://akizukidenshi.com/download/ds/core/TCV-331M-9A-8026.pdf
14	Nch パワー MOSFET	EKI04047	http://akizukidenshi.com/download/ds/sanken/eki04047_ds_en.pdf

付録 B

新高出力モータドライバ 電子部品リスト

	部 品 名	型 番	PDF URL
1	4P,EI コ ネ ク タ ピ ン ヘ ッ ダ	171825-4-50P	https://jp.misumi-ec.com/pdf/el/2015_H/0380.pdf
2	回 生 ダ イ オ ー ド	20ETS12FP	http://akizukidenshi.com/download/ds/vishay/vs20ets.pdf
3	タ ー ミ ナ ル ブ ロ ッ ク	P-02333	http://akizukidenshi.com/download/ds/alphaplus/TB111-2-x-x-x-x.pdf
4	カ ー ボ ン 被 膜 抵 抗 10k Ω	R-25103	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
5	カ ー ボ ン 被 膜 抵 抗 47k Ω	R-25103	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
6	カ ー ボ ン 被 膜 抵 抗 47 Ω	R-25470	http://akizukidenshi.com/download/ds/faithful/R1_CF.pdf
7	汎 用 小 信 号 高 速 ス イ ッ チ ン グ・ダ イ オ ー ド	1N4148	http://akizukidenshi.com/download/1n4148.pdf
8	セ ラ ミ ッ ク コ ン デ ン サ 0.1 μ	P-00090	http://akizukidenshi.com/download/ds/murata/RPEF11H104Z2P1A01B_a.pdf
9	セ ラ ミ ッ ク コ ン デ ン サ 10 μ	P-03095	http://akizukidenshi.com/download/rd_series.pdf

10	ハーフブリッジドライバ 8-DIP	IR2302PBF	http://akizukidenshi.com/download/ds/ir/ir2302.pdf
11	ピンソケット 14 × 2P	c-03951	http://akizukidenshi.com/download/ds/kakusya/FH-2X00SG.pdf
12	RX200 マイコンボード	K-08769	http://akizukidenshi.com/download/ds/akizuki/RX220_CPU_Manual.pdf
13	トロイダルコイル 330 μ H9A	P-06731	http://akizukidenshi.com/download/ds/core/TCV-331M-9A-8026.pdf
14	Nch パワー MOSFET	EKI04047	http://akizukidenshi.com/download/ds/sanken/eki04047_ds_en.pdf
15	3mm 砲弾型 LED	I-09851	http://akizukidenshi.com/download/ds/lg/LEBWL34A06AA00.pdf
16	タクトスイッチ	TVDP01-060CB	http://akizukidenshi.com/download/ds/cosland/DTS-6-V.PDF
17	温度センサ	MCP9700	http://akizukidenshi.com/download/MCP9701-ETO.pdf
18	電流センサ	ACS758LCB-100B	https://www.digikey.jp/product-detail/ja/allegro-microsystems-llc/ACS758LCB-100B-PFF-T/620-1321-ND/2042746
19	RS485 トランシーバ	LT1785CN8	http://akizukidenshi.com/download/lt1785cn8.pdf

付録 C

ロボコン用高出力モータドライバ回路図

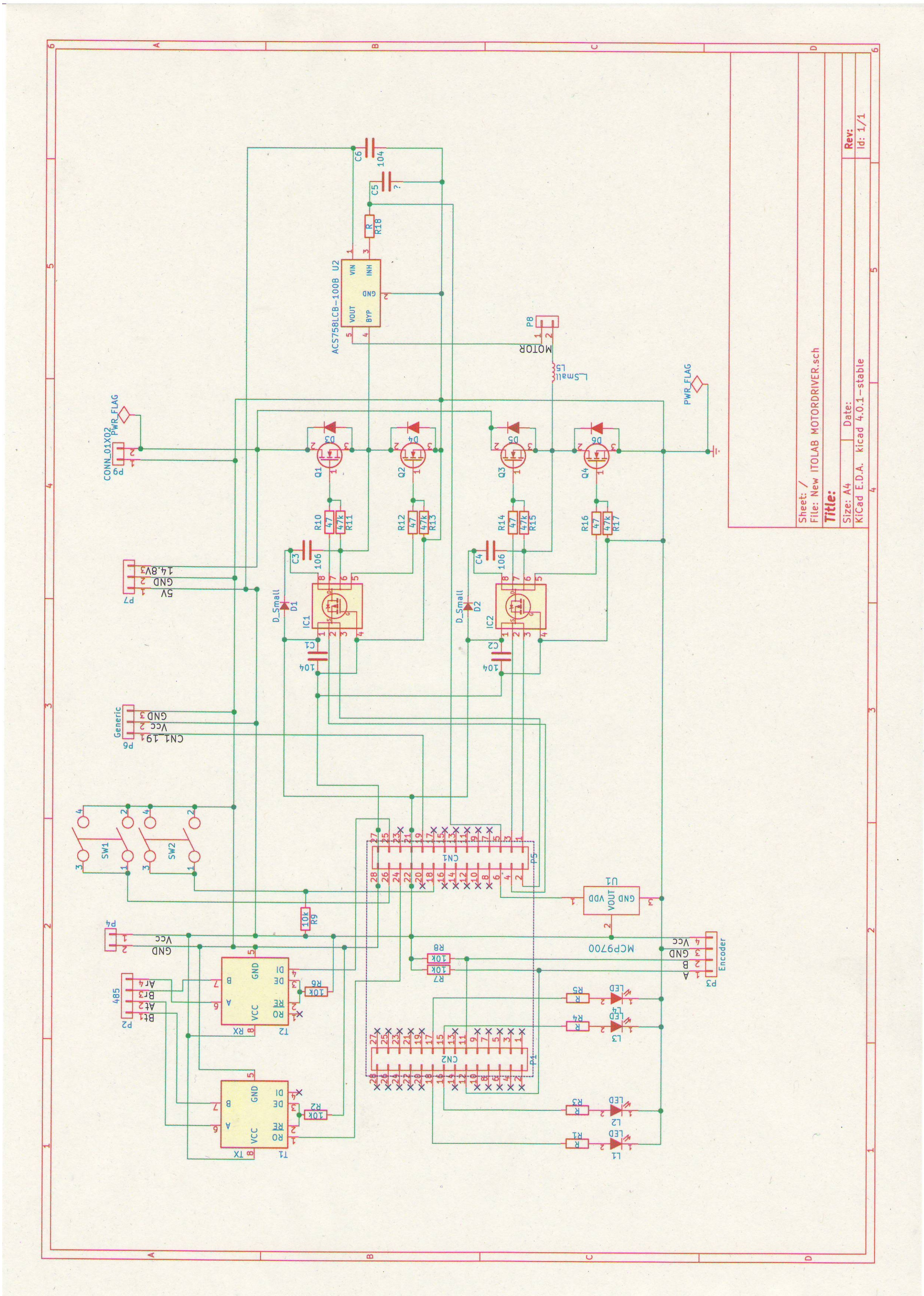

Sheet: /
File: New ITOLAB MOTORDRIVER.sch
Title:
Size: A4
Date:
KiCad E.D.A. kicad 4.0.1-stable
Rev:
Id: 1/1
ACS758LCB-100B U2
MOTOR
PWR_FLAG
CONN_01X02
MCP9700
Encoder
Generic
485
CN1
CN2
SW1
SW2

図 C.1　回路図

付録 D

RX マイコンと各部品との接続

ピン No.	ポート番号	接続先
CN1-1	P4-0(出力)	右ゲートローサイド
CN1-2	P4-1(出力)	左ゲートローサイド
CN1-3	P4-2(出力)	右ゲートハイサイド
CN1-4	P4-3(出力)	左ゲートハイサイド
CN1-5	P4-4(入力)	電流センサ
CN1-6	P4-6(入力)	温度センサ
CN1-18	PO-3(入力)	汎用スイッチ
CN1-19	PO-5(入力/出力)	汎用ポート
CN1-21		5V
CN1-22		5V
CN1-24	RS232(RXD)	TX 信号
CN1-25	RS232(TXD)	RX 信号
CN1-26	RES ＃	リセットスイッチ
CN1-27		GND
CN1-28		GND
CN2-11	MTCLKA	エンコーダ B
CN2-12	MTCLKB	エンコーダ A
CN2-15	PH-0(出力)	汎用 LED
CN2-16	PH-1(出力)	汎用 LED
CN2-17	PH-2(出力)	汎用 LED
CN2-18	PH-3(出力)	汎用 LED

付録 E

KiCad の使い方

1) KiCad の ホ ー ム か ら, 図 E.1 の よ う に 回 路 図 エ デ ィ タ を 開 く.

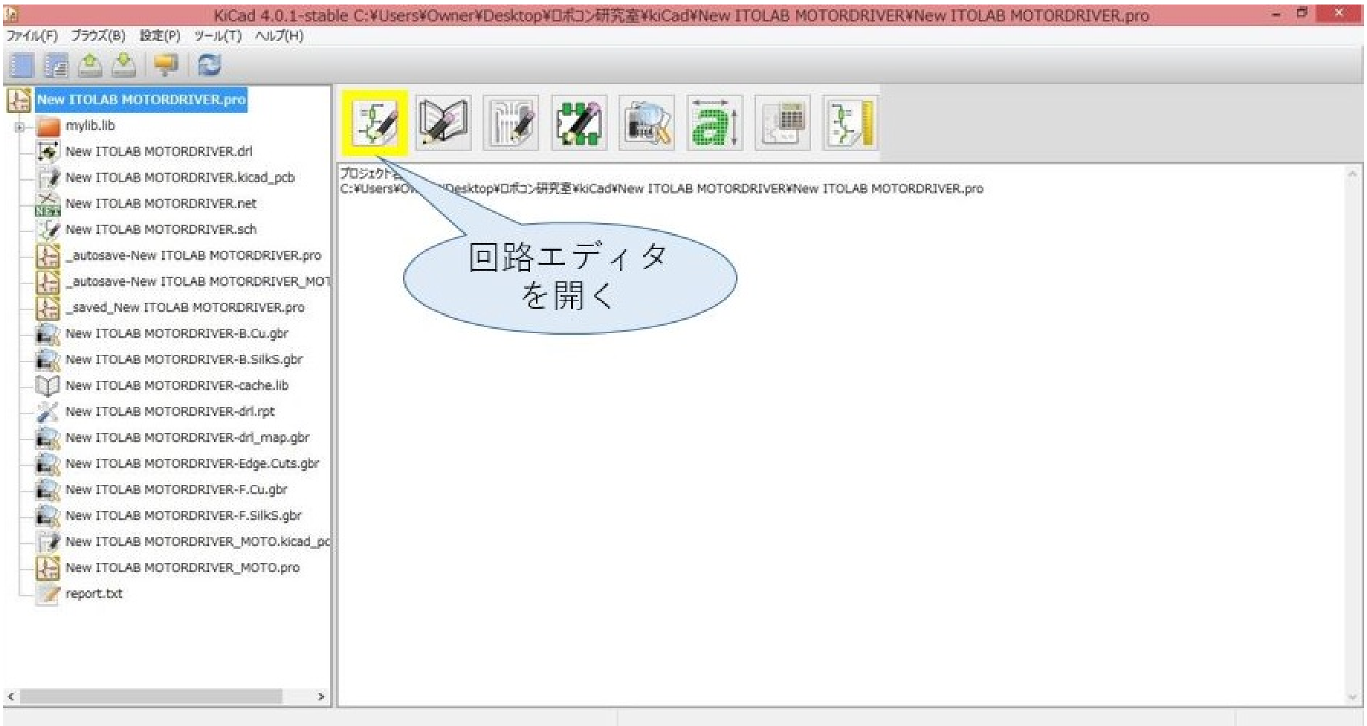


図 E.1　ホーム画面

2) 回 路 エ デ ィ タ で, 図 E.2 の よ う に 電 子 部 品, 電 源, 配 線 を 選 択 し て 回 路 図 を 作 成 す る.

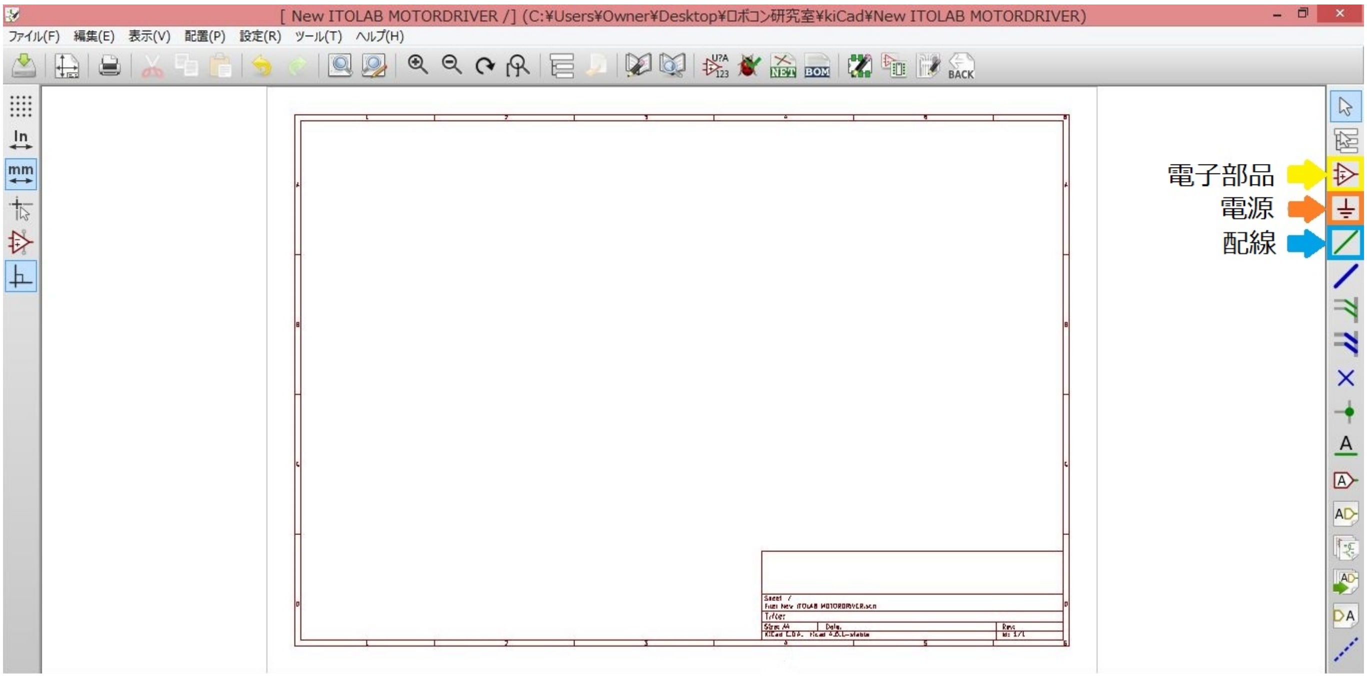


図 E.2　回路エディタ

3) 回 路 図 作 成 後, 図 E.3 の よ う に ネ ッ ト リ ス ト の 作 成 を 行 う.

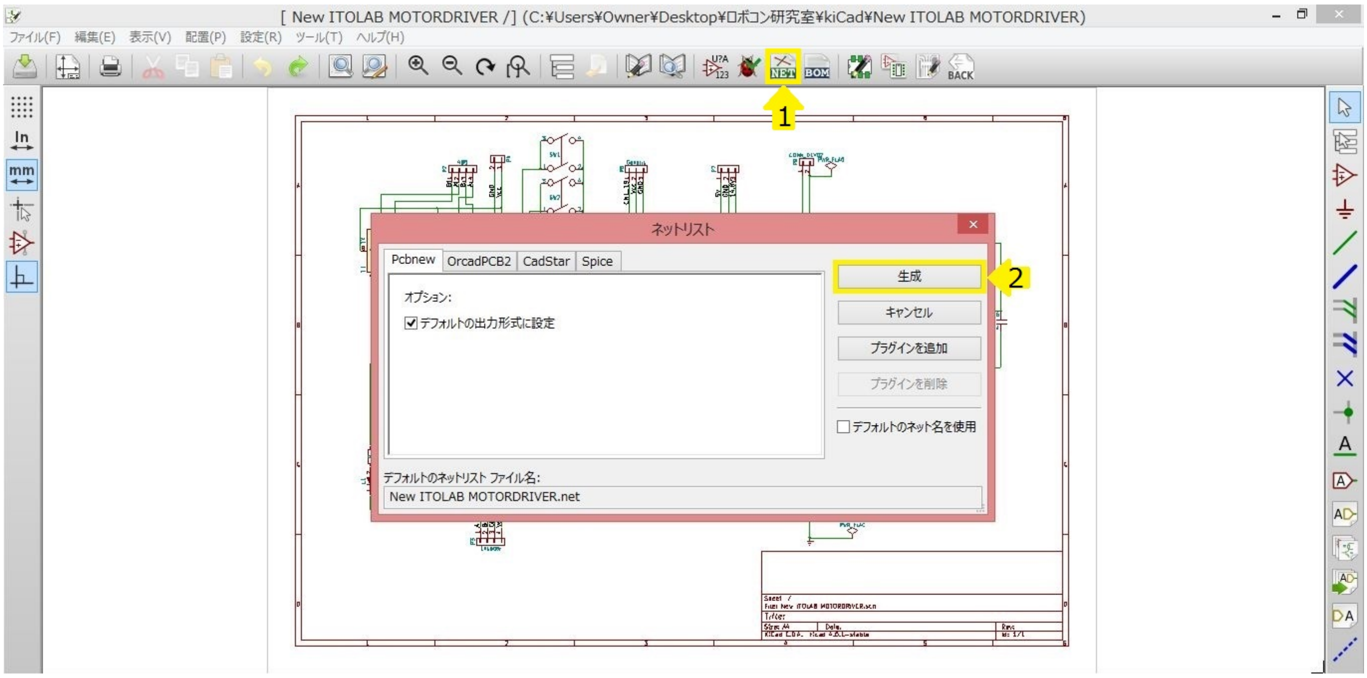


図 E.3　回路エディタ

4) 図 E.4 の よ う に し て コ ン ポ ー ネ ン ト と フ ッ ト プ リ ン ト の 関 連 付 け を 行 う.

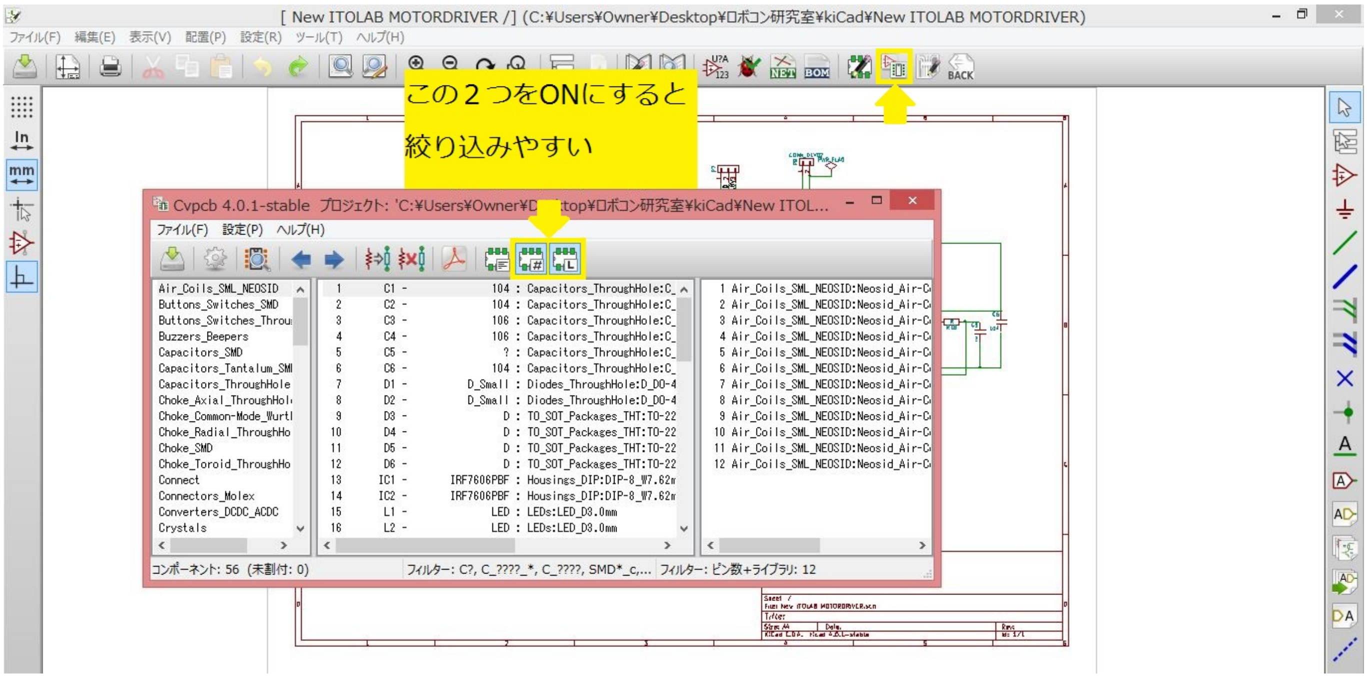


図 E.4　回路エディタ

5) 図 E.5 のように，アイコンをクリックしてプリント基板のレイアウトの実行を行う．

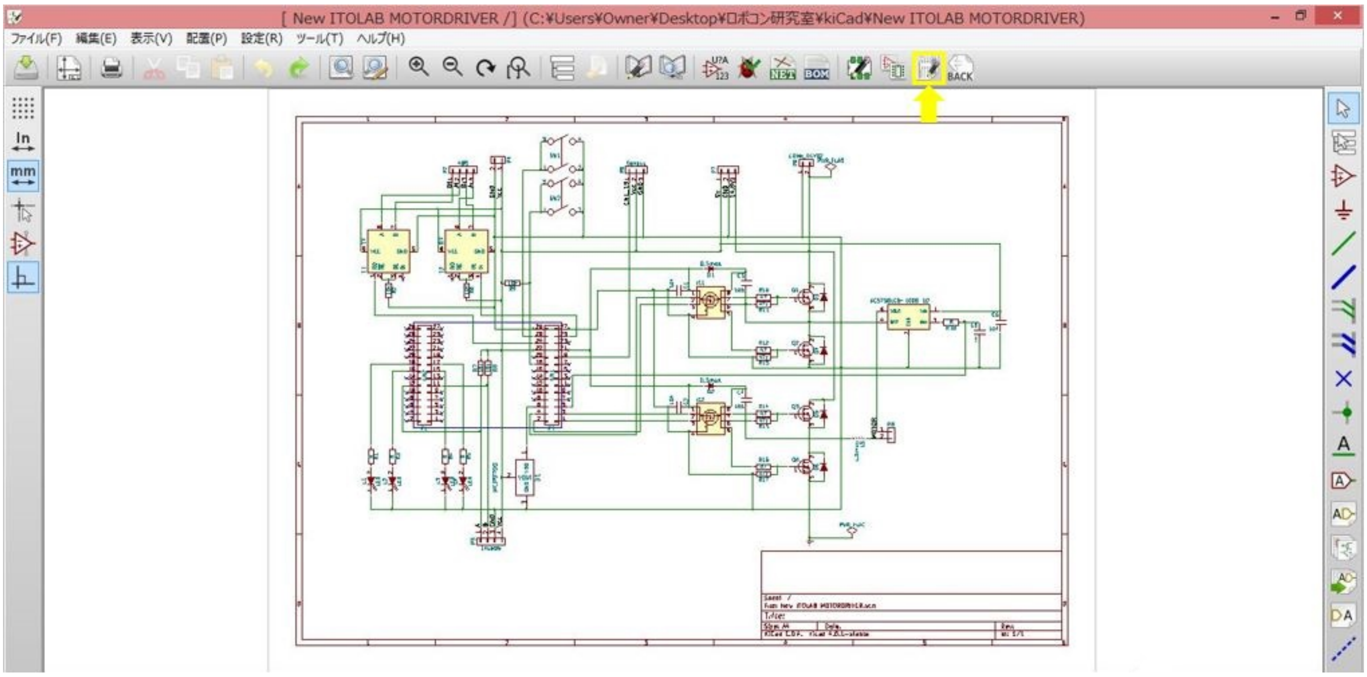


図 E.5　基板レイアウトの実行

6) 図 E.6 のようにして，ネットリストを読み込む．

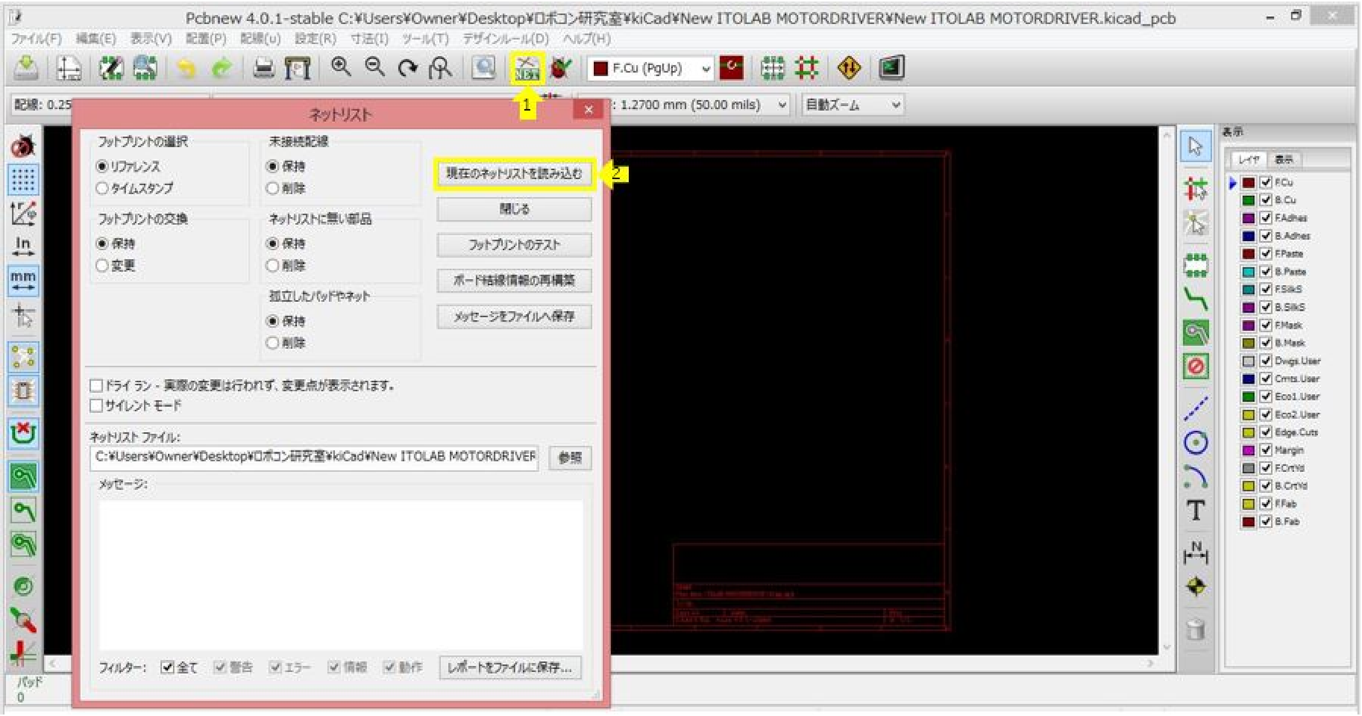


図 E.6　ネットリストの読み込み

7) 図 E.7 の よ う に 部 品 が 表 示 さ れ る の で, 部 品 を き れ い に 配 置 す る.

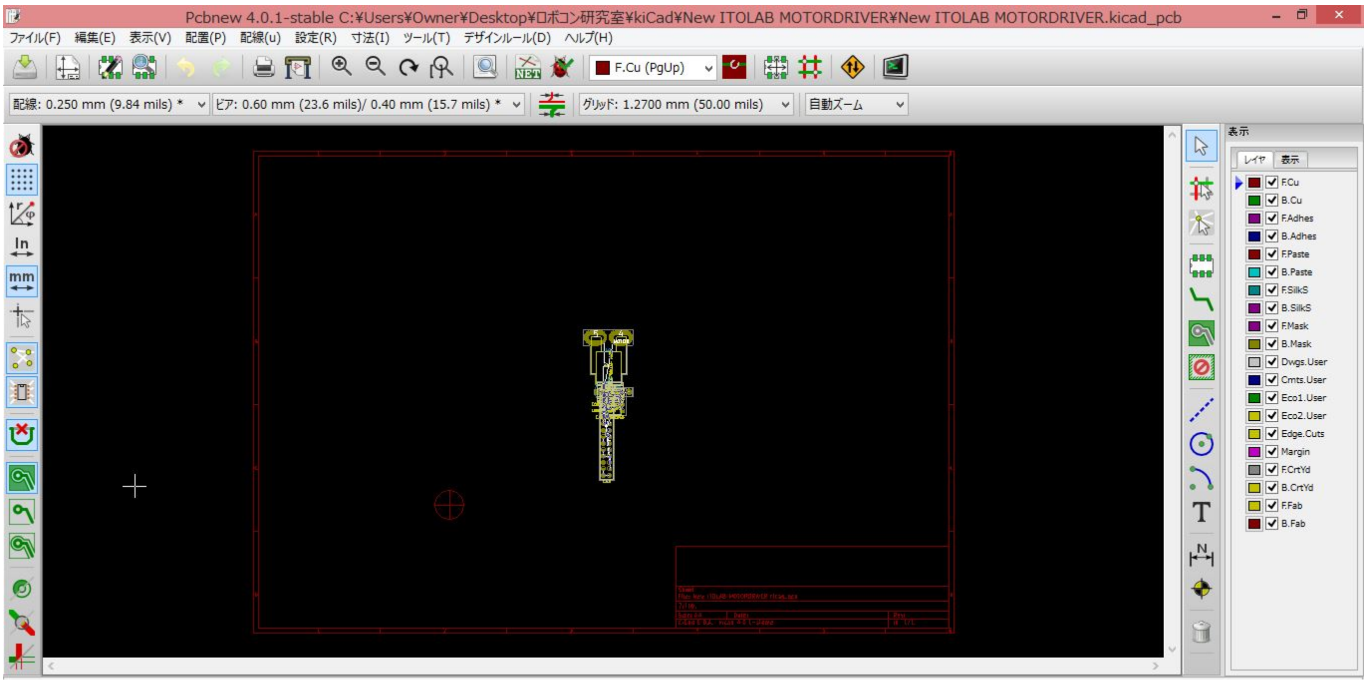


図 E.7　表示された部品

8) 図 E.8 の よ う に, 配 線, 基 板 枠 の 作 成 を 行 う.

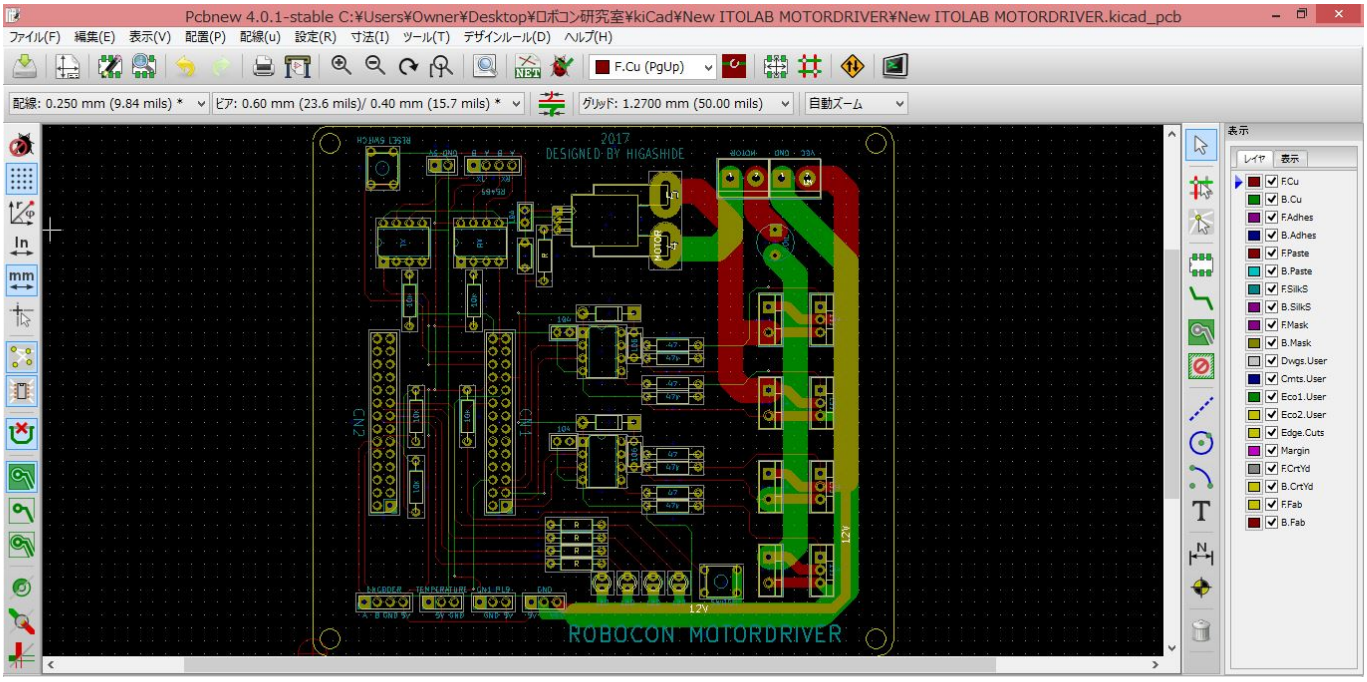


図 E.8　配線後

9) 図 E.9 の よ う に,GND を ベ タ に す る.

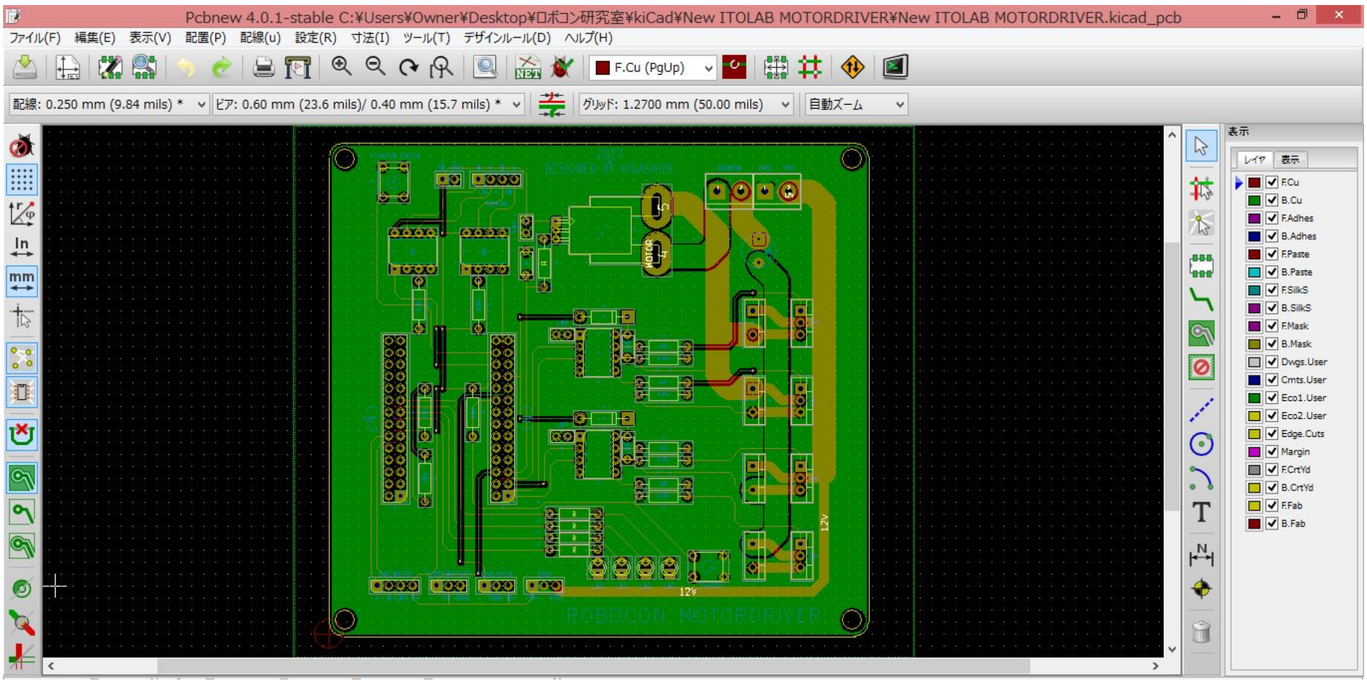


図 E.9　GND ベタ

付録 F

温度センサのデータシート

MCP9700/9700A
MCP9701/9701A

Low-Power Linear Active Thermistor™ ICs

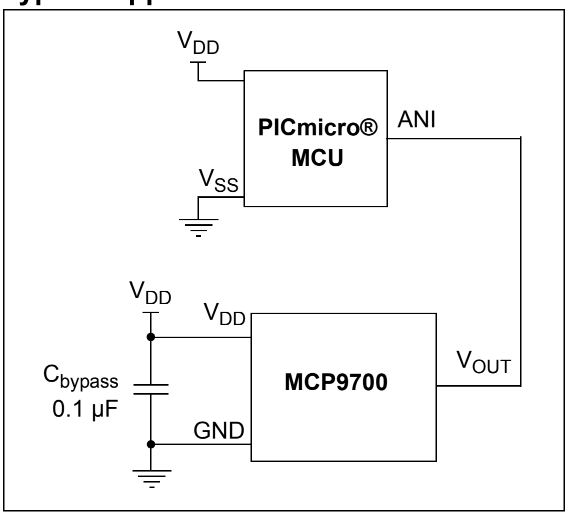
Features

- Tiny Analog Temperature Sensor
- Available Packages: SC-70-5, TO-92-3
- Wide Temperature Measurement Range:
  - -40°C to +125°C
- Accuracy:
  - ±2°C (max.), 0°C to +70°C (**MCP9700A/9701A)**
  - ±4°C (max.), 0°C to +70°C (**MCP9700/9701**)
- Optimized for Analog-to-Digital Converters (ADCs):
  - 10.0 mV/°C (typ.) **MCP9700/9700A**
  - 19.5 mV/°C (typ.) **MCP9701/9701A**
- Wide Operating Voltage Range:
  - V_{DD} = 2.3V to 5.5V **MCP9700/9700A**
  - V_{DD} = 3.1V to 5.5V **MCP9701/9701A**
- Low Operating Current: 6 µA (typ.)
- Optimized to Drive Large Capacitive Loads

Typical Applications

- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Home Appliance
- Office Equipment
- Battery Packs and Portable Equipment
- General Purpose Temperature Monitoring

Typical Application Circuit



Description

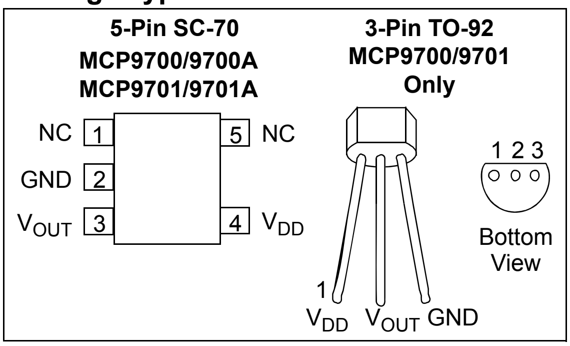
The MCP9700/9700A and MCP9701/9701A family of Linear Active Thermistor™ Intergrated Circuit (IC) is an analog temperature sensor that converts temperature to analog voltage. It's a low-cost, low-power sensor with an accuracy of ±2°C from 0°C to +70°C (MCP9700A/9701A) ±4°C from 0°C to +70°C (MCP9700/9701) while consuming 6 µA (typ.) of operating current.

Unlike resistive sensors (such as thermistors), the Linear Active Thermistor IC does not require an additional signal-conditioning circuit. Therefore, the biasing circuit development overhead for thermistor solutions can be avoided by implementing this low-cost device. The voltage output pin (V_{OUT}) can be directly connected to the ADC input of a microcontroller. The MCP9700/9700A and MCP9701/9701A temperature coefficients are scaled to provide a 1°C/bit resolution for an 8-bit ADC with a reference voltage of 2.5V and 5V, respectively.

The MCP9700/9700A and MCP9701/9701A provide a low-cost solution for applications that require measurement of a relative change of temperature. When measuring relative change in temperature from +25°C, an accuracy of ±1°C (typ.) can be realized from 0°C to +70°C. This accuracy can also be achieved by applying system calibration at +25°C.

In addition, this family is immune to the effects of parasitic capacitance and can drive large capacitive loads. This provides Printed Circuit Board (PCB) layout design flexibility by enabling the device to be remotely located from the microcontroller. Adding some capacitance at the output also helps the output transient response by reducing overshoots or undershoots. However, capacitive load is not required for sensor output stability.

Package Type



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD}:.. 6.0V

Storage temperature: .... -65°C to +150°C

Ambient Temp. with Power Applied:.. -40°C to +125°C

Junction Temperature (T_J):................................. 150°C

ESD Protection On All Pins (HBM:MM):.... (4 kV:200V)

Latch-Up Current at Each Pin: .... ±200 mA

†Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameter	Sym	Min	Typ	Max	Unit	Conditions
Power Supply						
Operating Voltage Range	V_{DD} V_{DD}	2.3 3.1	— —	5.5 5.5	V V	**MCP9700/9700A** **MCP9701/9701A**
Operating Current	I_{DD}	—	6	12	µA	
Power Supply Rejection	Δ°C/ΔV_{DD}	—	0.1	—	°C/V	
Sensor Accuracy (Notes 1, 2)						
T_A = +25°C	T_{ACY}	—	±1	—	°C	
T_A = 0°C to +70°C	T_{ACY}	-2.0	—	+2.0	°C	**MCP9700A/9701A**
T_A = -40°C to +125°C	T_{ACY}	-2.0	—	+4.0	°C	**MCP9700A**
T_A = -10°C to +125°C	T_{ACY}	-2.0	—	+4.0	°C	**MCP9701A**
T_A = 0°C to +70°C	T_{ACY}	-4.0	—	+4.0	°C	**MCP9700/9701**
T_A = -40°C to +125°C	T_{ACY}	-4.0	—	+6.0	°C	**MCP9700**
T_A = -10°C to +125°C	T_{ACY}	-4.0	—	+6.0	°C	**MCP9701**
Sensor Output						
Output Voltage, T_A = 0°C	$V_{0°C}$	—	500	—	mV	**MCP9700/9700A**
Output Voltage, T_A = 0°C	$V_{0°C}$	—	400	—	mV	**MCP9701/9701A**
Temperature Coefficient	T_C	—	10.0	—	mV/°C	**MCP9700/9700A**
	T_C	—	19.5	—	mV/°C	**MCP9701/9701A**
Output Non-linearity	V_{ONL}	—	±0.5	—	°C	T_A = 0°C to +70°C **(Note 2)**
Output Current	I_{OUT}	—	—	100	µA	
Output Impedance	Z_{OUT}	—	20	—	Ω	I_{OUT} = 100 µA, f = 500 Hz
Output Load Regulation	ΔV_{OUT}/ ΔI_{OUT}	—	1	—	Ω	T_A = 0°C to +70°C, I_{OUT} = 100 µA

Note 1: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.

2: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2.

3: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.

4: SC-70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

DC ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameter	Sym	Min	Typ	Max	Unit	Conditions
Turn-on Time	t_{ON}	—	800	—	µs	
Typical Load Capacitance (**Note 3**)	C_{LOAD}	—	—	1000	pF	
SC-70 Thermal Response to 63%	t_{RES}	—	1.3	—	s	30°C (Air) to +125°C (Fluid Bath) (**Note 4**)
TO-92 Thermal Response to 63%	t_{RES}	—	1.65	—	s	

Note 1: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.

2: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2.

3: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.

4: SC-70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+125	°C	**MCP9700/9700A** (**Note**)
	T_A	-10	—	+125	°C	**MCP9701/9701A** (**Note**)
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, SC-70-5	θ_{JA}	—	331	—	°C/W	
Thermal Resistance, TO-92-3	θ_{JA}	—	131.9	—	°C/W	

Note: Operation in this range must not cause T_J to exceed Maximum Junction Temperature (+150°C).

2.0 TYPICAL PERFORMANCE CURVES

> **Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

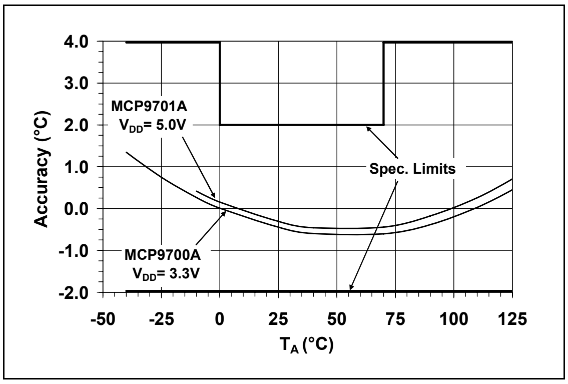


FIGURE 2-1: Accuracy vs. Ambient Temperature (MCP9700A/9701A).

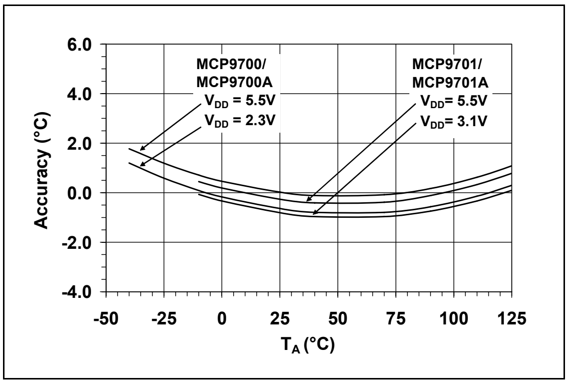


FIGURE 2-2: Accuracy vs. Ambient Temperature, with V_{DD}.

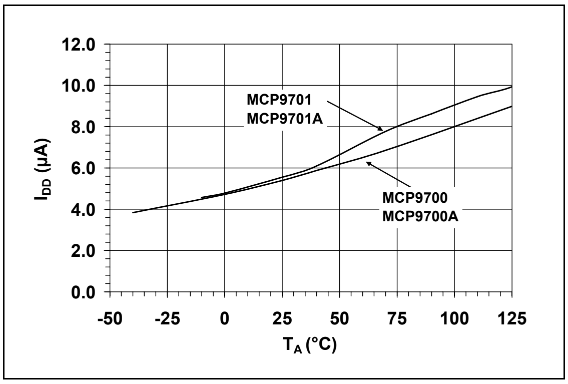


FIGURE 2-3: Supply Current vs. Temperature.

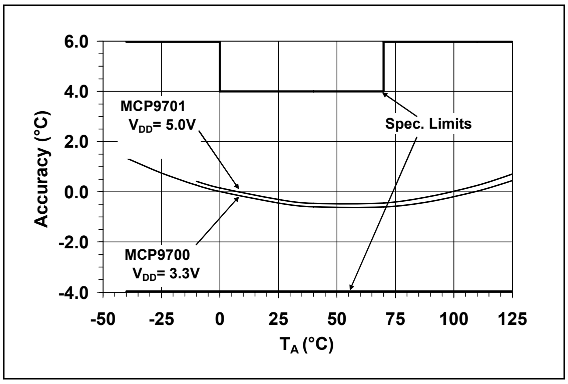


FIGURE 2-4: Accuracy vs. Ambient Temperature (MCP9700/9701).

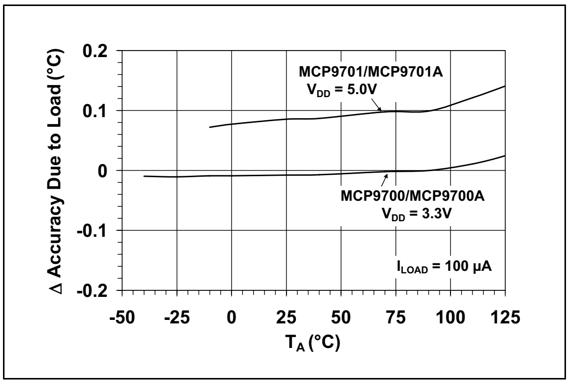


FIGURE 2-5: Changes in Accuracy vs. Ambient Temperature (Due to Load).

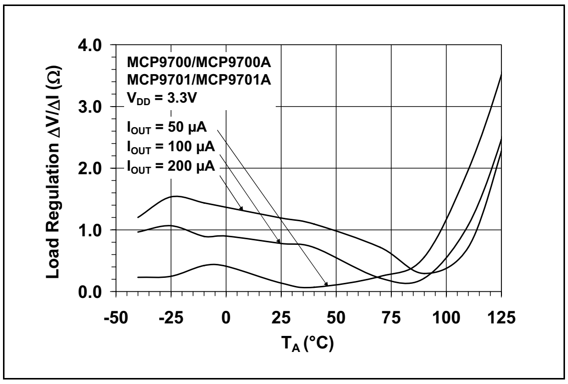


FIGURE 2-6: Load Regulation vs. Ambient Temperature.

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

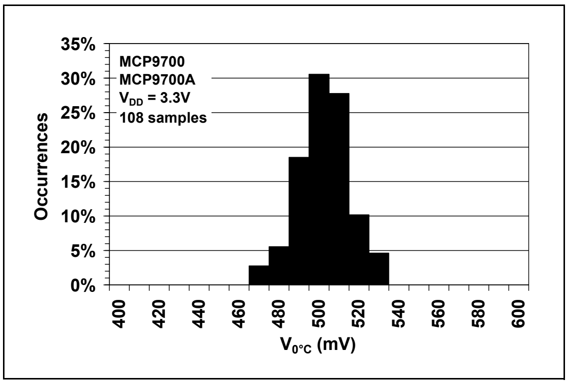


FIGURE 2-7: *Output Voltage at 0°C (MCP9700/9700A).*

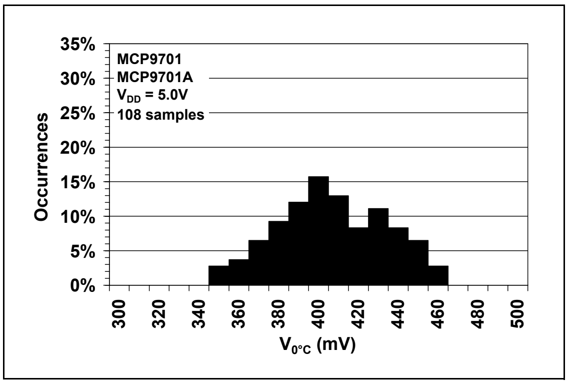


FIGURE 2-10: *Output Voltage at 0°C (MCP9701/9701A).*

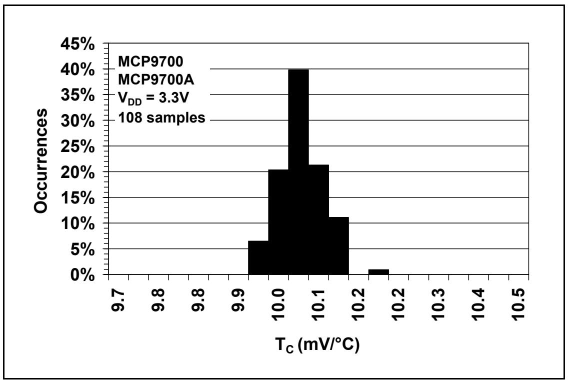


FIGURE 2-8: *Occurrences vs. Temperature Coefficient (MCP9700/9700A).*

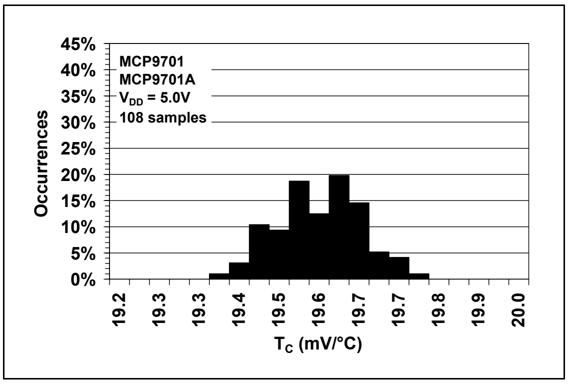


FIGURE 2-11: *Occurrences vs. Temperature Coefficient (MCP9701/9701A).*

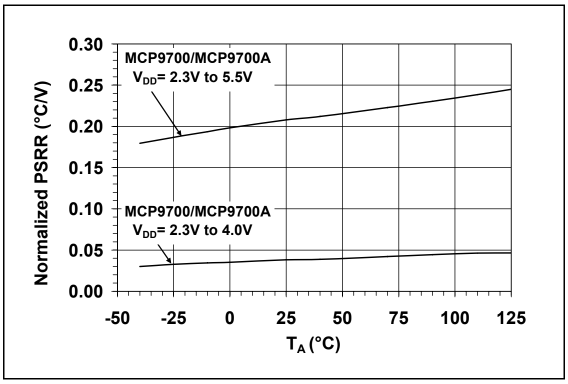


FIGURE 2-9: *Power Supply Rejection (Δ°C/ΔV_{DD}) vs. Ambient Temperature.*

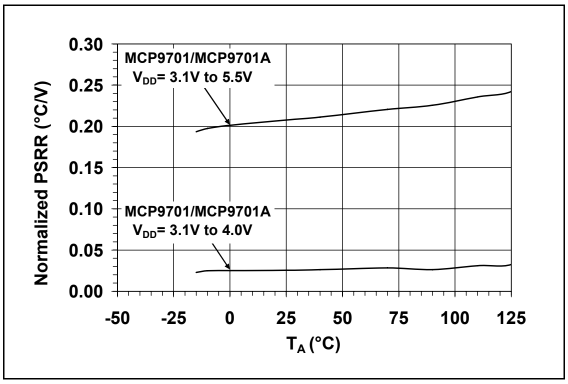


FIGURE 2-12: *Power Supply Rejection (Δ°C/ΔV_{DD}) vs. Temperature.*

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

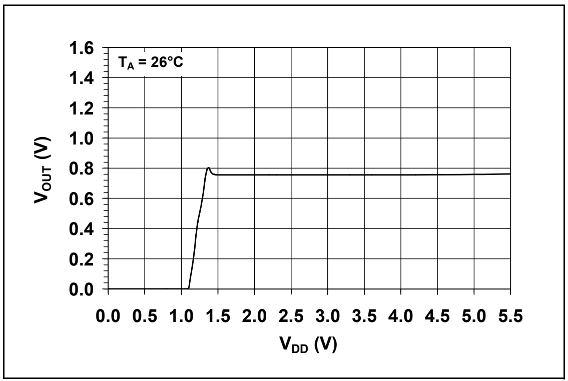


FIGURE 2-13: *Output Voltage vs. Power Supply.*

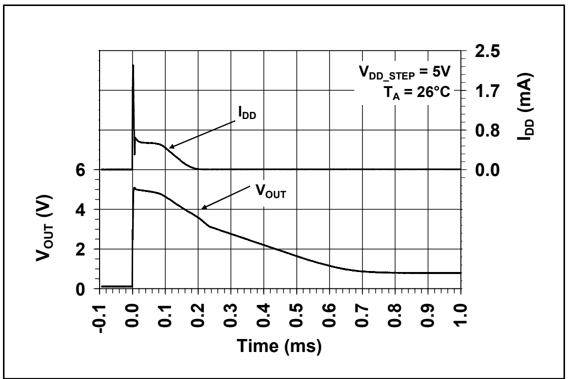


FIGURE 2-14: *Output vs. Settling Time to step V_{DD}.*

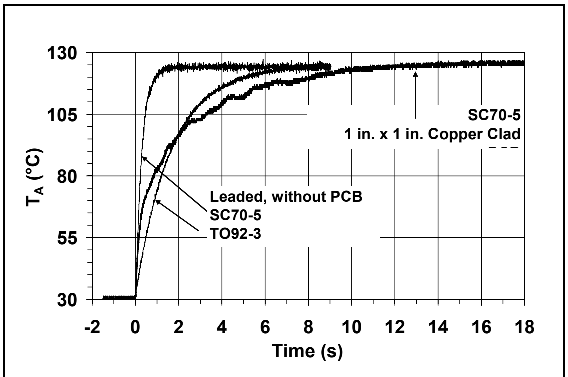


FIGURE 2-15: *Thermal Response (Air to Fluid Bath).*

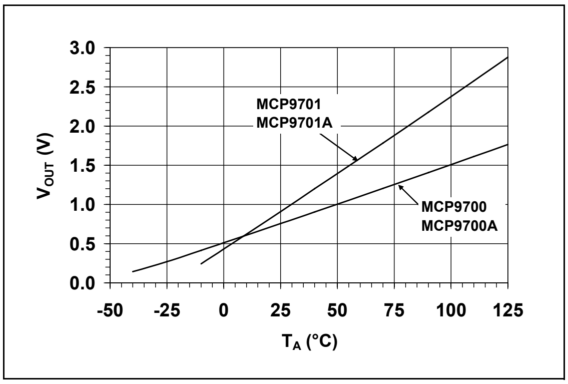


FIGURE 2-16: *Output Voltage vs. Ambient Temperature.*

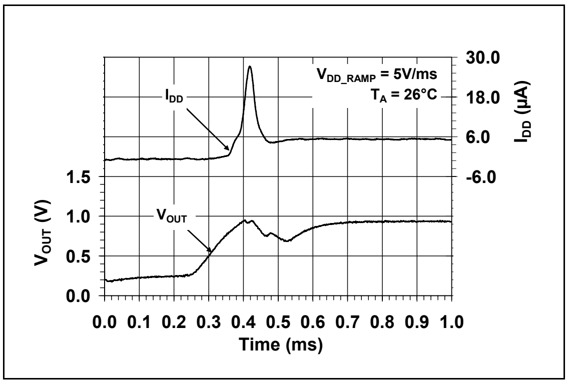


FIGURE 2-17: *Output vs. Settling Time to Ramp V_{DD}.*

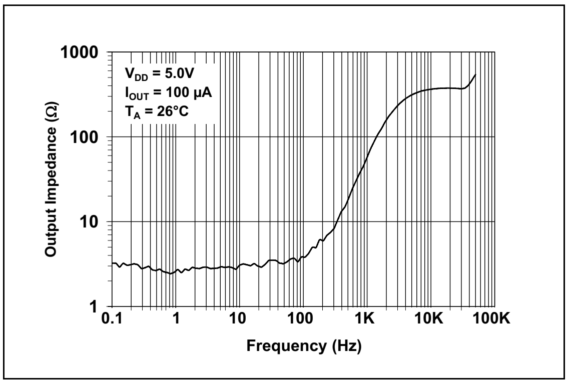


FIGURE 2-18: *Output Impedance vs. Frequency.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin No. SC-70	Pin No. TO-92	Symbol	Function
1	—	NC	No Connect
2	3	GND	Power Ground Pin
3	2	V_{OUT}	Output Voltage Pin
4	1	V_{DD}	Power Supply Input
5	—	NC	No Connect

3.1 Power Ground Pin (GND)

GND is the system ground pin.

3.2 Output Voltage Pin (V_{OUT})

The sensor output can be measured at V_{OUT}. The voltage range over the operating temperature range for the MCP9700/9700A is 100 mV to 1.75V and for the MCP9701/9701A, 200 mV to 3V .

3.3 Power Supply Input (V_{DD})

The operating voltage as specified in the **“DC Electrical Characteristics”** table is applied to V_{DD}.

4.0 APPLICATIONS INFORMATION

The Linear Active Thermistor™ IC uses an internal diode to measure temperature. The diode electrical characteristics have a temperature coefficient that provides a change in voltage based on the relative ambient temperature from -40°C to 125°C. The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typ.) for the MCP9700/9700A and 19.5 mV/°C (typ.) for the MCP9701/9701A. The output voltage at 0°C is also scaled to 500 mV (typ.) and 400 mV (typ.) for the MCP9700/9700A and MCP9701/9701A, respectively. This linear scale is described in the first-order transfer function shown in Equation 4-1.

EQUATION 4-1: SENSOR TRANSFER FUNCTION

$$V_{OUT} = T_C \bullet T_A + V_{0°C}$$

Where:

T_A = Ambient Temperature
V_{OUT} = Sensor Output Voltage
$V_{0°C}$ = Sensor Output Voltage at 0°C
T_C = Temperature Coefficient

4.1 Improving Accuracy

The MCP9700/9700A and MCP9701/9701A accuracy can be improved by performing a system calibration at a specific temperature. For example, calibrating the system at +25°C ambient improves the measurement accuracy to a ±0.5°C (typ.) from 0°C to +70°C, as shown in Figure 4-1. Therefore, when measuring relative temperature change, this family measures temperature with higher accuracy.

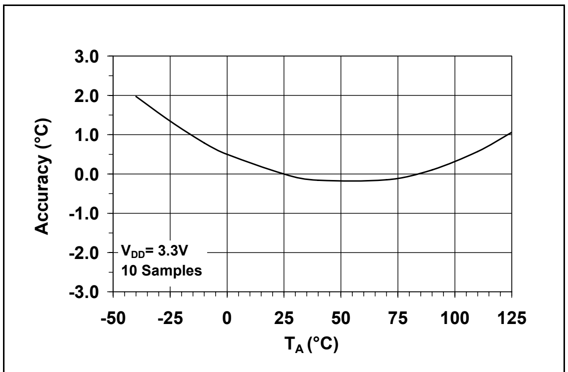


FIGURE 4-1: *Relative Accuracy to +25°C vs. Temperature.*

The change in accuracy from the calibration temperature is due to the output non-linearity from the first-order equation, as specified in Equation 4-2. The accuracy can be further improved by compensating for the output non-linearity.

For higher accuracy using a sensor compensation technique, refer to AN1001 *"IC Temperature Sensor Accuracy Compensation with a PICmicro® Microcontroller"* (DS01001). The application note shows that if the MCP9700 is compensated in addition to room temperature calibration, the sensor accuracy can be improved to ±0.5°C (typ.) accuracy over the operating temperature (Figure 4-2).

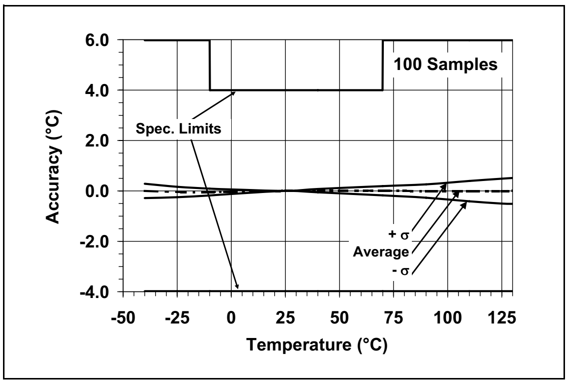


FIGURE 4-2: *MCP9700/9700A Calibrated Sensor Accuracy.*

The compensation technique provides a linear temperature reading. A firmware look-up table can be generated to compensate for the sensor error.

4.2 Shutdown Using Microcontroller I/O Pin

The MCP9700/9700A and MCP9701/9701A family of low operating current of 6 µA (typ.) makes it ideal for battery-powered applications. However, for applications that require tighter current budget, this device can be powered using a microcontroller Input/Output (I/O) pin. The I/O pin can be toggled to shut down the device. In such applications, the microcontroller internal digital switching noise is emitted to the MCP9700/9700A and MCP9701/9701A as power supply noise. This switching noise compromises measurement accuracy. Therefore, a decoupling capacitor and series resistor will be necessary to filter out the system noise.

4.3 Layout Considerations

The MCP9700/9700A and MCP9701/9701A family does not require any additional components to operate. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. In high-noise applications, connect the power supply voltage to the V_{DD} pin using a 200Ω resistor with a 1 µF decoupling capacitor. A high frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the V_{DD} and GND pins in order to provide effective noise protection. In addition, avoid tracing digital lines in close proximity to the sensor.

4.4 Thermal Considerations

The MCP9700/9700A and MCP9701/9701A family measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the sensor effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator from the die. However, the plastic device package insulates the die and restricts device thermal response. This limitation applies to plastic-packaged silicon temperature sensors. If the application requires measuring ambient air, the PCB needs to be designed with proper thermal conduction to the sensor pins.

The MCP9700/9700A and MCP9701/9701A is designed to source/sink 100 µA (max.). The power dissipation due to the output current is relatively insignificant. The effect of the output current can be described using Equation 4-2.

EQUATION 4-2: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD}I_{DD} + (V_{DD} - V_{OUT})I_{OUT})$$

Where:

T_J = Junction Temperature

T_A = Ambient Temperature

θ_{JA} = Package Thermal Resistance (331°C/W)

V_{OUT} = Sensor Output Voltage

I_{OUT} = Sensor Output Current

I_{DD} = Operating Current

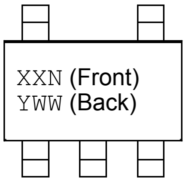
V_{DD} = Operating Voltage

At T_A = +25°C (V_{OUT} = 0.75V) and maximum specification of I_{DD} = 12 µA, V_{DD} = 5.5V and I_{OUT} = +100 µA, the self-heating due to power dissipation ($T_J – T_A$) is 0.179°C.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

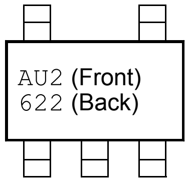
5-Lead SC-70 (**MCP9700/MCP9700A**)



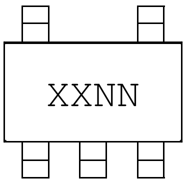
Device	Code
MCP9700/9700A	AUN
MCP9701/9701A	AVN

Note: Applies to 5-Lead SC-70.

Example:



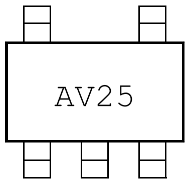
5-Lead SC-70 (**MCP9701/MCP9701A**)



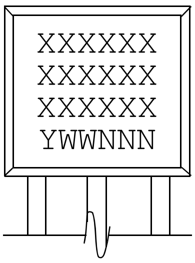
Device	Code
MCP9700/9700A	AUNN
MCP9701/9701A	AVNN

Note: Applies to 5-Lead SC-70.

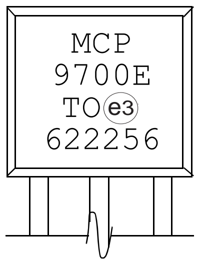
Example:



3-Lead TO-92 (**MCP9700/MCP9701**)



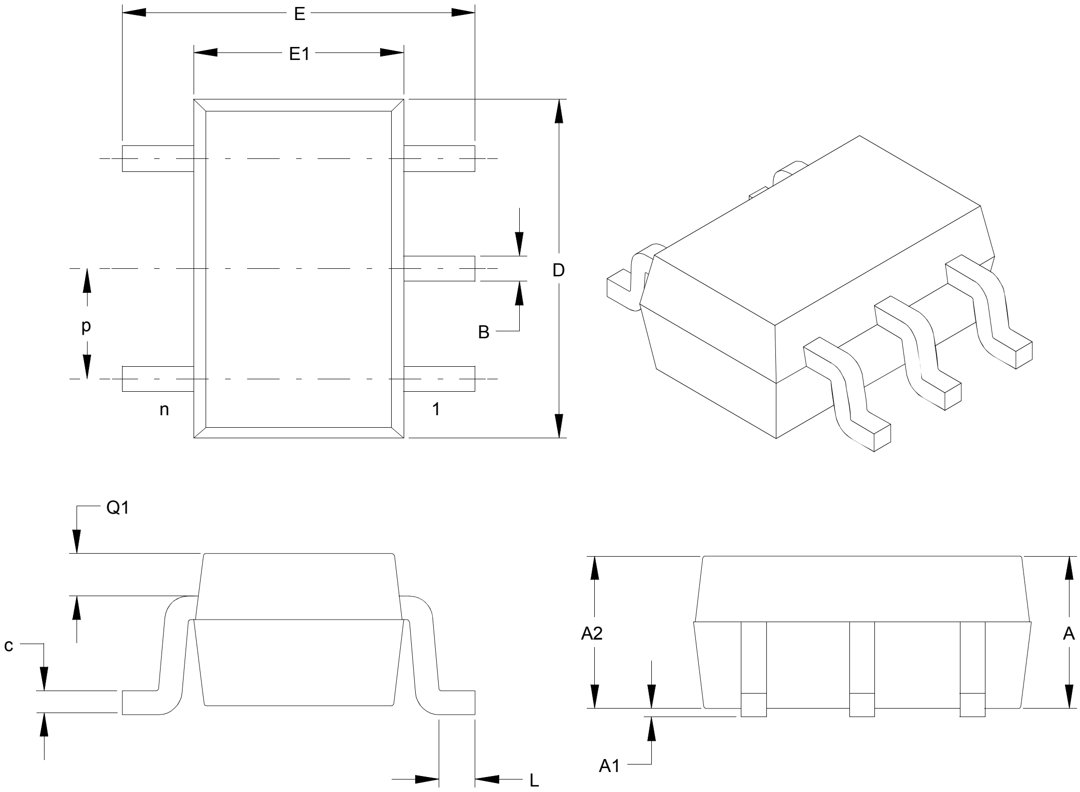
Example



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

5-Lead Plastic Small Outline Transistor (LT) (SC-70)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.026 (BSC)			0.65 (BSC)	
Overall Height	A	.031		.043	0.80		1.10
Molded Package Thickness	A2	.031		.039	0.80		1.00
Standoff	A1	.000		.004	0.00		0.10
Overall Width	E	.071		.094	1.80		2.40
Molded Package Width	E1	.045		.053	1.15		1.35
Overall Length	D	.071		.087	1.80		2.20
Foot Length	L	.004		.012	0.10		0.30
Top of Molded Pkg to Lead Shoulder	Q1	.004		.016	0.10		0.40
Lead Thickness	c	.004		.007	0.10		0.18
Lead Width	B	.006		.012	0.15		0.30

* Controlling Parameter

Notes:

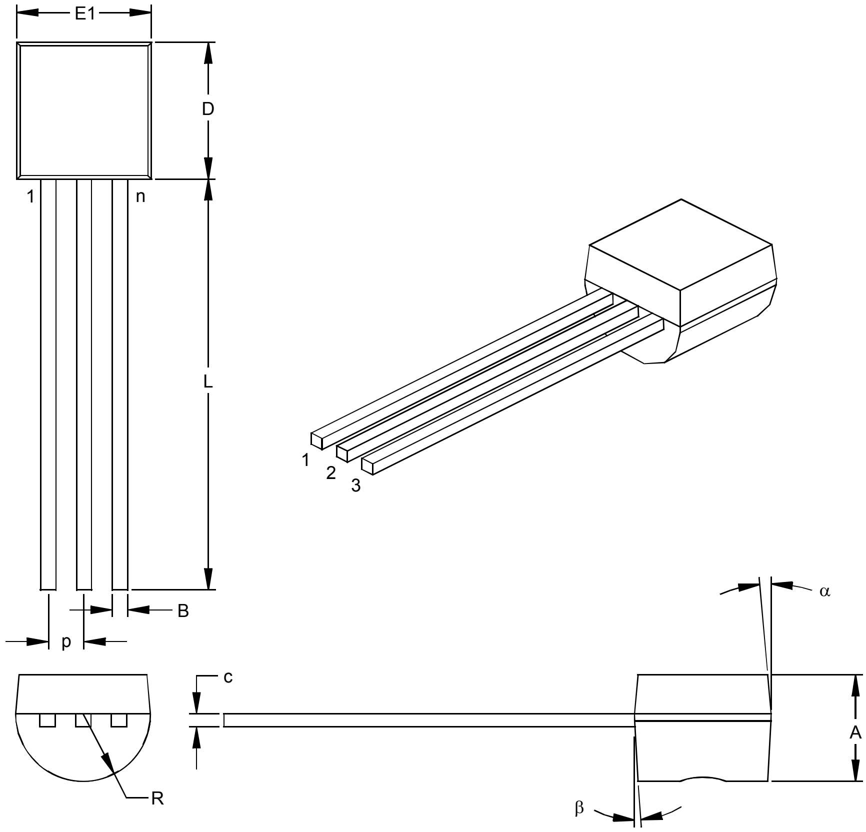
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.
See ASME Y14.5M

JEITA (EIAJ) Standard: SC-70
Drawing No. C04-061

Revised 07-19-05

3-Lead Plastic Transistor Outline (TO) (TO-92)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		3			3	
Pitch	p		.050			1.27	
Bottom to Package Flat	A	.130	.143	.155	3.30	3.62	3.94
Overall Width	E1	.175	.186	.195	4.45	4.71	4.95
Overall Length	D	.170	.183	.195	4.32	4.64	4.95
Molded Package Radius	R	.085	.090	.095	2.16	2.29	2.41
Tip to Seating Plane	L	.500	.555	.610	12.70	14.10	15.49
Lead Thickness	c	.014	.017	.020	0.36	0.43	0.51
Lead Width	B	.016	.019	.022	0.41	0.48	0.56
Mold Draft Angle Top	α	4	5	6	4	5	6
Mold Draft Angle Bottom	β	2	3	4	2	3	4

* Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.

JEDEC Equivalent: TO-92

Drawing No. C04-101

APPENDIX A: REVISION HISTORY

Revision C (June 2006)

- Added the MCP9700A and MCP9701A devices to data sheet
- Added TO92 package for the MCP9700/MCP9701

Revision B (October 2005)

The following is the list of modifications:

- Added **Section 3.0 "Pin Descriptions"**
- Added the Linear Active Thermistor™ IC trademark
- Removed the 2^{nd} order temperature equation and the temperature coeficient histogram
- Added a reference to AN1001 and corresponding verbiage
- Added Figure 4-2 and corresponding verbiage

Revision A (November 2005)

- Original Release of this Document.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	–	X	/XX
Device		Temperature Range	Package

Device:	MCP9700T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9700AT:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9701T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9701AT:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
Temperature Range:	E =	-40°C to +125°C
Package:	LT =	Plastic Small Outline Transistor, 5-lead
	TO =	Plastic Plastic Transistor Outline, 3-lead (MCP9700, MCP9701 only)

Examples:

a) MCP9700T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.
b) MCP9700-E/TO: Linear Active Thermistor™ IC, 3LD TO-92 package.
c) MCP9700AT-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

a) MCP9701T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.
b) MCP9701-E/TO: Linear Active Thermistor™ IC, 3LD TO-92 package.
c) MCP9701AT-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

NOTES:

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://support.microchip.com
Web Address:
www.microchip.com

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Habour City, Kowloon
Hong Kong
Tel: 852-2401-1200
Fax: 852-2401-3431

Atlanta
Alpharetta, GA
Tel: 770-640-0034
Fax: 770-640-0307

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Farmington Hills, MI
Tel: 248-538-2250
Fax: 248-538-2260

Kokomo
Kokomo, IN
Tel: 765-864-8360
Fax: 765-864-8387

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

San Jose
Mountain View, CA
Tel: 650-215-1444
Fax: 650-961-0286

Toronto
Mississauga, Ontario,
Canada
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8528-2100
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8676-6200
Fax: 86-28-8676-6599

China - Fuzhou
Tel: 86-591-8750-3506
Fax: 86-591-8750-3521

China - Hong Kong SAR
Tel: 852-2401-1200
Fax: 852-2401-3431

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8203-2660
Fax: 86-755-8203-1760

China - Shunde
Tel: 86-757-2839-5507
Fax: 86-757-2839-5571

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7250
Fax: 86-29-8833-7256

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-4182-8400
Fax: 91-80-4182-8422

India - New Delhi
Tel: 91-11-5160-8631
Fax: 91-11-5160-8632

India - Pune
Tel: 91-20-2566-1512
Fax: 91-20-2566-1513

Japan - Yokohama
Tel: 81-45-471- 6166
Fax: 81-45-471-6122

Korea - Gumi
Tel: 82-54-473-4301
Fax: 82-54-473-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Penang
Tel: 60-4-646-8870
Fax: 60-4-646-5086

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-572-9526
Fax: 886-3-572-6459

Taiwan - Kaohsiung
Tel: 886-7-536-4818
Fax: 886-7-536-4803

Taiwan - Taipei
Tel: 886-2-2500-6610
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-3910
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

UK - Wokingham
Tel: 44-118-921-5869
Fax: 44-118-921-5820

06/08/06

付録 G

電流センサのデータシート

Thermally Enhanced, Fully Integrated, Hall-Effect-Based Linear Current Sensor IC with 100 µΩ Current Conductor

Not for New Design

These parts are in production but have been determined to be NOT FOR NEW DESIGN. This classification indicates that sale of this device is currently restricted to existing customer applications. The device should not be purchased for new design applications because obsolescence in the near future is probable. Samples are no longer available.

Date of status change: June 5, 2017

Recommended Substitutions:

For existing customer transition, and for new customers or new applications, use ACS770xCB.

NOTE: For detailed information on purchasing options, contact your local Allegro field applications engineer or sales representative.

Allegro MicroSystems, LLC reserves the right to make, from time to time, revisions to the anticipated product life cycle plan for a product to accommodate changes in production capabilities, alternative product availabilities, or market demand. The information included herein is believed to be accurate and reliable. However, Allegro MicroSystems, LLC assumes no responsibility for its use; nor for any infringements of patents or other rights of third parties which may result from its use.

Thermally Enhanced, Fully Integrated, Hall-Effect-Based Linear Current Sensor IC with 100 µΩ Current Conductor

FEATURES AND BENEFITS

- Industry-leading noise performance through proprietary amplifier and filter design techniques
- Integrated shield greatly reduces capacitive coupling from current conductor to die due to high dV/dt signals, and prevents offset drift in high-side, high-voltage applications
- Total output error improvement through gain and offset trim over temperature
- Small package size, with easy mounting capability
- Monolithic Hall IC for high reliability
- Ultralow power loss: 100 µΩ internal conductor resistance
- Galvanic isolation allows use in economical, high-side current sensing in high-voltage systems
- AEC-Q100 qualified

Continued on the next page…

TÜV America
Certificate Number:
U8V 14 05 54214 028
UL Certified
File No.: E316429

PACKAGE: 5-Pin CB Package

PFF Leadform **PSF Leadform** **PSS Leadform**

DESCRIPTION

The Allegro™ ACS758 family of current sensor ICs provides economical and precise solutions for AC or DC current sensing. Typical applications include motor control, load detection and management, power supply and DC-to-DC converter control, inverter control, and overcurrent fault detection.

The device consists of a precision, low-offset linear Hall circuit with a copper conduction path located near the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional output voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy at the factory.

High-level immunity to current conductor dV/dt and stray electric fields, offered by Allegro proprietary integrated shield technology, provides low output voltage ripple and low offset drift in high-side, high-voltage applications.

The output of the device has a positive slope ($>V_{CC}/2$) when an increasing current flows through the primary copper conduction path (from terminal 4 to terminal 5), which is the path used for current sampling. The internal resistance of this conductive path is 100 µΩ typical, providing low power loss.

The thickness of the copper conductor allows survival of the device at high overcurrent conditions. The terminals of the conductive path are electrically isolated from the signal leads

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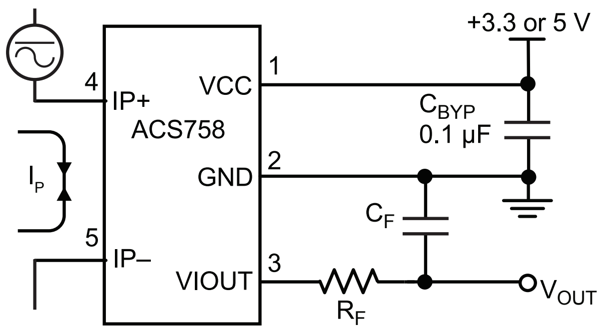


Application 1: The ACS758 outputs an analog signal, V_{OUT}, that varies linearly with the uni- or bi-directional AC or DC primary sampled current, I_P, within the range specified. C_F is for optimal noise management, with values that depend on the application.

Typical Application

FEATURES AND BENEFITS (CONTINUED)

- 3.0 to 5.5 V, single supply operation
- 120 kHz typical bandwidth
- 3 μs output rise time in response to step input current
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis

DESCRIPTION (CONTINUED)

(pins 1 through 3). This allows the ACS758 family of sensor ICs to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The device is fully calibrated prior to shipment from the factory. The ACS758 family is lead (Pb) free. All leads are plated with 100% matte tin, and there is no Pb inside the package. The heavy gauge leadframe is made of oxygen-free copper.

Selection Guide

<table>
<tr><th rowspan="2">Part Number [1]</th><th colspan="2">Package</th><th rowspan="2">Primary Sampled Current, I_P (A)</th><th rowspan="2">Sensitivity Sens (Typ.) (mV/A)</th><th rowspan="2">Current Directionality</th><th rowspan="2">T_{OP} (°C)</th><th rowspan="2">Packing [2]</th></tr>
<tr><th>Terminals</th><th>Signal Pins</th></tr>
<tr><td>ACS758LCB-050B-PFF-T</td><td>Formed</td><td>Formed</td><td>±50</td><td>40</td><td>Bidirectional</td><td rowspan="5">–40 to 150</td><td rowspan="14">34 pieces per tube</td></tr>
<tr><td>ACS758LCB-050U-PFF-T</td><td>Formed</td><td>Formed</td><td>50</td><td>60</td><td>Unidirectional</td></tr>
<tr><td>ACS758LCB-100B-PFF-T</td><td>Formed</td><td>Formed</td><td>±100</td><td>20</td><td>Bidirectional</td></tr>
<tr><td>ACS758LCB-100B-PSF-T</td><td>Straight</td><td>Formed</td><td>±100</td><td>20</td><td>Bidirectional</td></tr>
<tr><td>ACS758LCB-100U-PFF-T</td><td>Formed</td><td>Formed</td><td>100</td><td>40</td><td>Unidirectional</td></tr>
<tr><td>ACS758KCB-150B-PFF-T</td><td>Formed</td><td>Formed</td><td>±150</td><td>13.3</td><td>Bidirectional</td><td rowspan="4">–40 to 125</td></tr>
<tr><td>ACS758KCB-150U-PSF-T</td><td>Straight</td><td>Formed</td><td>150</td><td>26.7</td><td>Unidirectional</td></tr>
<tr><td>ACS758KCB-150B-PSS-T</td><td>Straight</td><td>Straight</td><td>±150</td><td>13.3</td><td>Bidirectional</td></tr>
<tr><td>ACS758KCB-150U-PFF-T</td><td>Formed</td><td>Formed</td><td>150</td><td>26.7</td><td>Unidirectional</td></tr>
<tr><td>ACS758ECB-200B-PFF-T</td><td>Formed</td><td>Formed</td><td>±200</td><td>10</td><td>Bidirectional</td><td rowspan="5">–40 to 85</td></tr>
<tr><td>ACS758ECB-200B-PSF-T</td><td>Straight</td><td>Formed</td><td>±200</td><td>10</td><td>Bidirectional</td></tr>
<tr><td>ACS758ECB-200U-PSF-T</td><td>Straight</td><td>Formed</td><td>200</td><td>20</td><td>Unidirectional</td></tr>
<tr><td>ACS758ECB-200B-PSS-T</td><td>Straight</td><td>Straight</td><td>±200</td><td>10</td><td>Bidirectional</td></tr>
<tr><td>ACS758ECB-200U-PFF-T</td><td>Formed</td><td>Formed</td><td>200</td><td>20</td><td>Unidirectional</td></tr>
</table>

[1] Additional leadform options available for qualified volumes.
[2] Contact Allegro for additional packing options.

SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Units
Forward Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.5	V
Forward Output Voltage	V_{IOUT}		28	V
Reverse Output Voltage	V_{RIOUT}		–0.5	V
Output Source Current	$I_{OUT(Source)}$	VIOUT to GND	3	mA
Output Sink Current	$I_{OUT(Sink)}$	VCC to VIOUT	1	mA
Nominal Operating Ambient Temperature	T_{OP}	Range E	–40 to 85	°C
		Range K	–40 to 125	°C
		Range L	–40 to 150	°C
Maximum Junction	T_J(max)		165	°C
Storage Temperature	T_{stg}		–65 to 165	°C

ISOLATION CHARACTERISTICS

Characteristic	Symbol	Notes	Rating	Unit
Dielectric Strength Test Voltage [1]	V_{ISO}	Agency type-tested for 60 seconds per UL standard 60950-1, 2nd Edition	4800	VAC
Working Voltage for Basic Isolation	V_{WFSI}	For basic (single) isolation per UL standard 60950-1, 2nd Edition	990	VDC or V_{pk}
			700	V_{rms}
Working Voltage for Reinforced Isolation	V_{WFRI}	For reinforced (double) isolation per UL standard 60950-1, 2nd Edition	636	VDC or V_{pk}
			450	V_{rms}

[1] Allegro does not conduct 60-second testing. It is done only during the UL certification process.

THERMAL CHARACTERISTICS: May require derating at maximum conditions

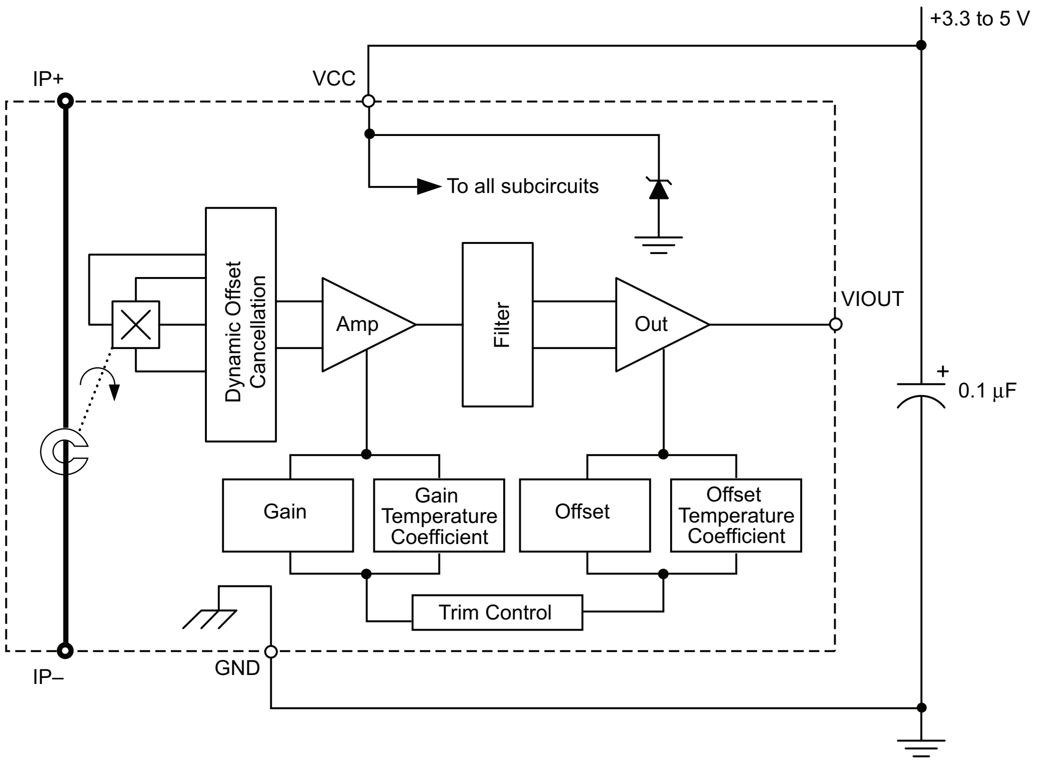
Characteristic	Symbol	Test Conditions [1]	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	Mounted on the Allegro evaluation board with 2800 mm^2 (1400 mm^2 on component side and 1400 mm^2 on opposite side) of 4 oz. copper connected to the primary leadframe and with thermal vias connecting the copper layers. Performance is based on current flowing through the primary leadframe and includes the power consumed by the PCB.	7	°C/W

[1] Additional thermal information available on the Allegro website

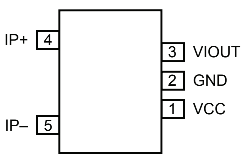
TYPICAL OVERCURRENT CAPABILITIES [2][3]

Characteristic	Symbol	Notes	Rating	Units
Overcurrent	I_{POC}	T_A = 25°C, 1 second duration, 1% duty cycle	1200	A
		T_A = 85°C, 1 second duration, 1% duty cycle	900	A
		T_A = 150°C, 1 second duration, 1% duty cycle	600	A

[2] Test was done with Allegro evaluation board. The maximum allowed current is limited by T_J(max) only.
[3] For more overcurrent profiles, please see FAQ on the Allegro website, www.allegromicro.com.



Functional Block Diagram



Pinout Diagram

Terminal List Table

Number	Name	Description
1	VCC	Device power supply terminal
2	GND	Signal ground terminal
3	VIOUT	Analog output signal
4	IP+	Terminal for current being sampled
5	IP–	Terminal for current being sampled

COMMON OPERATING CHARACTERISTICS [1]: Valid at T_{OP} = –40°C to 150°C and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Supply Voltage [2]	V_{CC}		3	5.0	5.5	V
Supply Current	I_{CC}	Output open	–	10	13.5	mA
Power-On Delay	t_{POD}	T_A = 25°C	–	10	–	μs
Rise Time [3]	t_r	I_P step = 60% of I_P+, 10% to 90% rise time, T_A = 25°C, C_{OUT} = 0.47 nF	–	3	–	μs
Propagation Delay Time [3]	t_{PROP}	T_A = 25°C, C_{OUT} = 0.47 nF	–	1	–	μs
Response Time	$t_{RESPONSE}$	Measured as sum of t_{PROP} and t_r	–	4	–	μs
Internal Bandwidth [4]	BW_i	–3 dB; T_A = 25°C, C_{OUT} = 0.47 nF	–	120	–	kHz
Output Load Resistance	$R_{LOAD(MIN)}$	VIOUT to GND	4.7	–	–	kΩ
Output Load Capacitance	$C_{LOAD(MAX)}$	VIOUT to GND	–	–	10	nF
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	100	–	μΩ
Symmetry [3]	E_{SYM}	Over half-scale of I_P	99	100	101	%
Quiescent Output Voltage [5]	$V_{IOUT(QBI)}$	Bidirectional variant, I_P = 0 A, T_A = 25°C	–	V_{CC}/2	–	V
	$V_{IOUT(QUNI)}$	Unidirectional variant, I_P = 0 A, T_A = 25°C, $V_{IOUT(QUNI)}$ is ratiometric to V_{CC}	–	0.6	–	V
Ratiometry [3]	V_{RAT}	V_{CC} = 4.5 to 5.5 V	–	100	–	%

[1] Device is factory-trimmed at 5 V, for optimal accuracy.
[2] Devices are programmed for maximum accuracy at 5.0 V V_{CC} levels. The device contains ratiometry circuits that accurately alter the 0 A Output Voltage and Sensitivity level of the device in proportion to the applied V_{CC} level. However, as a result of minor nonlinearities in the ratiometry circuit additional output error will result when V_{CC} varies from the 5 V V_{CC} level. Customers that plan to operate the device from a 3.3 V regulated supply should contact their local Allegro sales representative regarding expected device accuracy levels under these bias conditions.
[3] See Characteristic Definitions section of this datasheet.
[4] Calculated using the formula $BW_i = 0.35 / t_r$.
[5] $V_{IOUT(Q)}$ may drift over the lifetime of the device by as much as ±25 mV.

X050B PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 150°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–50	–	50	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	40	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	39.4	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	41	–	mV/A
Noise [2]	V_{NOISE}	T_A = 25°C, 10 nF on VIOUT pin to GND	–	10	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	–1	–	1	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 150°C	–	±15	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±35	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 50 A	–	100	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	–1.2	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	2	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 2.5 V.
[4] Percentage of I_P. Output filtered.

X050U PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 150°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		0	–	50	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	60	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	59	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	61	–	mV/A
Noise [2]	V_{NOISE}	T_A = 25°C, 10 nF on VIOUT pin to GND	–	15	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	–1	–	1	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 150°C	–	±20	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±40	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 50 A	–	100	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	–1.2	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	2	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 0.6 V.
[4] Percentage of I_P. Output filtered.

*X*100B PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 150°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–100	–	100	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	20	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	19.75	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	20.5	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	6	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	–1.25	–	1.25	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 150°C	–	±20	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±20	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 100 A	–	150	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	–1.3	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	2.4	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 2.5 V.
[4] Percentage of I_P. Output filtered.

*X*100U PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 150°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		0	–	100	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	40	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	39.5	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	41	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	12	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	–1.25	–	1.25	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 150°C	–	±20	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±20	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 100 A	–	150	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 150°C	–	–1.3	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	2.4	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 0.6 V.
[4] Percentage of I_P. Output filtered.

X150B PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 125°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–150	–	150	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	13.3	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–	13.1	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	13.5	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	4	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	– 1	–	1	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 125°C	–	±14	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±24	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 150 A	–	205	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–	–1.8	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	1.6	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 2.5 V.
[4] Percentage of I_P. Output filtered.

X150U PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 125°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		0	–	150	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	26.6	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–	26.6	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	27.4	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	8	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	– 1	–	1	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 125°C	–	±14	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±24	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 150 A	–	205	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 125°C	–	–1.8	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	1.6	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 0.6 V.
[4] Percentage of I_P. Output filtered.

*X*200B PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 85°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		–200	–	200	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	10	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–	9.88	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	10.13	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	3	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	– 1	–	1	%
Electrical Offset Voltage [3][	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 85°C	–	±15	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±25	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 200 A	–	230	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–	–1.2	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	1.2	–	%

[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 2.5 V .
[4] Percentage of I_P. Output filtered.

*X*200U PERFORMANCE CHARACTERISTICS [1]: T_{OP} = –40°C to 85°C, V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Primary Sampled Current	I_P		0	–	200	A
Sensitivity	$Sens_{TA}$	Full scale of I_P applied for 5 ms, T_A = 25°C	–	20	–	mV/A
	$Sens_{(TOP)HT}$	Full scale of I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–	19.7	–	mV/A
	$Sens_{(TOP)LT}$	Full scale of I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	20.3	–	mV/A
Noise [2]	V_{NOISE}	T_A= 25°C, 10 nF on VIOUT pin to GND	–	6	–	mV
Nonlinearity	E_{LIN}	Up to full scale of I_P, I_P applied for 5 ms	– 1	–	1	%
Electrical Offset Voltage [3]	$V_{OE(TA)}$	I_P = 0 A, T_A = 25°C	–	±5	–	mV
	$V_{OE(TOP)HT}$	I_P = 0 A, T_{OP} = 25°C to 85°C	–	±20	–	mV
	$V_{OE(TOP)LT}$	I_P = 0 A, T_{OP} = –40°C to 25°C	–	±35	–	mV
Magnetic Offset Error	I_{ERROM}	I_P = 0 A, T_A = 25°C, after excursion of 200 A	–	230	–	mA
Total Output Error [4]	$E_{TOT(HT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = 25°C to 85°C	–	–1.2	–	%
	$E_{TOT(LT)}$	Over full scale of I_P, I_P applied for 5 ms, T_{OP} = –40°C to 25°C	–	1.2	–	%

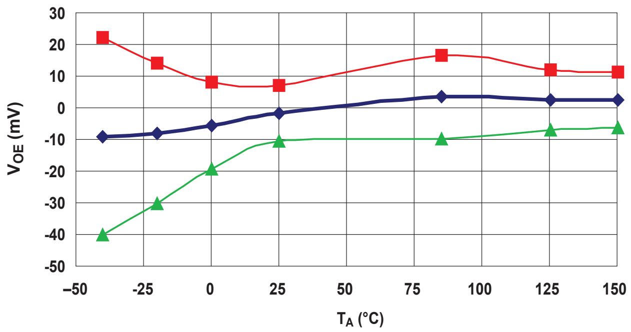
[1] See Characteristic Performance Data page for parameter distributions over temperature range.
[2] ±3 sigma noise voltage.
[3] $V_{OE(TOP)}$ drift is referred to ideal $V_{IOUT(Q)}$ = 0.6 V .
[4] Percentage of I_P. Output filtered.

CHARACTERISTIC PERFORMANCE DATA

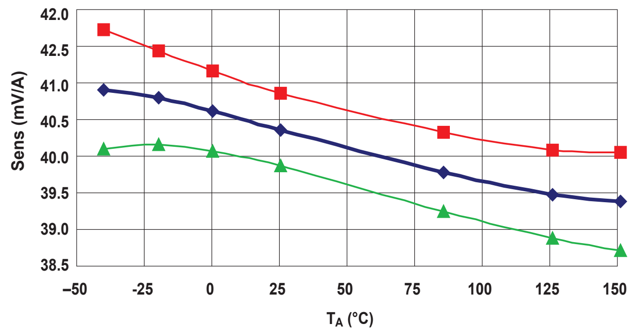
Data taken using the ACS758LCB-050B

Accuracy Data

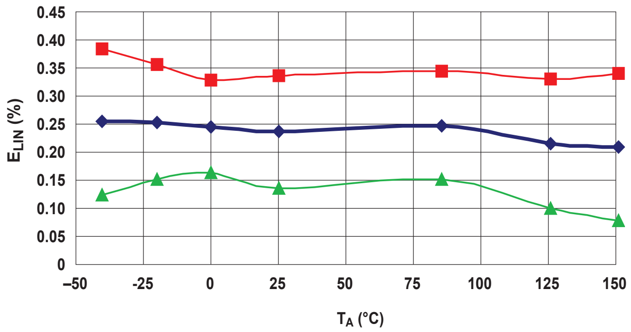
Electrical Offset Voltage versus Ambient Temperature



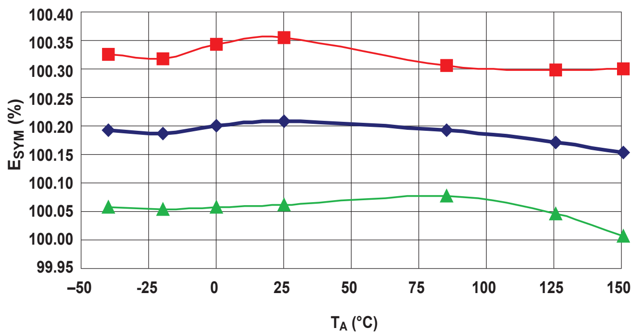
Sensitivity versus Ambient Temperature



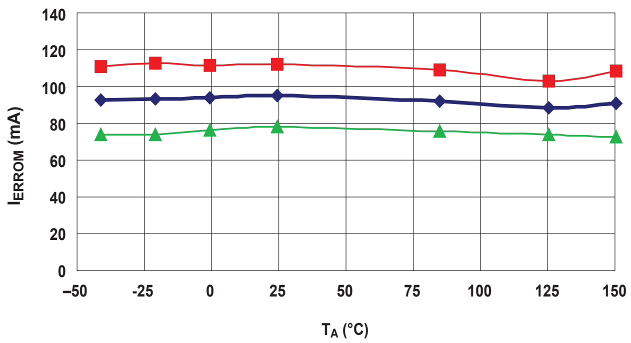
Nonlinearity versus Ambient Temperature



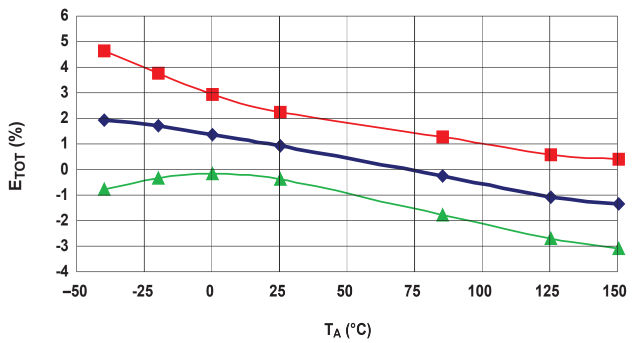
Symmetry versus Ambient Temperature



Magnetic Offset Error versus Ambient Temperature



Total Output Error versus Ambient Temperature



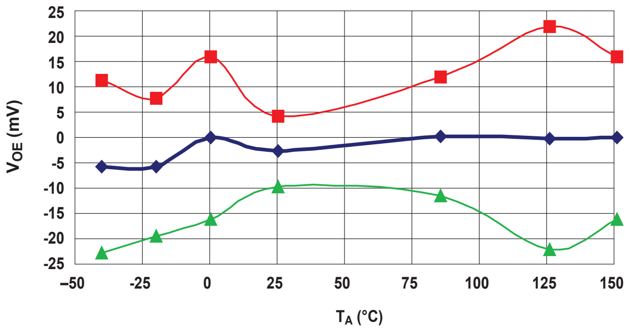
Typical Maximum Limit — Mean — Typical Minimum Limit

CHARACTERISTIC PERFORMANCE DATA

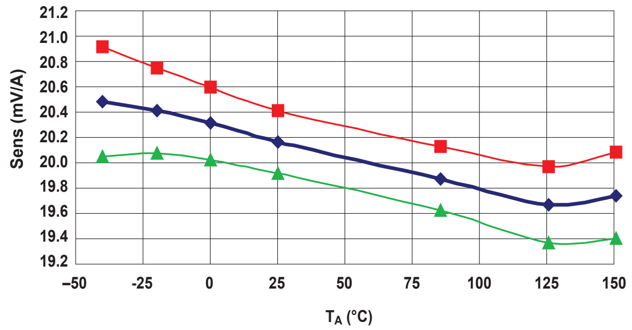
Data taken using the ACS758LCB-100B

Accuracy Data

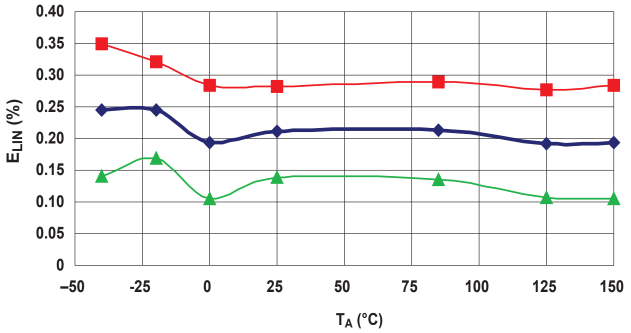
Electrical Offset Voltage versus Ambient Temperature



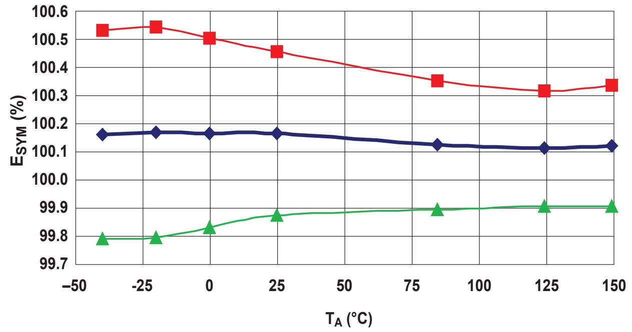
Sensitivity versus Ambient Temperature



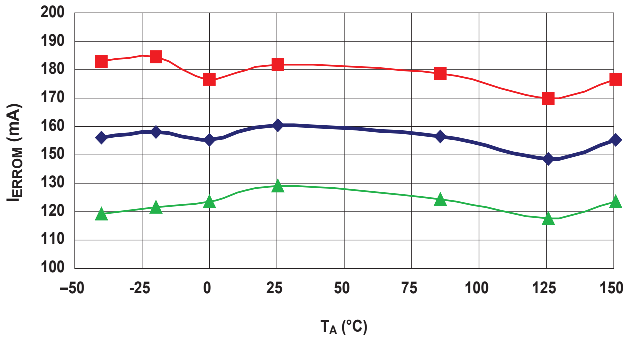
Nonlinearity versus Ambient Temperature



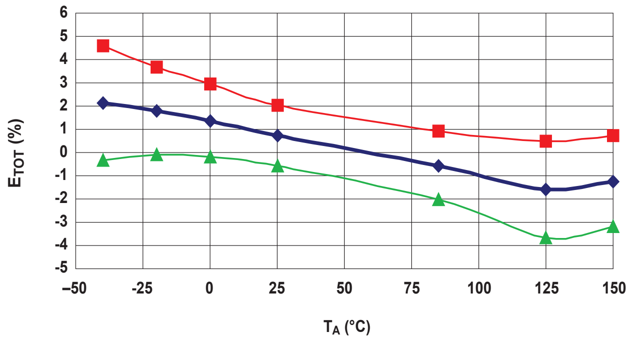
Symmetry versus Ambient Temperature



Magnetic Offset Error versus Ambient Temperature



Total Output Error versus Ambient Temperature

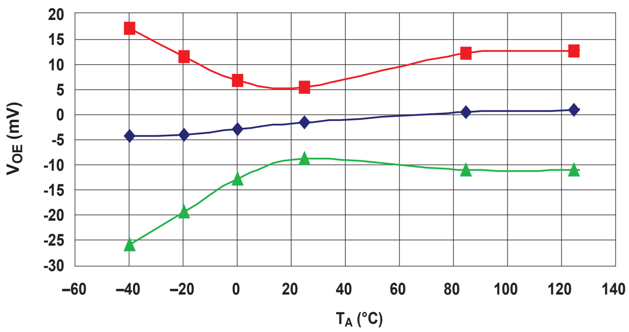


Typical Maximum Limit   Mean   Typical Minimum Limit

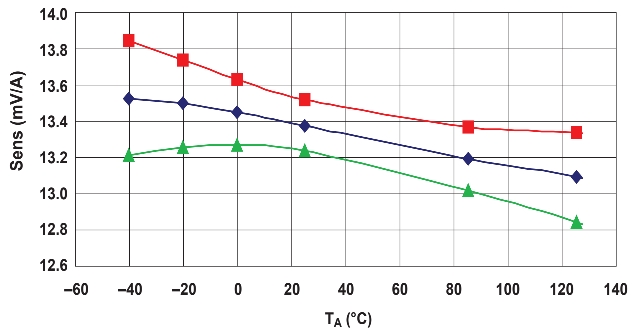
CHARACTERISTIC PERFORMANCE DATA
Data taken using the ACS758KCB-150B

Accuracy Data

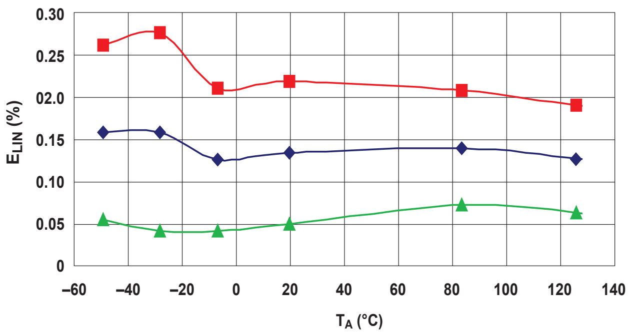
Electrical Offset Voltage versus Ambient Temperature



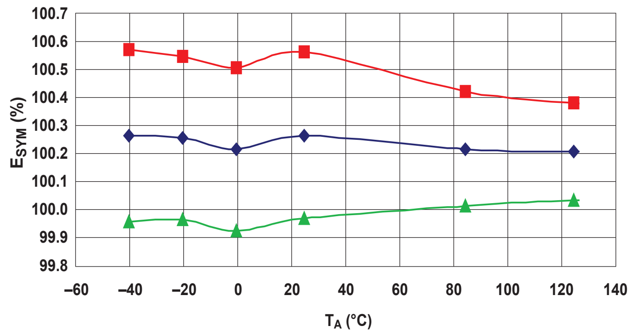
Sensitivity versus Ambient Temperature



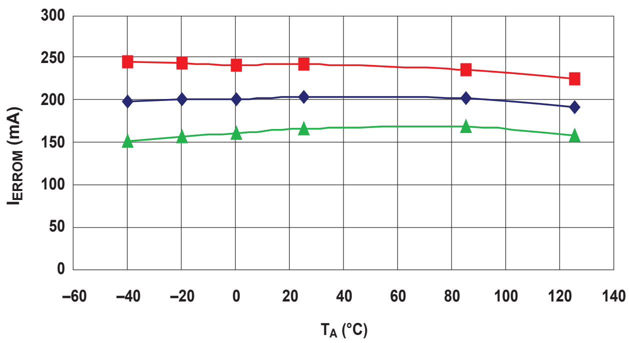
Nonlinearity versus Ambient Temperature



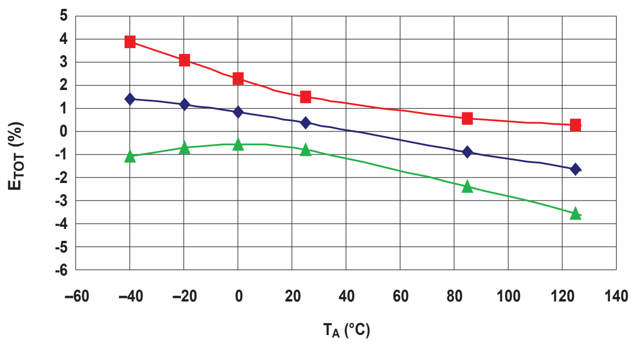
Symmetry versus Ambient Temperature



Magnetic Offset Error versus Ambient Temperature



Total Output Error versus Ambient Temperature



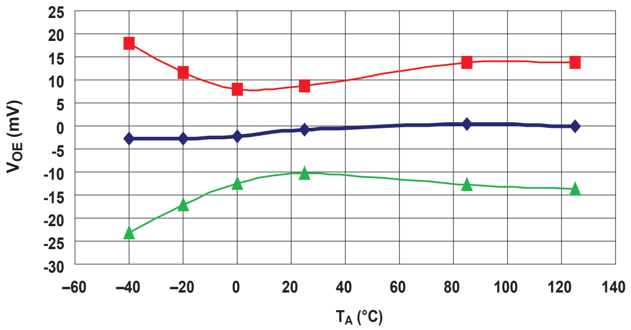
Typical Maximum Limit — Mean — Typical Minimum Limit

CHARACTERISTIC PERFORMANCE DATA

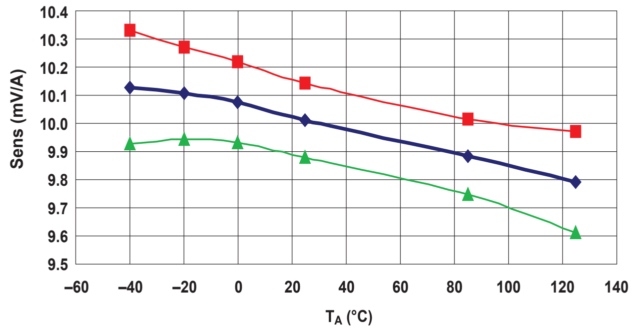
Data taken using the ACS758ECB-200B

Accuracy Data

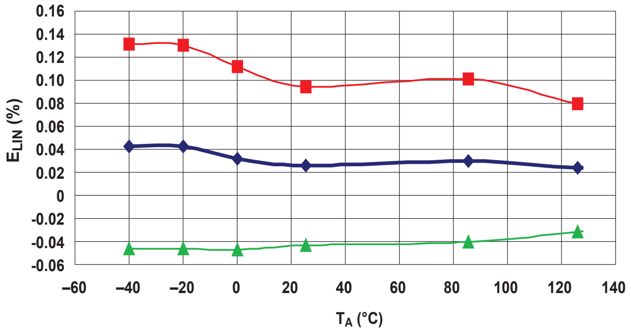
Electrical Offset Voltage versus Ambient Temperature



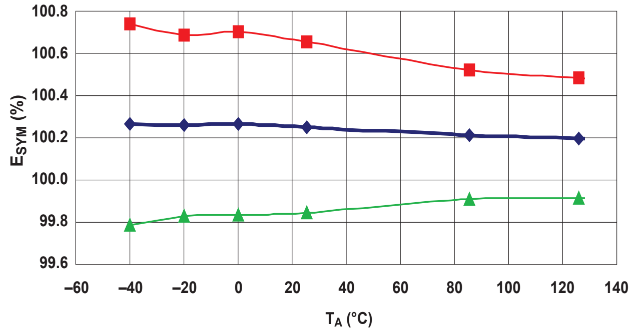
Sensitivity versus Ambient Temperature



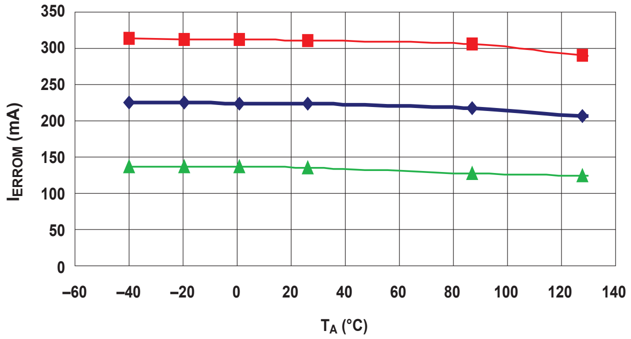
Nonlinearity versus Ambient Temperature



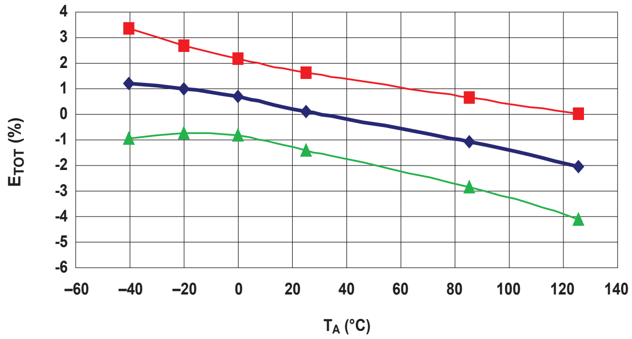
Symmetry versus Ambient Temperature



Magnetic Offset Error versus Ambient Temperature



Total Output Error versus Ambient Temperature



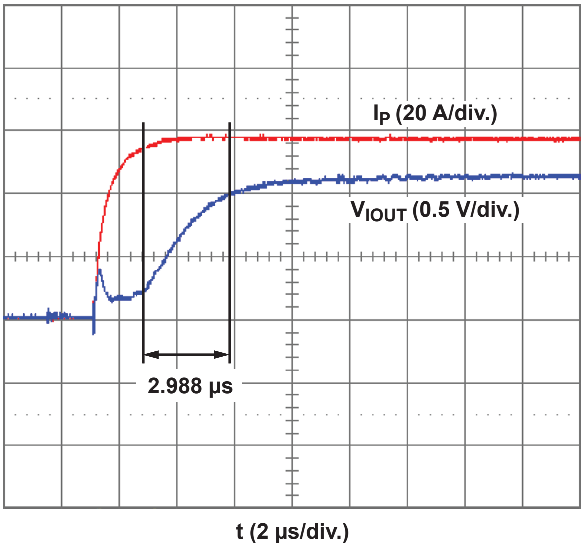
Typical Maximum Limit — Mean — Typical Minimum Limit

CHARACTERISTIC PERFORMANCE DATA

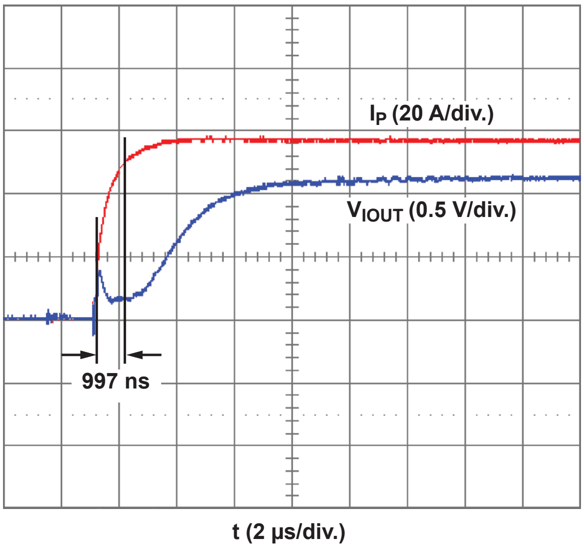
Data taken using the ACS758LCB-100B

Timing Data

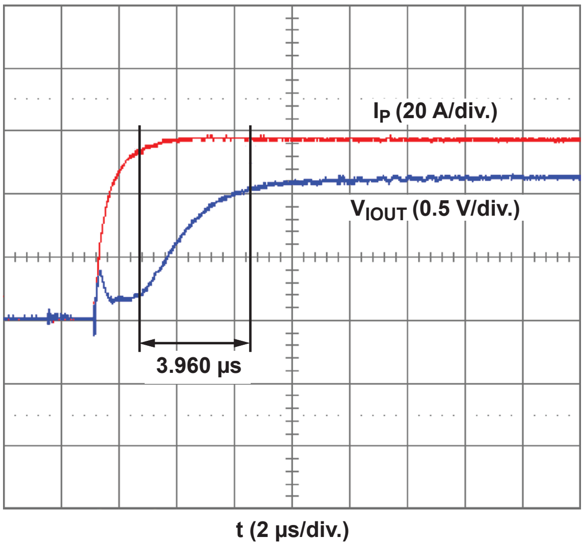
Rise Time



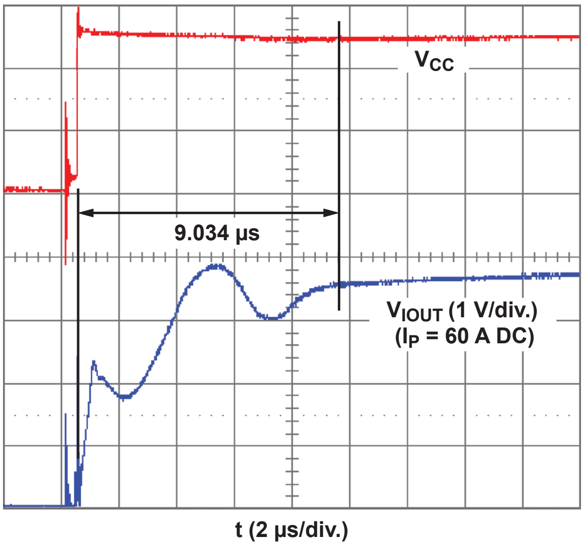
Propagation Delay Time



Response Time



Power-on Delay



CHARACTERISTIC DEFINITIONS

Definitions of Accuracy Characteristics

Sensitivity (Sens). The change in device output in response to a 1 A change through the primary conductor. The sensitivity is the product of the magnetic circuit sensitivity (G/A) and the linear IC amplifier gain (mV/G). The linear IC amplifier gain is programmed at the factory to optimize the sensitivity (mV/A) for the half-scale current of the device.

Noise (V_{NOISE}). The noise floor is derived from the thermal and shot noise observed in Hall elements. Dividing the noise (mV) by the sensitivity (mV/A) provides the smallest current that the device is able to resolve.

Nonlinearity (E_{LIN}). The degree to which the voltage output from the IC varies in direct proportion to the primary current through its half-scale amplitude. Nonlinearity in the output can be attributed to the saturation of the flux concentrator approaching the half-scale current. The following equation is used to derive the linearity:

$$100\left\{1-\left[\frac{\Delta\text{ gain}\times\%\text{ sat}\,(V_{\text{IOUT\_half-scale amperes}}-V_{\text{IOUT(Q)}})}{2\,(V_{\text{IOUT\_quarter-scale amperes}}-V_{\text{IOUT(Q)}})}\right]\right\}$$

where

Δ gain = the gain variation as a function of temperature changes from 25°C,

% sat = the percentage of saturation of the flux concentrator, which becomes significant as the current being sampled approaches half-scale $\pm I_P$, and

$V_{IOUT\_half\text{-}scale\ amperes}$ = the output voltage (V) when the sampled current approximates half-scale $\pm I_P$.

Symmetry (E_{SYM}). The degree to which the absolute voltage output from the IC varies in proportion to either a positive or negative half-scale primary current. The following equation is used to derive symmetry:

$$100\left(\frac{V_{\text{IOUT\_+ half-scale amperes}}-V_{\text{IOUT(Q)}}}{V_{\text{IOUT(Q)}}-V_{\text{IOUT\_–half-scale amperes}}}\right)$$

Ratiometry. The device features a ratiometric output. This means that the quiescent voltage output, V_{IOUTQ}, and the magnetic sensitivity, Sens, are proportional to the supply voltage, V_{CC}.

The ratiometric change (%) in the quiescent voltage output is defined as:

$$\Delta V_{\text{IOUTQ}(\Delta V)}=\frac{V_{\text{IOUTQ}(V_{CC})}\big/V_{\text{IOUTQ(5V)}}}{V_{CC}\big/5\text{ V}}\times 100\%$$

and the ratiometric change (%) in sensitivity is defined as:

$$\Delta\text{Sens}_{(\Delta V)}=\frac{\text{Sens}_{(V_{CC})}\big/\text{Sens}_{(5V)}}{V_{CC}\big/5\text{ V}}\times 100\%$$

Quiescent output voltage ($V_{IOUT(Q)}$). Quiescent output voltage ($V_{IOUT(Q)}$). The output of the device when the primary current is zero. For bidirectional devices, it nominally remains at $V_{CC}/2$. Thus, V_{CC} = 5 V translates into $V_{IOUT(QBI)}$ = 2.5 V. For unidirectional devices, it nominally remains at 0.12 × V_{CC}. Thus, V_{CC} = 5 V translates into $V_{IOUT(QUNI)}$ = 0.6 V. Variation in $V_{IOUT(Q)}$ can be attributed to the resolution of the Allegro linear IC quiescent voltage trim, magnetic hysteresis, and thermal drift.

Electrical offset voltage (V_{OE}). The deviation of the device output from its ideal quiescent value of $V_{CC}/2$ for bidirectional and 0.1 × V_{CC} for unidirectional devices, due to nonmagnetic causes.

Magnetic offset error (I_{ERROM}). The magnetic offset is due to the residual magnetism (remnant field) of the core material. The magnetic offset error is highest when the magnetic circuit has been saturated, usually when the device has been subjected to a full-scale or high-current overload condition. The magnetic offset is largely dependent on the material used as a flux concentrator. The larger magnetic offsets are observed at the lower operating temperatures.

Total Output Error (E_{TOT}). The maximum deviation of the actual output from its ideal value, also referred to as *accuracy*, illustrated graphically in the output voltage versus current chart on the following page.

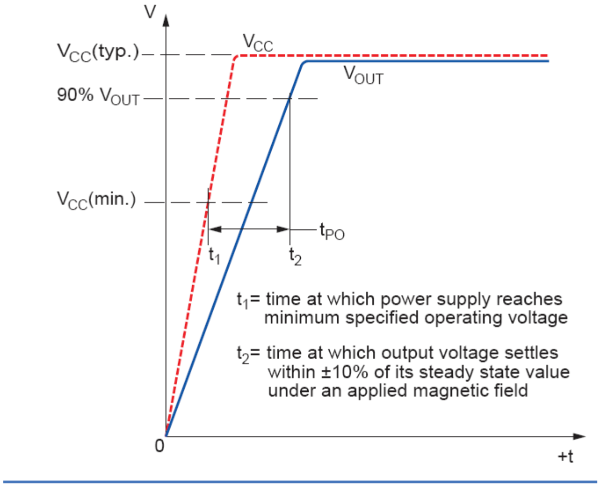
E_{TOT} is divided into four areas:

- **0 A at 25°C.** Accuracy at the zero current flow at 25°C, without the effects of temperature.
- **0 A over Δ temperature.** Accuracy at the zero current flow including temperature effects.
- **Half-scale current at 25°C.** Accuracy at the the half-scale current at 25°C, without the effects of temperature.
- **Half-scale current over Δ temperature.** Accuracy at the half-scale current flow including temperature effects.

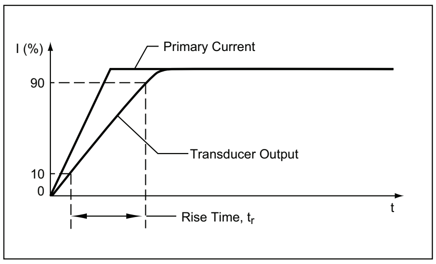
Definitions of Dynamic Response Characteristics

Power-On Time (t_{PO}). When the supply is ramped to its operating voltage, the device requires a finite time to power its internal components before responding to an input magnetic field.

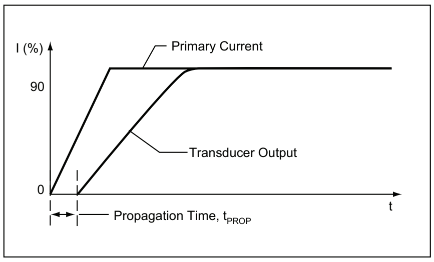
Power-On Time, t_{PO} , is defined as the time it takes for the output voltage to settle within ±10% of its steady state value under an applied magnetic field, after the power supply has reached its minimum specified operating voltage, V_{CC}(min), as shown in the chart at right.



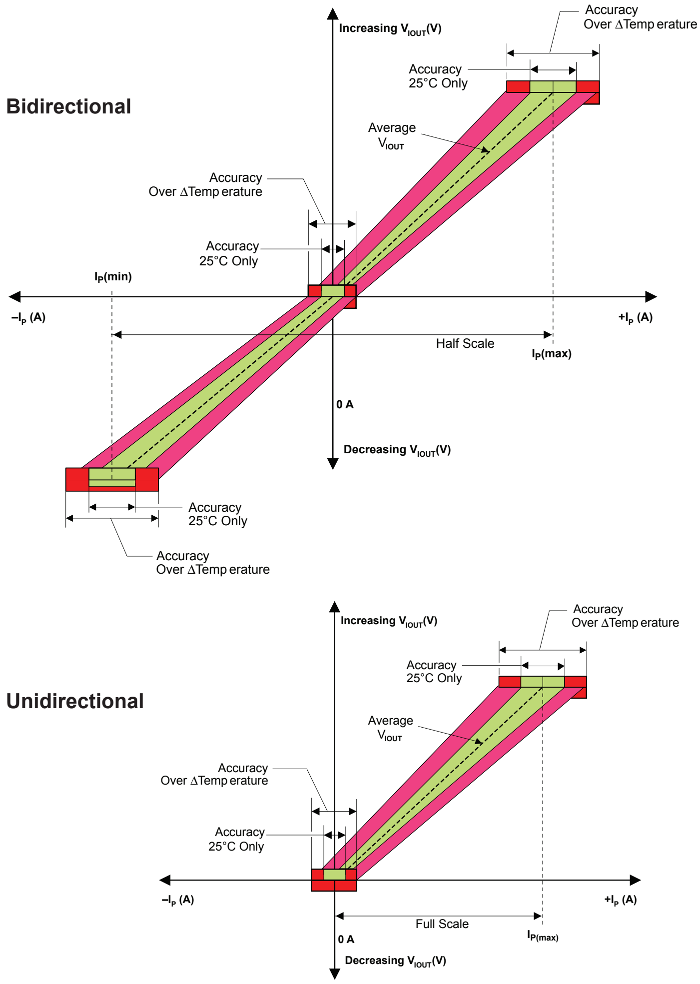
Rise time (t_r). The time interval between a) when the device reaches 10% of its full scale value, and b) when it reaches 90% of its full scale value. The rise time to a step response is used to derive the bandwidth of the device, in which $f(–3\text{ dB}) = 0.35 / t_r$. Both t_r and $t_{RESPONSE}$ are detrimentally affected by eddy current losses observed in the conductive IC ground plane.



Propagation delay (t_{PROP}). The time required for the device output to reflect a change in the primary current signal. Propagation delay is attributed to inductive loading within the linear IC package, as well as in the inductive loop formed by the primary conductor geometry. Propagation delay can be considered as a fixed time offset and may be compensated.



Output Voltage versus Sampled Current
Total Output Error at 0 A and at Half-Scale Current



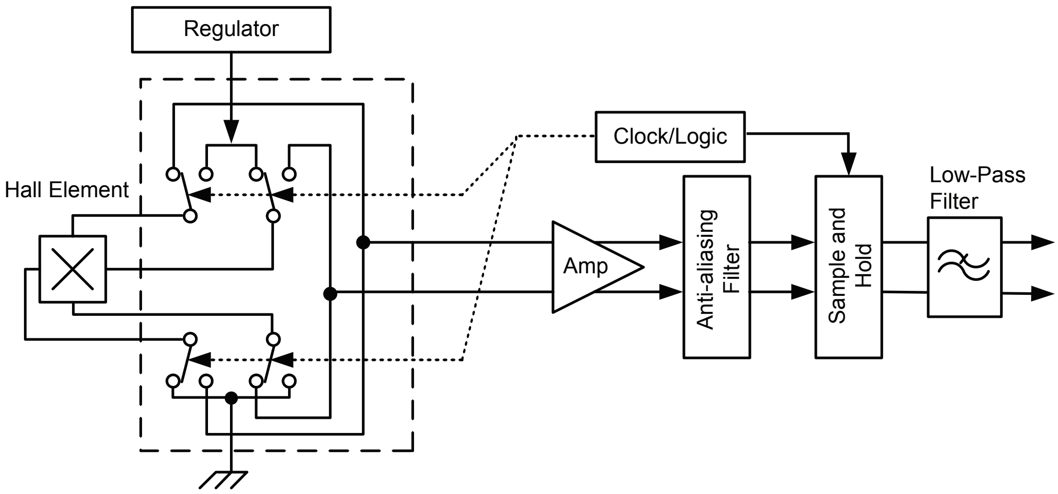
Chopper Stabilization Technique

Chopper Stabilization is an innovative circuit technique that is used to minimize the offset voltage of a Hall element and an associated on-chip amplifier. The technique nearly eliminates Hall IC output drift induced by temperature or package stress effects.

This offset reduction technique is based on a signal modulation-demodulation process. Modulation is used to separate the undesired DC offset signal from the magnetically induced signal in the frequency domain. Then, using a low-pass filter, the modulated DC offset is suppressed while the magnetically induced signal passes through the filter. The anti-aliasing filter prevents aliasing from happening in applications with high frequency signal components which are beyond the user's frequency range of interest.

As a result of this chopper stabilization approach, the output voltage from the Hall IC is desensitized to the effects of temperature and mechanical stress. This technique produces devices that have an extremely stable Electrical Offset Voltage, are immune to thermal stress, and have precise recoverability after temperature cycling.

This technique is made possible through the use of a BiCMOS process that allows the use of low-offset and low-noise amplifiers in combination with high-density logic integration and sample and hold circuits.

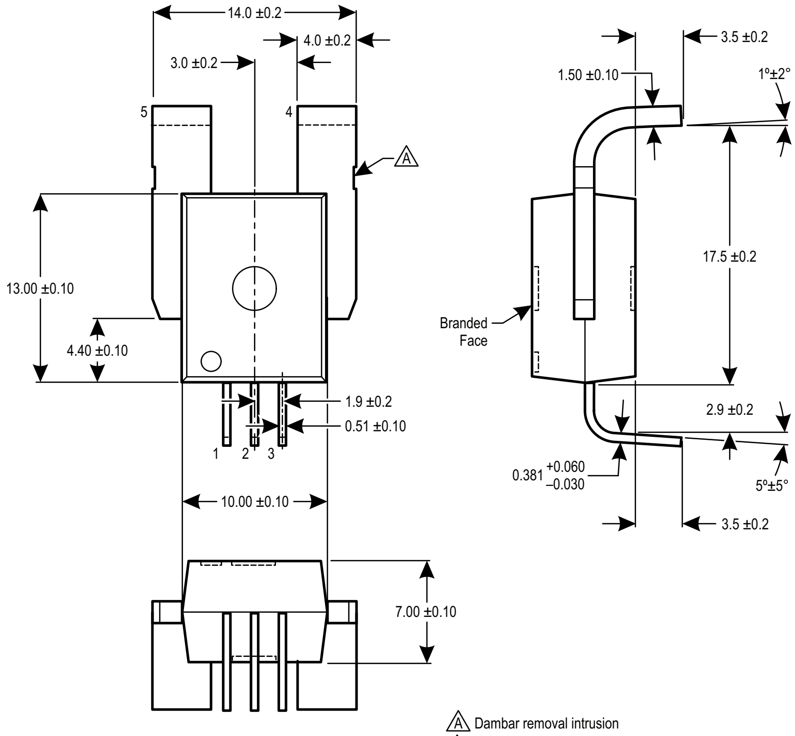


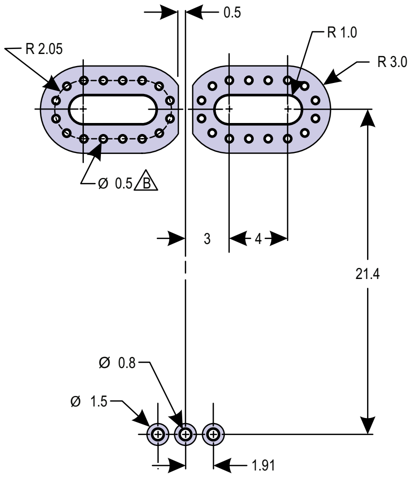
Concept of Chopper Stabilization Technique

PACKAGE OUTLINE DRAWINGS

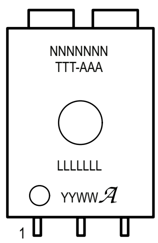
For Reference Only – Not for Tooling Use

(Reference DWG-9111 & DWG-9110)
Dimensions in millimeters – NOT TO SCALE
Dimensions exclusive of mold flash, gate burs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown





B PCB Layout Reference View



A Dambar removal intrusion
B Perimeter through-holes recommended
C Branding scale and appearance at supplier discretion

C Standard Branding Reference View

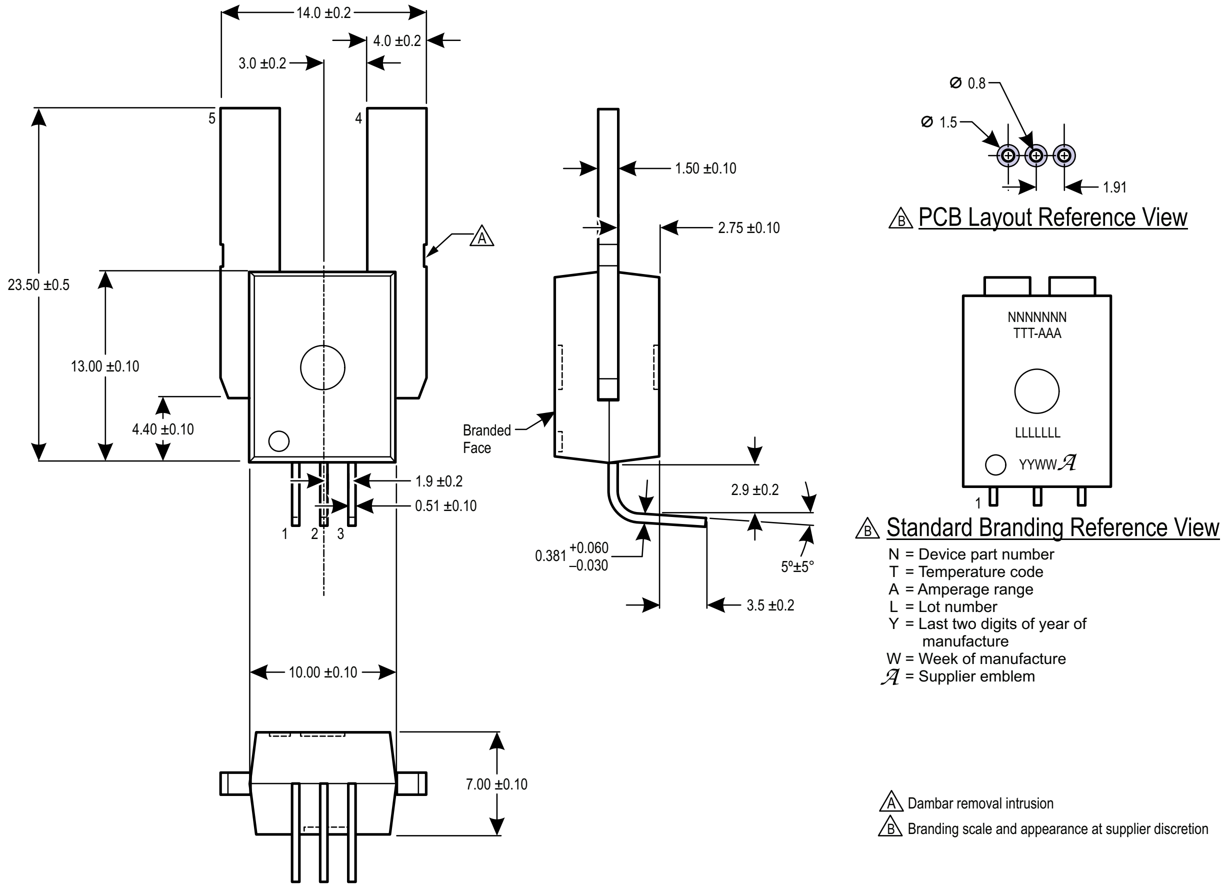
N = Device part number
T = Temperature code
A = Amperage range
L = Lot number
Y = Last two digits of year of manufacture
W = Week of manufacture
= Supplier emblem

Creepage distance, current terminals to signal pins: 7.25 mm
Clearance distance, current terminals to signal pins: 7.25 mm
Package mass: 4.63 g typical

Package CB, 5-pin Package, Leadform PFF

For Reference Only – Not for Tooling Use

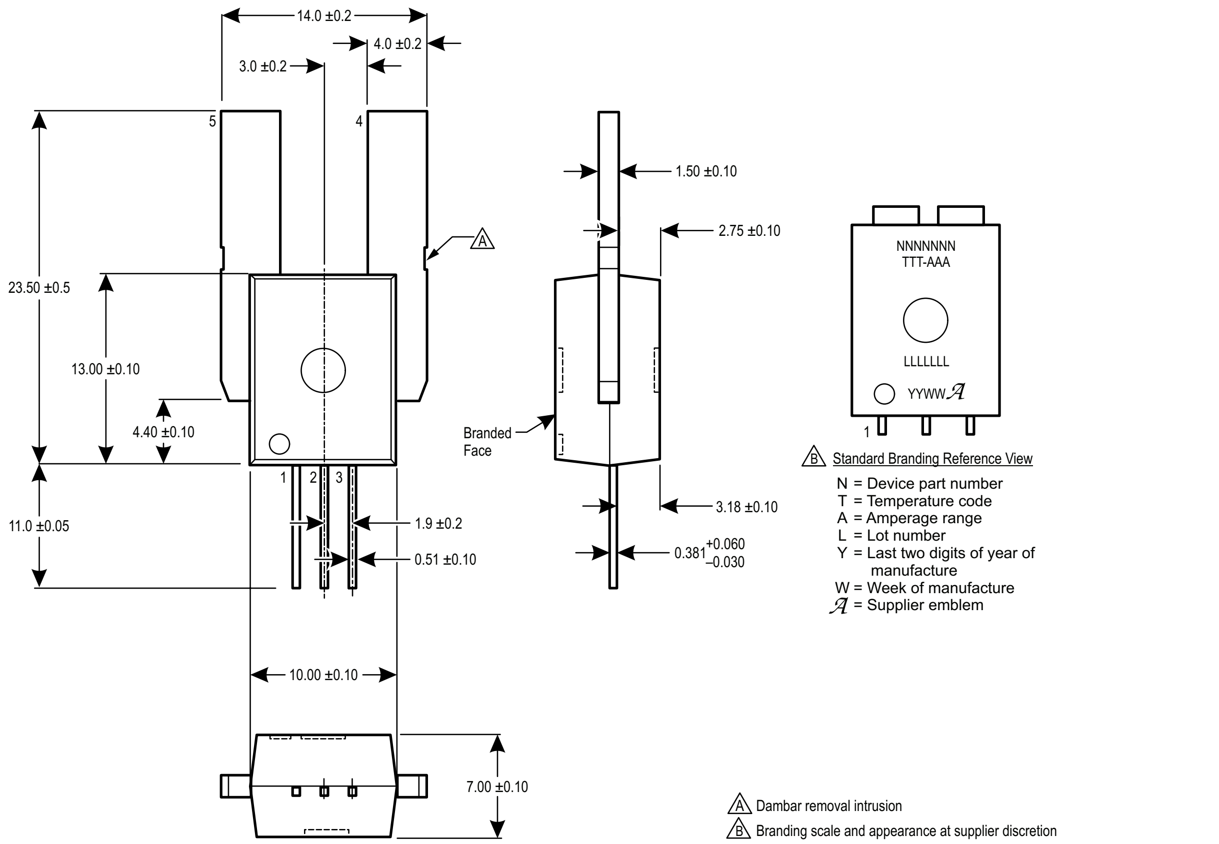
(Reference DWG-9111, DWG-9110)
Dimensions in millimeters – NOT TO SCALE
Dimensions exclusive of mold flash, gate burs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown



Package CB, 5-pin Package, Leadform PSF

For Reference Only – Not for Tooling Use

(Reference DWG-9111, DWG-9110)
Dimensions in millimeters – NOT TO SCALE
Dimensions exclusive of mold flash, gate burs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown



Creepage distance, current terminals to signal pins: 7.25 mm
Clearance distance, current terminals to signal pins: 7.25 mm
Package mass: 4.63 g typical

Package CB, 5-pin Package, Leadform PSS

Revision History

Number	Date	Description
8	January 17, 2014	Update features list and product offering.
9	April 7, 2015	Updated TUV certification and reformatted document.
10	November 17, 2016	Updated PCB Layout Reference View in Package Outline Drawing on page 19.
11	June 5, 2017	Updated product status

For the latest version of this document, visit our website:

www.allegromicro.com

付録 H

RS485 トランシーバのデータシート

LT1785/LT1785A/
LT1791/LT1791A

60V Fault Protected RS485/RS422 Transceivers

FEATURES

- **Protected from Overvoltage Line Faults to ±60V**
- Pin Compatible with LTC485 and LTC491
- High Input Impedance Supports Up to 128 Nodes
- No Damage or Latchup to ESD
  IEC-1000-4-2 Level 4: ±15kV Air Discharge
  IEC-1000-4-2 Level 2: ±4kV Contact Discharge
- Controlled Slew Rates for EMI Emissions Control
- Guaranteed High Receiver Output State for Floating, Shorted or Inactive Inputs
- Outputs Assume a High Impedance When Off or Powered Down
- Drives Low Cost, Low Impedance Cables
- Short-Circuit Protection on All Outputs
- Thermal Shutdown Protection
- Guaranteed Operation to 125°C

APPLICATIONS

- Industrial Control Data Networks
- CAN Bus Applications
- HVAC Controls

DESCRIPTION

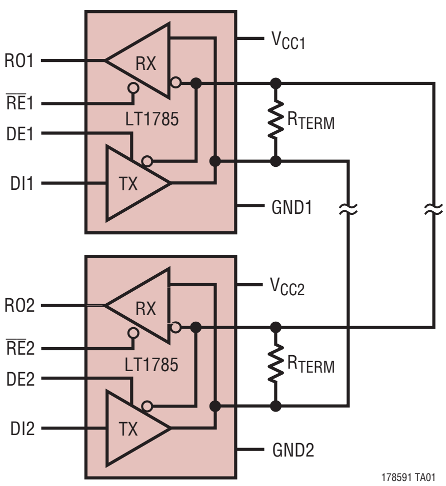
The LT®1785/LT1791 are half-duplex and full-duplex differential bus transceivers for RS485 and RS422 applications which feature on-chip protection from overvoltage faults on the data transmission lines. Receiver input and driver output pins can withstand voltage faults up to ±60V with respect to ground with no damage to the device. Faults may occur while the transceiver is active, shut down or powered off.

Data rates to 250kbaud on networks of up to 128 nodes are supported. Controlled slew rates on the driver outputscontrol EMI emissions and improve data transmission integrity on improperly terminated lines. Drivers are specified to operate with inexpensive cables as low as 72Ω characteristic impedance.

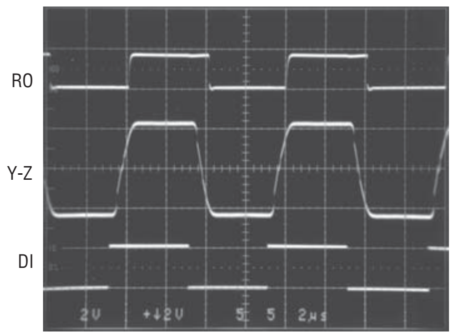
The LT1785A/LT1791A devices have "fail-safe" receiver inputs to guarantee a receiver output high for shorted, open or inactive data lines. On-chip ESD protection eliminates need for external protection devices.

The LT1785/LT1785A are available in 8-lead DIP and SO packages and the LT1791/LT1791A in 14-lead DIP and SO packages.

TYPICAL APPLICATION



Normal Operation Waveforms at 250kBaud

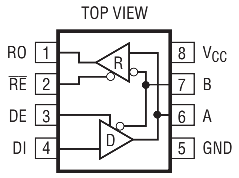


178591 TA02

ABSOLUTE MAXIMUM RATINGS (Note 1)

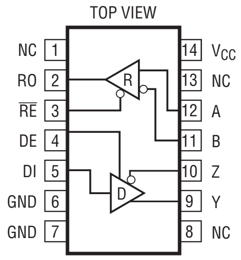
Supply Voltage (V_{CC}) 18V
Receiver Enable Input Voltage..................... –0.3V to 6V
Driver Enable Input Voltage......................... –0.3V to 6V
Driver Input Voltage .... –0.3V to 18V
Receiver Input Voltage .... –60V to 60V
Driver Output Voltage................................ –60V to 60V
Receiver Output Voltage.................. –0.3V to (V_{CC} + 6V)
Operating Temperature Range
LT1785C/LT1791C/
LT1785AC/LT1791AC.................................. 0°C to 70°C
LT1785I/LT1791I/
LT1785AI/LT1791AI .... –40°C to 85°C
LT1785H/LT1791H/
LT1785AH/LT1791AH .... –40°C to 125°C
Storage Temperature Range.................. –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PIN CONFIGURATION



N8 PACKAGE 8-LEAD PDIP S8 PACKAGE 8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 150°C/W (S8)



N PACKAGE 14-LEAD PDIP S PACKAGE 14-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 150°C/W (S)

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT1785CN8#PBF	LT1785CN8#TRPBF	1785	8-Lead PDIP	0°C to 70°C
LT1785CS8#PBF	LT1785CS8#TRPBF	1785	8-Lead Plastic SO	0°C to 70°C
LT1785IN8#PBF	LT1785IN8#TRPBF	1785I	8-Lead PDIP	–40°C to 85°C
LT1785IS8#PBF	LT1785IS8#TRPBF	1785I	8-Lead Plastic SO	–40°C to 85°C
LT1785ACN8#PBF	LT1785ACN8#TRPBF	1785A	8-Lead PDIP	0°C to 70°C
LT1785ACS8#PBF	LT1785ACS8#TRPBF	1785A	8-Lead Plastic SO	0°C to 70°C
LT1785AIN8#PBF	LT1785AIN8#TRPBF	1785AI	8-Lead PDIP	–40°C to 85°C
LT1785AIS8#PBF	LT1785AIS8#TRPBF	1785AI	8-Lead Plastic SO	–40°C to 85°C
LT1785HN8#PBF	LT1785HN8#TRPBF	1785H	8-Lead PDIP	–40°C to 125°C
LT1785HS8#PBF	LT1785HS8#TRPBF	1785H	8-Lead Plastic SO	–40°C to 125°C
LT1785AHN8#PBF	LT1785AHN8#TRPBF	1785AH	8-Lead PDIP	–40°C to 125°C
LT1785AHS8#PBF	LT1785AHS8#TRPBF	1785AH	8-Lead Plastic SO	–40°C to 125°C
LT1791CN#PBF	LT1791CN#TRPBF	1791	14-Lead PDIP	0°C to 70°C
LT1791CS#PBF	LT1791CS#TRPBF	1791	14-Lead Plastic SO	0°C to 70°C

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT1791IN#PBF	LT1791IN#TRPBF	1791I	14-Lead PDIP	–40°C to 85°C
LT1791IS#PBF	LT1791IS#TRPBF	1791I	14-Lead Plastic SO	–40°C to 85°C
LT1791ACN#PBF	LT1791ACN#TRPBF	1791A	14-Lead PDIP	0°C to 70°C
LT1791ACS#PBF	LT1791ACS#TRPBF	1791A	14-Lead Plastic SO	0°C to 70°C
LT1791AIN#PBF	LT1791AIN#TRPBF	1791AI	14-Lead PDIP	–40°C to 85°C
LT1791AIS#PBF	LT1791AIS#TRPBF	1791AI	14-Lead Plastic SO	–40°C to 85°C
LT1791HN#PBF	LT1791HN#TRPBF	1791H	14-Lead PDIP	–40°C to 125°C
LT1791HS#PBF	LT1791HS#TRPBF	1791H	14-Lead Plastic SO	–40°C to 125°C
LT1791AHN#PBF	LT1791AHN#TRPBF	1791AH	14-Lead PDIP	–40°C to 125°C
LT1791AHS#PBF	LT1791AHS#TRPBF	1791AH	14-Lead Plastic SO	–40°C to 125°C
LEAD BASED FINISH	**TAPE AND REEL**	**PART MARKING***	**PACKAGE DESCRIPTION**	**TEMPERATURE RANGE**
LT1785CN8	LT1785CN8#TR	1785	8-Lead PDIP	0°C to 70°C
LT1785CS8	LT1785CS8#TR	1785	8-Lead Plastic SO	0°C to 70°C
LT1785IN8	LT1785IN8#TR	1785I	8-Lead PDIP	–40°C to 85°C
LT1785IS8	LT1785IS8#TR	1785I	8-Lead Plastic SO	–40°C to 85°C
LT1785ACN8	LT1785ACN8#TR	1785A	8-Lead PDIP	0°C to 70°C
LT1785ACS8	LT1785ACS8#TR	1785A	8-Lead Plastic SO	0°C to 70°C
LT1785AIN8	LT1785AIN8#TR	1785AI	8-Lead PDIP	–40°C to 85°C
LT1785AIS8	LT1785AIS8#TR	1785AI	8-Lead Plastic SO	–40°C to 85°C
LT1785HN8	LT1785HN8#TR	1785H	8-Lead PDIP	–40°C to 125°C
LT1785HS8	LT1785HS8#TR	1785H	8-Lead Plastic SO	–40°C to 125°C
LT1785AHN8	LT1785AHN8#TR	1785AH	8-Lead PDIP	–40°C to 125°C
LT1785AHS8	LT1785AHS8#TR	1785AH	8-Lead Plastic SO	–40°C to 125°C
LT1791CN	LT1791CN#TR	1791	14-Lead PDIP	0°C to 70°C
LT1791CS	LT1791CS#TR	1791	14-Lead Plastic SO	0°C to 70°C
LT1791IN	LT1791IN#TR	1791I	14-Lead PDIP	–40°C to 85°C
LT1791IS	LT1791IS#TR	1791I	14-Lead Plastic SO	–40°C to 85°C
LT1791ACN	LT1791ACN#TR	1791A	14-Lead PDIP	0°C to 70°C
LT1791ACS	LT1791ACS#TR	1791A	14-Lead Plastic SO	0°C to 70°C
LT1791AIN	LT1791AIN#TR	1791AI	14-Lead PDIP	–40°C to 85°C
LT1791AIS	LT1791AIS#TR	1791AI	14-Lead Plastic SO	–40°C to 85°C
LT1791HN	LT1791HN#TR	1791H	14-Lead PDIP	–40°C to 125°C
LT1791HS	LT1791HS#TR	1791H	14-Lead Plastic SO	–40°C to 125°C
LT1791AHN	LT1791AHN#TR	1791AH	14-Lead PDIP	–40°C to 125°C
LT1791AHS	LT1791AHS#TR	1791AH	14-Lead Plastic SO	–40°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
This product is only offered in trays. For more information go to: http://www.linear.com/packaging/

DC ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C, V_{CC} = 5V.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OD1}	Differential Driver Output Voltage (Unloaded)	I_O = 0	●		4.1	5	V
V_{OD2}	Differential Driver Output Voltage (With Load)	R = 50Ω (RS422), Figure 1 R = 27Ω (RS485), Figure 1 R = 18Ω	● ● ●	2.0 1.5 1.2	2.70 2.45 2.2		V V V
V_{OD}	Change in Magnitude of Driver Differential Output Voltage for Complementary Output States	R = 27Ω or R = 50Ω, Figure 1	●			0.2	V
V_{OC}	Driver Common Mode Output Voltage	R = 27Ω or R = 50Ω, Figure 1	●	2	2.5	3	V
$\Delta\|V_{OC}\|$	Change in Magnitude of Driver Common Mode Output Voltage for Complementary Output States	R = 27Ω or R = 50Ω, Figure 1	●			0.2	V
V_{IH}	Input High Voltage	DI, DE, $\overline{RE}$	●	2			V
V_{IL}	Input Low Voltage	DI, DE, $\overline{RE}$	●			0.8	V
I_{IN1}	Input Current	DI, DE, $\overline{RE}$	●			5	µA
I_{IN2}	Input Current (A, B); (LT1791 or LT1785 with DE = 0V)	V_{IN} = 12V V_{IN} = –7V –60V ≤ V_{IN} ≤ 60V	● ● ●	 –0.15 –6	0.15 –0.08 	0.3 6	mA mA mA
V_{TH}	Differential Input Threshold Voltage for Receiver	LT1785/LT1791: –7V ≤ V_{CM} ≤ 12V LT1785A/LT1791A: –7V ≤ V_{CM} ≤ 12V	● ●	–0.2 –0.2		0.2 0	V V
ΔV_{TH}	Receiver Input Hysteresis	–7V < V_{CM} < 12V			20		mV
V_{OH}	Receiver Output High Voltage	I_O = –400µA, V_{ID} = 200mV	●	3.5	4		V
V_{OL}	Receiver Output Low Voltage	I_O = 1.6mA, V_{ID} = –200mV	●		0.3	0.5	V
	Three-State (High Impedance) Output Current at Receiver 0V < V_{OUT} < 6V	$\overline{RE}$ > 2V or Power Off	●	–1		1	µA
R_{IN}	Receiver Input Resistance (LT1791)	–7V ≤ V_{CM} ≤ 12V – 60V ≤ V_{CM} ≤ 60V	●	85	125 125		kΩ kΩ
	LT1785	–7V ≤ V_{CM} ≤ 12V	●	50	90		kΩ
	RS485 Unit Load					0.25	
I_{SC}	Driver Short-Circuit Current	V_{OUT} = HIGH, Force V_O = –7V V_{OUT} = LOW, Force V_O = 12V	● ●	35 35		250 250	mA mA
	Driver Output Fault Current	V_O = 60V V_O = –60V	● ●	 –6		6 	mA mA
	Receiver Short-Circuit Current	0V ≤ V_O ≤ V_{CC}	●			±35	mA
	Driver Three-State Output Current	–7V ≤ V_O ≤ 12V –60V ≤ V_O ≤ 60V	● ●	–0.2 –6		0.3 6	mA mA
I_{CC}	Supply Current	No Load, $\overline{RE}$ = 0V, DE = 5V No Load, $\overline{RE}$ = 5V, DE = 5V No Load, $\overline{RE}$ = 0V, DE = 0V No Load, $\overline{RE}$ = 5V, DE = 0V	● ● ● ●		5.5 5.5 4.5 0.2	9 9 8 0.3	mA mA mA mA

SWITCHING CHARACTERISTICS

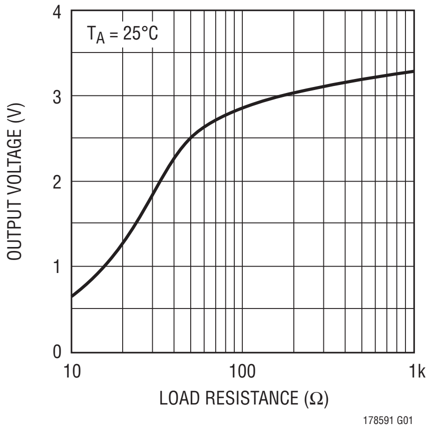
The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$, $V_{CC} = 5V$.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
t_{PLH}	Driver Input to Output	Figures 3, 5	●		700	2000	ns
t_{PHL}	Driver Input to Output	Figures 3, 5	●		700	2000	ns
t_{SKEW}	Driver Output to Output	Figures 3, 5			100		ns
t_r, t_f	Driver Rise or Fall Time	Figures 3, 5	●	200	800	2000	ns
t_{ZH}	Driver Enable to Output High	Figures 4, 6	●		500	3000	ns
t_{ZL}	Driver Enable to Output Low	Figures 4, 6	●		800	3000	ns
t_{LZ}	Driver Disable Time from Low	Figures 4, 6	●		200	5000	ns
t_{HZ}	Driver Disable Time from High	Figures 4, 6	●		800	5000	ns
t_{PLH}	Receiver Input to Output	Figures 3, 7	●		400	900	ns
t_{PHL}	Receiver Input to Output	Figures 3, 7	●		400	900	ns
t_{SKD}	Differential Receiver Skew				200		ns
t_{ZL}	Receiver Enable to Output Low	Figures 2, 8	●		300	1000	ns
t_{ZH}	Receiver Enable to Output High	Figures 2, 8	●		300	1000	ns
t_{LZ}	Receiver Disable from Low	Figures 2, 8	●		400	1000	ns
t_{HZ}	Receiver Disable from High	Figures 2, 8	●		400	1000	ns
f_{MAX}	Maximum Data Rate		●	250			kbps
t_{SHDN}	Time to Shut Down	Figures 2, 6, 8			3		μs
$t_{ZH(SHDN)}$	Driver Enable from Shutdown to Output High	Figures 2, 6; $\overline{RE}$ = 5V			12		μs
$t_{ZL(SHDN)}$	Driver Enable from Shutdown to Output Low	Figures 2, 6; $\overline{RE}$ = 5V			12		μs
$t_{ZH(SHDN)}$	Receiver Enable from Shutdown to Output High	Figures 2, 8; DE = 0V			4		μs
$t_{ZL(SHDN)}$	Receiver Enable from Shutdown to Output Low	Figures 2, 8; DE = 0V			4		μs

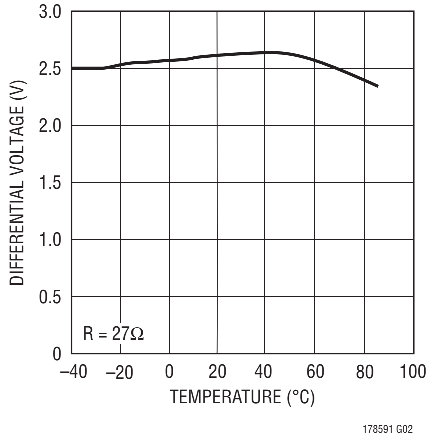
Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

TYPICAL PERFORMANCE CHARACTERISTICS

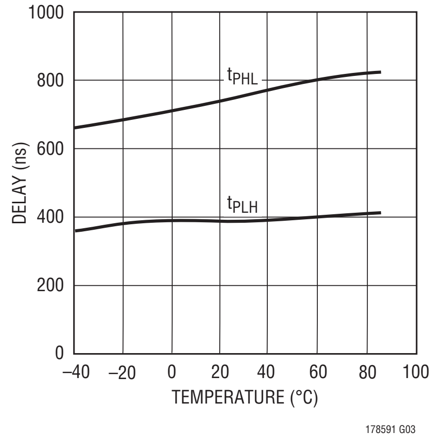
Driver Differential Output Voltage vs Load Resistance



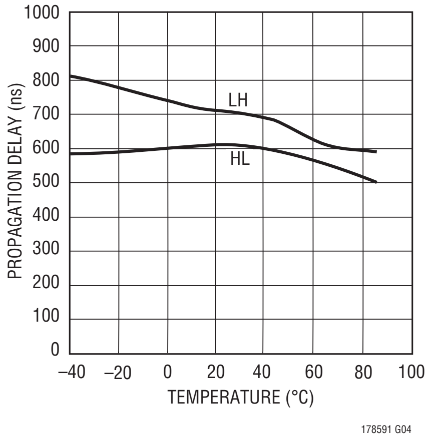
Driver Differential Output Voltage vs Temperature



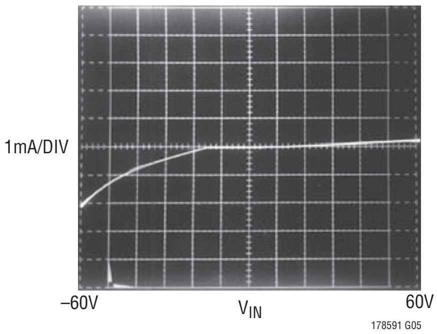
Receiver Propagation Delay vs Temperature



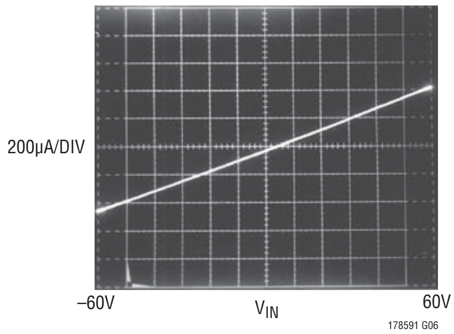
Driver Propagation Delay vs Temperature



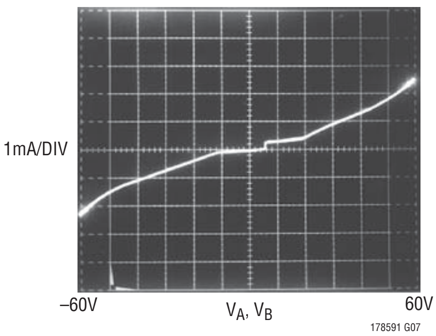
LT1791 Driver Output Leakage DE = 0V



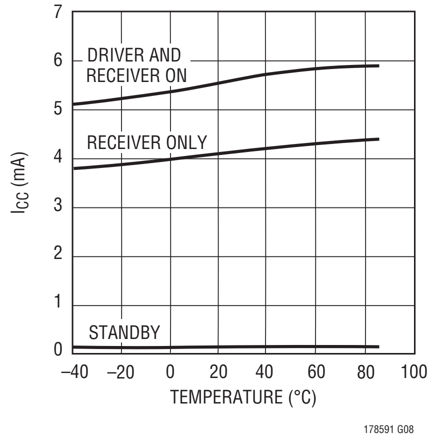
LT1791 Receiver Input Current vs V_{IN}



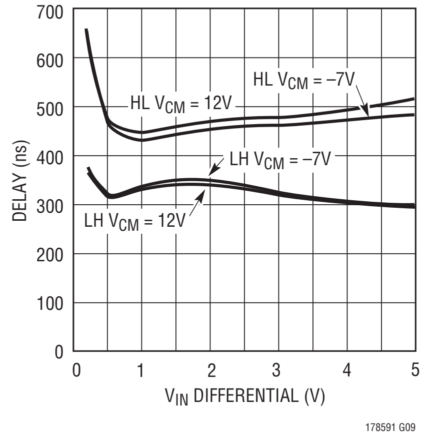
LT1785 Input Characteristics Pins A or B; DE = $\overline{RE}$ = 0V



Supply Current vs Temperature



Receiver Propagation Delay vs Differential Input Voltage



PIN FUNCTIONS

RO: Receiver Output. TTL level logic output. If the receiver is active ($\overline{RE}$ pin low), RO is high if receiver input A ≥ B by 200mV. If A ≤ B by 200mV, then RO will be low. RO assumes a high impedance output state when $\overline{RE}$ is high or the part is powered off. RO is protected from output shorts from ground to 6V.

$\overline{RE}$: Receiver Output Enable. TTL level logic input. A logic low on $\overline{RE}$ enables normal operation of the receiver output RO. A logic high level at $\overline{RE}$ places the receiver output pin RO into a high impedance state. If receiver enable $\overline{RE}$ and driver enable DE are both in the disable state, the circuit-goes to a low power shutdown state. Placing either $\overline{RE}$ or DE into its active state brings the circuit out of shutdown. Shutdown state is not entered until a 3μs delay after both $\overline{RE}$ and DE are disabled, allowing for logic skews in toggling between transmit and receive modes of operation. For CAN bus applications, $\overline{RE}$ should be tied low to prevent the circuit from entering shutdown.

DE: Driver Output Enable. TTL level logic input. A logic high on DE enables normal operation of the driver outputs (Y and Z on LT1791, A and B on LT1785). A logic low level at DE places the driver output pins into a high impedance state. If receiver enable $\overline{RE}$ and driver enable DE are both in the disable state, the circuit goes to a low power shutdown state. Placing either $\overline{RE}$ or DE into its active state brings the circuit out of shutdown. Shutdown state is not entered until a 3μs delay after both $\overline{RE}$ and DE are disabled, allowing for logic skews in toggling between transmit and receive modes of operation. For CAN bus operation the DE pin is used for signal input to place the data bus in dominant or recessive states.

DI: Driver Input. TTL level logic input. A logic high at DI causes driver output A or Y to a high state, and output B or Z to a low state. Complementary output states occur for DI low. For CAN bus applications DI should be tied low.

GND: Ground.

Y: Driver Output. The Y driver output is in phase with the driver input DI. In the LT1785 driver output Y is internally connected to receiver input A. The driver output assumes a high impedance state when DE is low, power is off or thermal shutdown is activated. The driver output is protected from shorts between ±60V in both active and high impedance modes. For CAN applications, output Y is the CANL output node.

Z: Driver Output. The Z driver output is opposite in phase to the driver input DI. In the LT1785 driver output Z is internally connected to receiver input B. The driver output assumes a high impedance state when DE is low, power is off or thermal shutdown is activated. The driver output is protected from shorts between ±60V in both active and high impedance modes. For CAN applications, output Z is the CANH output node.

A: Receiver Input. The A receiver input forces a high receiver output when V(A) ≥ [V(B) + 200mV]. V(A) ≤ [V(B)– 200mV] forces a receiver output low. Receiver inputs A and B are protected against voltage faults between ±60V. The high input impedance allows up to 128 LT1785 or LT1791 transceivers on one RS485 data bus.

The LT1785A/LT1791A have guaranteed receiver input thresholds –200mV < V_{TH} < 0. Receiver outputs are guaranteed to be in a high state for 0V inputs.

B: Receiver Input. The B receiver input forces a high receiver output when V(A) ≥ [V(B) + 200mV]. When V(A) ≤ [V(B) – 200mV], the B receiver forces a receiver output low. Receiver inputs A and B are protected against voltage faults between ±60V. The high input impedance allows up to 128 LT1785 or LT1791 transceivers on one RS485 data bus.

The LT1785A/LT1791A have guaranteed receiver input-thresholds –200mV < V_{TH} < 0. Receiver outputs are guaranteed to be in a high state for 0V inputs.

V_{CC}: Positive Supply Input. For RS422 or RS485 operation, 4.75V ≤ V_{CC} ≤ 5.25V. Higher V_{CC} input voltages increase output drive swing. V_{CC} should be decoupled with a 0.1μF low ESR capacitor directly at Pin 8 (V_{CC}).

TEST CIRCUITS

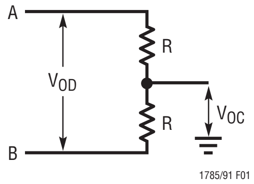


Figure 1. Driver DC Test Load

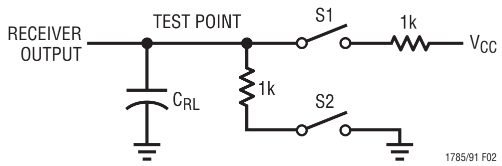


Figure 2. Receiver Timing Test Load

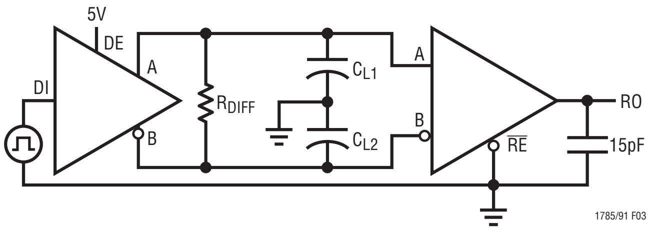


Figure 3. Driver/Receiver Timing Test Circuit

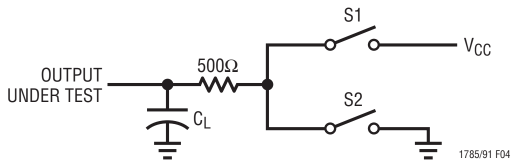


Figure 4. Driver Timing Test Load

FUNCTION TABLES

LT1785 Transmitting

	INPUTS		OUTPUTS		
$\overline{RE}$	DE	DI	A	B	RO
0	1	0	0	1	0
0	1	1	1	0	1
1	0	X	Hi-Z	Hi-Z	Hi-Z
1	1	0	0	1	Hi-Z
1	1	1	1	0	Hi-Z

LT1785 Receiving

	INPUTS			OUTPUT
$\overline{RE}$	DE	DI	A-B	RO
0	0	X	≤ –200mV	0
0	0	X	≥ 200mV*	1
0	0	X	Open	1
1	0	X	X	Hi-Z

* ≥ 0mV for LT1785A

LT1791

INPUTS				OUTPUTS		
$\overline{RE}$	DE	DI	A-B	Y	Z	RO
0	0	X	≤ –200mV	Hi-Z	Hi-Z	0
0	0	X	≥ 200mV*	Hi-Z	Hi-Z	1
0	0	X	Open	Hi-Z	Hi-Z	1
0	1	0	≤ –200mV	0	1	0
0	1	0	≥ 200mV*	0	1	1
0	1	0	Open	0	1	1
0	1	1	≤ –200mV	1	0	0
0	1	1	≥ 200mV*	1	0	1
0	1	1	Open	1	0	1
1	0	X	X	Hi-Z	Hi-Z	Hi-Z
1	1	0	X	0	1	Hi-Z
1	1	1	X	1	0	Hi-Z

* ≥ 0mV for LT1791A

SWITCHING TIME WAVEFORMS

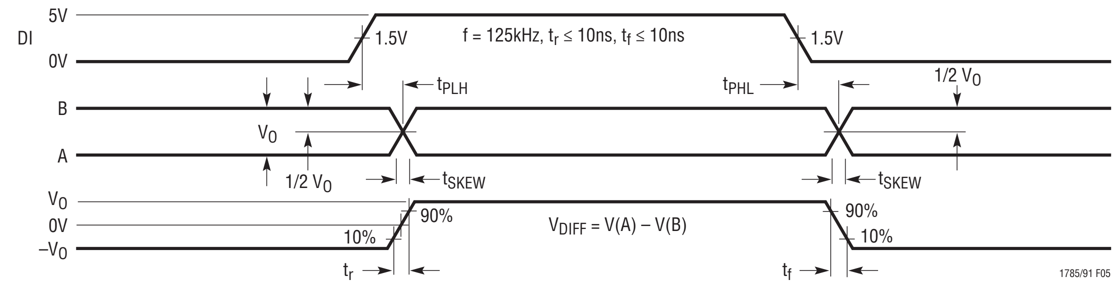


Figure 5. Driver Propagation Delays

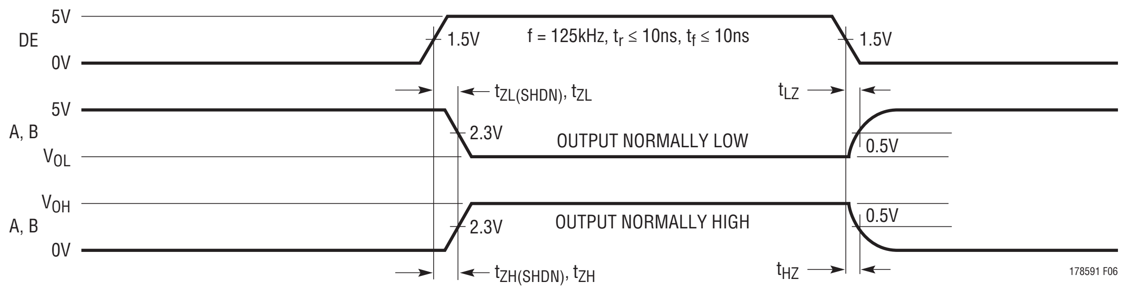


Figure 6. Driver Enable and Disable Times

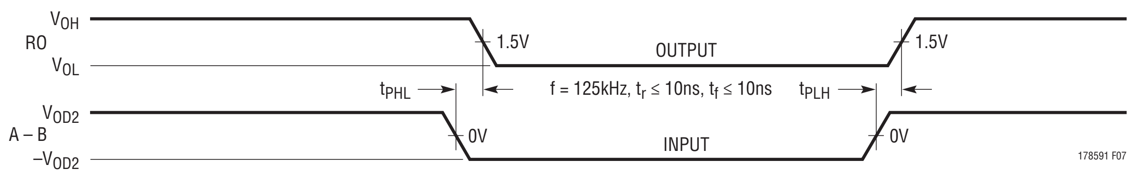


Figure 7. Receiver Propagation Delays

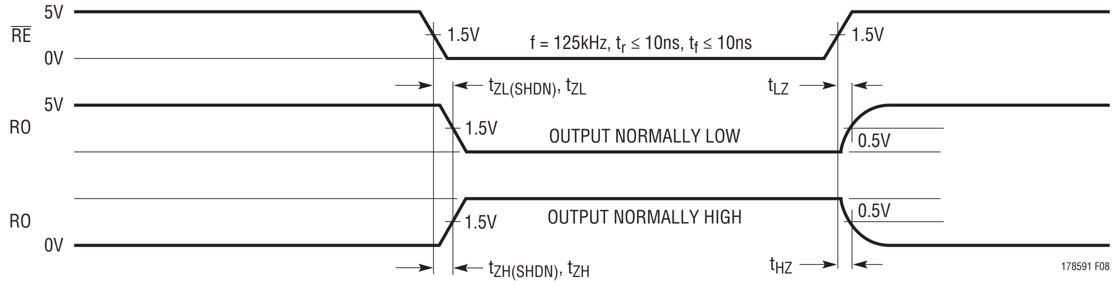


Figure 8. Receiver Enable and Disable Times

APPLICATIONS INFORMATION

Overvoltage Protection

The LT1785/LT1791 RS485/RS422 transceivers answer an applications need for overvoltage fault tolerance on data networks. Industrial installations may encounter common mode voltages between nodes far greater than the –7V to 12V range specified for compliance to RS485 standards. CMOS RS485 transceivers can be damaged by voltages above their absolute maximum ratings of typically –8V to 12.5V. Replacement of standard RS485 transceiver components with the LT1785 or LT1791 devices eliminates field failures due to overvoltage faults or the use of costly external protection devices. The limited overvoltage tolerance of CMOS RS485 transceivers makes implementation of effective external protection networks difficult without interfering with proper data network performance within the –7V to 12V region of RS485 operation.

The high overvoltage rating of the LT1785/LT1791 facilitates easy extension to almost any level. Simple discrete component networks that limit the receiver input and driver output voltages to less than ±60V can be added to the device to extend protection to any desired level. Figure 11 shows a protection network against faults to the120VAC line voltage.

The LT1785/LT1791 protection is achieved by using a high voltage bipolar integrated circuit process for the transceivers. The naturally high breakdown voltages of the bipolar process provides protection in powered-off and high impedance conditions. The driver outputs use a foldback current limit design to protect against overvoltage faults while still allowing high current output drive.

ESD Protection

The LT1785/LT1791 I/O pins have on-chip ESD protection circuitry to eliminate field failures caused by discharges to exposed ports and cables in application environments. The LT1785 pins A and B and the LT1791 driver output pins Y and Z are protected to IEC-1000-4-2 level 2. These pins will survive multiple ESD strikes of ±15kV air discharge or ±4kV contact discharge. Due to their very high input impedance, the LT1791 receiver pins are protected to IEC-1000-4-2 level 2, or ±15kV air and ±4kV contact discharges. This level of ESD protection will guarantee immunity from field failures in all but the most severe ESD environments. The LT1791 receiver input ESD tolerance may be increased to IEC level 4 compliance by adding 2.2k resistors in series with these pins.

Low Power Shutdown

The LT1785/LT1791 have $\overline{RE}$ and DE logic inputs to control the receive and transmit modes of the transceivers. The $\overline{RE}$ input allows normal data reception when in the low state. The receiver output goes to a high impedance state when $\overline{RE}$ is high, allowing multiplexing the RO data line. The DE logic input performs a similar function on the driver outputs. A high state on DE activates the differential driver outputs, a low state places both driver outputs in to high impedance. Tying the $\overline{RE}$ and DE logic inputs together may be done to allow one logic signal to toggle the transceiver from receive to transmit modes. The DE input is used as the data input in CAN bus applications.

Disabling both the driver and receiver places the device into a low supply current shutdown mode. An internal time delay of 3μs minimum prevents entering shutdown due to small logic skews when a toggle between receive and transmit is desired. The recovery time from shutdown mode is typically 12μs. The user must be careful to allow for this wake-up delay from shutdown mode. To allow full 250kbaud data rate transmission in CAN applications, the $\overline{RE}$ pin should be tied low to prevent entering shutdown mode.

APPLICATIONS INFORMATION

Slew Limiting for EMI Emissions Control

The LT1785/LT1791 feature controlled driver output slew rates to control high frequency EMI emissions from equipment and data cables. The slew limiting limits data rate operation to 250kbaud. Slew limiting also mitigates the adverse affects of imperfect transmission line termination caused by stubs or mismatched cable. In some low speed, short distance networks, cable termination may be eliminated completely with no adverse effect on data transmission.

Data Network Cable Selection and Termination

Long distance data networks operating at high data transmission rates should use high quality, low attenuation cable with well-matched cable terminations. Short distance networks at low data rates may use much less expensive PVC cable. These cables have characteristic impedances as low as 72Ω. The LT1785/LT1791 output drivers are guaranteed to drive cables as low as 72Ω.

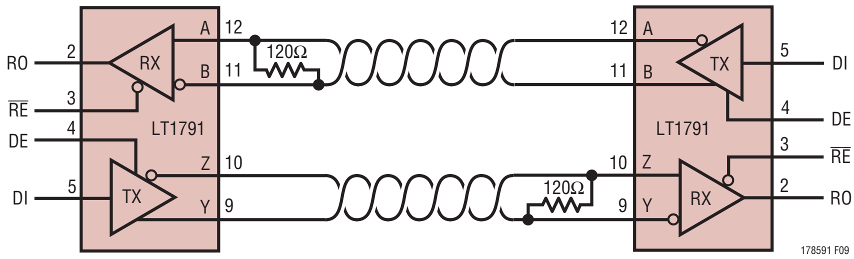
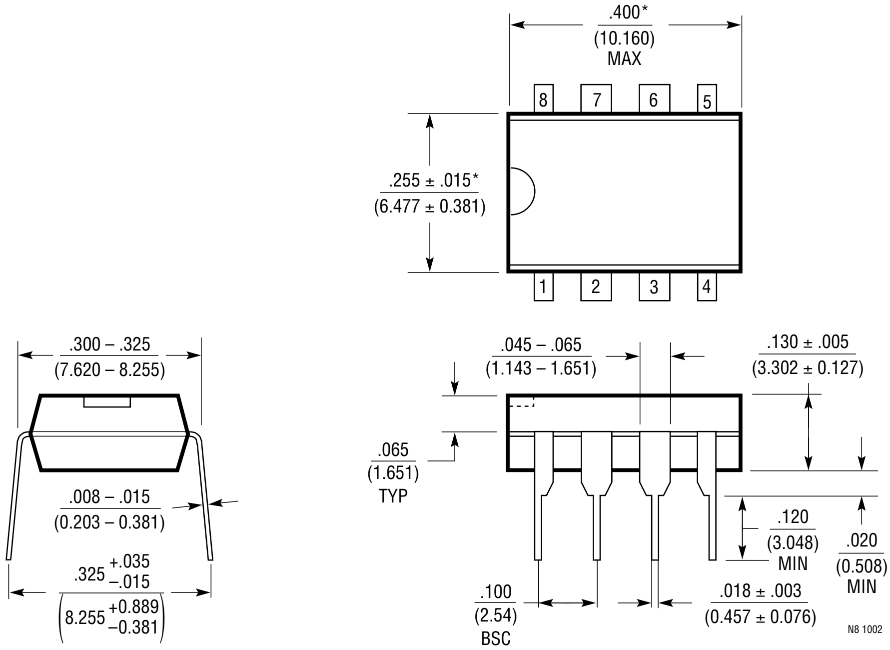


Figure 9. Full-Duplex RS422

PACKAGE DESCRIPTION

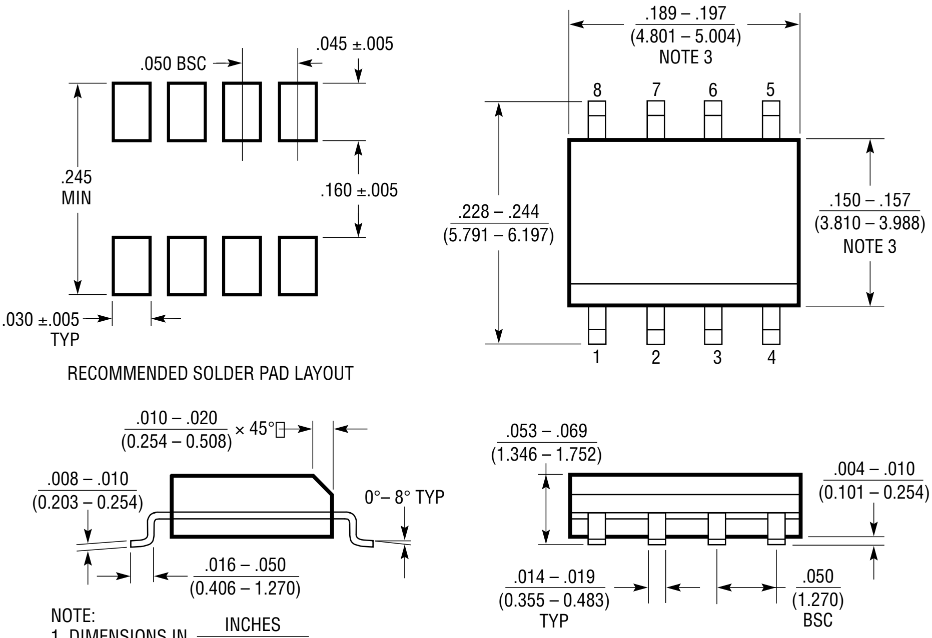
N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

PACKAGE DESCRIPTION

S8 Package
8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)

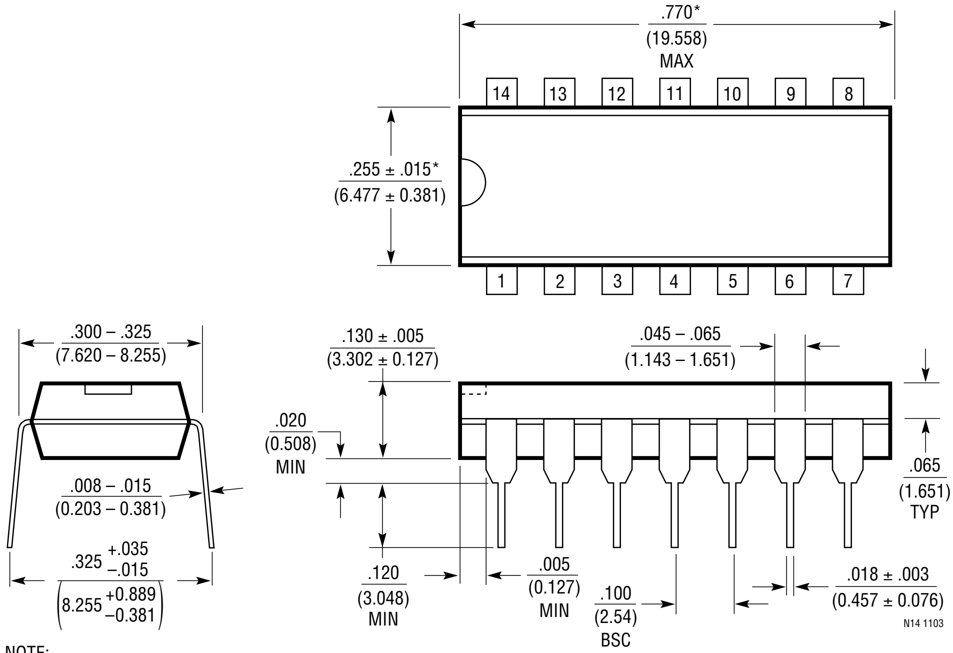


NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

PACKAGE DESCRIPTION

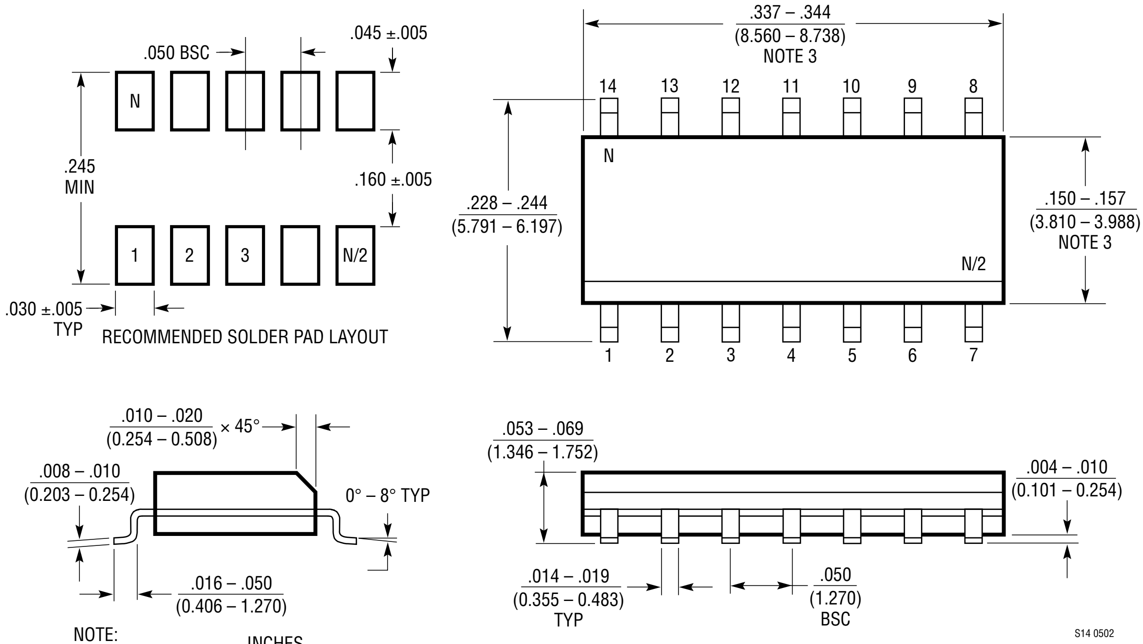
N Package
14-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

PACKAGE DESCRIPTION

S Package
14-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)



NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{(MILLIMETERS)}}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

TYPICAL APPLICATION

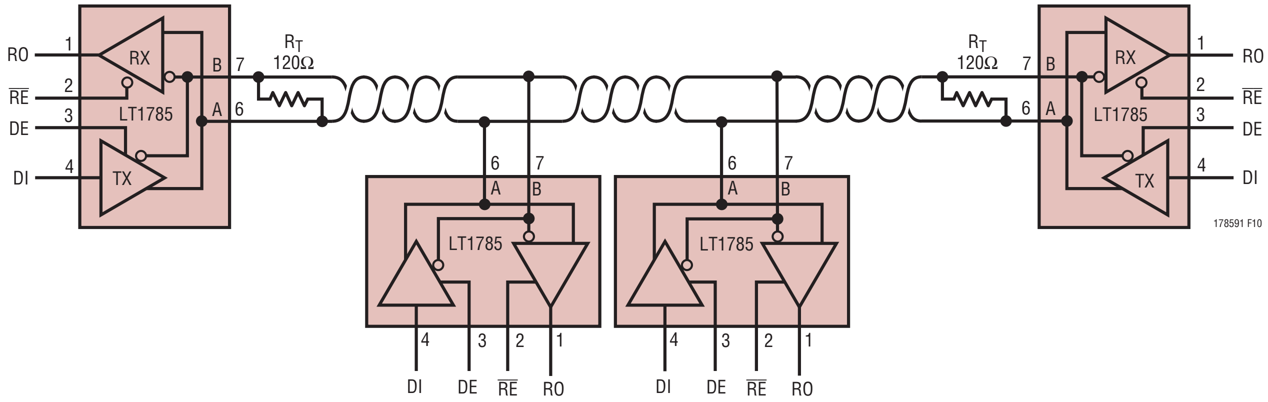


Figure 10. Half-Duplex RS485 Network Operation

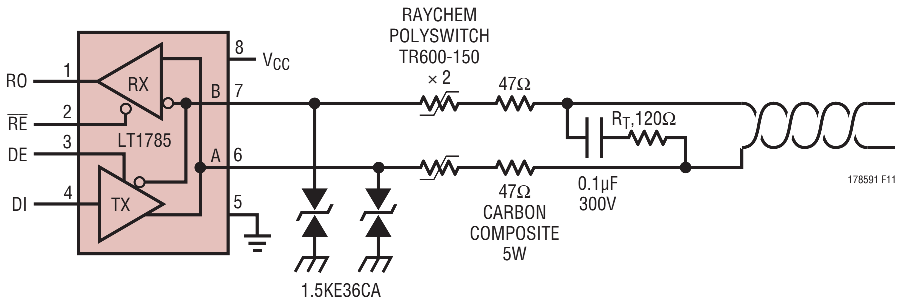


Figure 11. RS485 Network with 120V AC Line Fault Protection

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC485	Low Power RS485 Interface Transceiver	I_{CC} = 300µA (Typ)
LTC491	Differential Driver and Receiver Pair	I_{CC} = 300µA
LTC1483	Ultralow Power RS485 Low EMI Transceiver	Controlled Driver Slew Rate
LTC1485	Differential Bus Transceiver	10Mbaud Operation
LTC1487	Ultralow Power RS485 with Low EMI, Shutdown and High Input Impedance	Up to 256 Transceivers on the Bus
LTC1520	50Mbps Precision Quad Line Receiver	Channel-to-Channel Skew 400ps (Typ)
LTC1535	Isolated RS485 Full-Duplex Transceiver	2500V_{RMS} Isolation in Surface Mount Package
LTC1685	52Mbps RS485 Half-Duplex Transceiver	Propagation Delay Skew 500ps (Typ)
LTC1687	52Mbps RS485 Full-Duplex Transceiver	Propagation Delay Skew 500ps (Typ)

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com
LT 0608 REV B • PRINTED IN USA

付録 I

FET のデータシート

40 V, 80 A, 4.1 mΩ Low RDS(ON)
N ch Trench Power MOSFET

EKI04047

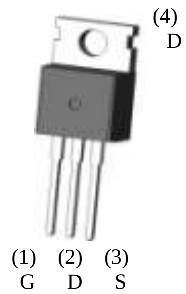
Features

- $V_{(BR)DSS}$ --------------------------------- 40 V (I_D = 100 µA)
- I_D -- 80 A
- $R_{DS(ON)}$ ----------5.2 mΩ max. (V_{GS} = 10 V, I_D = 42.8 A)
- Q_g------16.0 nC (V_{GS} = 4.5 V, V_{DS} = 20 V, I_D = 42.8 A)

- Low Total Gate Charge
- High Speed Switching
- Low On-Resistance
- Capable of 4.5 V Gate Drive
- 100 % UIL Tested
- RoHS Compliant

Package

TO-220

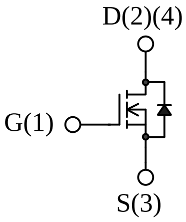


Not to scale

Applications

- DC-DC converters
- Synchronous Rectification
- Power Supplies

Equivalent circuit



Absolute Maximum Ratings

- Unless otherwise specified, T_A = 25 °C

Parameter	Symbol	Test conditions	Rating	Unit
Drain to Source Voltage	V_{DS}		40	V
Gate to Source Voltage	V_{GS}		± 20	V
Continuous Drain Current	I_D	T_C = 25 °C	80	A
Pulsed Drain Current	I_{DM}	PW ≤ 100µs Duty cycle ≤ 1 %	161	A
Continuous Source Current (Body Diode)	I_S		80	A
Pulsed Source Current (Body Diode)	I_{SM}	PW ≤ 100µs Duty cycle ≤ 1 %	161	A
Single Pulse Avalanche Energy	E_{AS}	V_{DD} = 20 V, L = 1 mH, I_{AS} = 9.4 A, unclamped, R_G = 4.7 Ω Refer to Figure 1	89	mJ
Avalanche Current	I_{AS}		16.7	A
Power Dissipation	P_D	T_C = 25 °C	90	W
Operating Junction Temperature	T_J		150	°C
Storage Temperature Range	T_{STG}		− 55 to 150	°C

Thermal Characteristics

• Unless otherwise specified, T_A = 25 °C

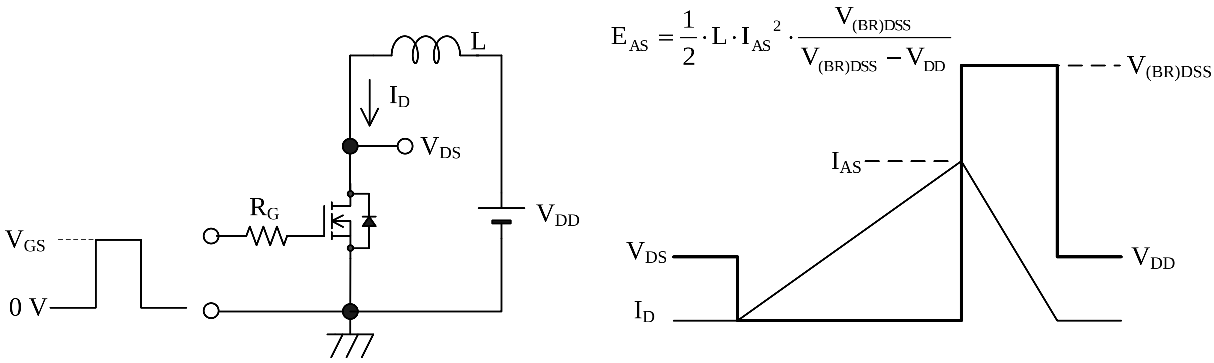
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Thermal Resistance (Junction to Case)	$R_{\theta JC}$		–	–	1.4	°C/W
Thermal Resistance (Junction to Ambient)	$R_{\theta JA}$		–	–	62.5	°C/W

Electrical Characteristics

• Unless otherwise specified, T_A = 25 °C

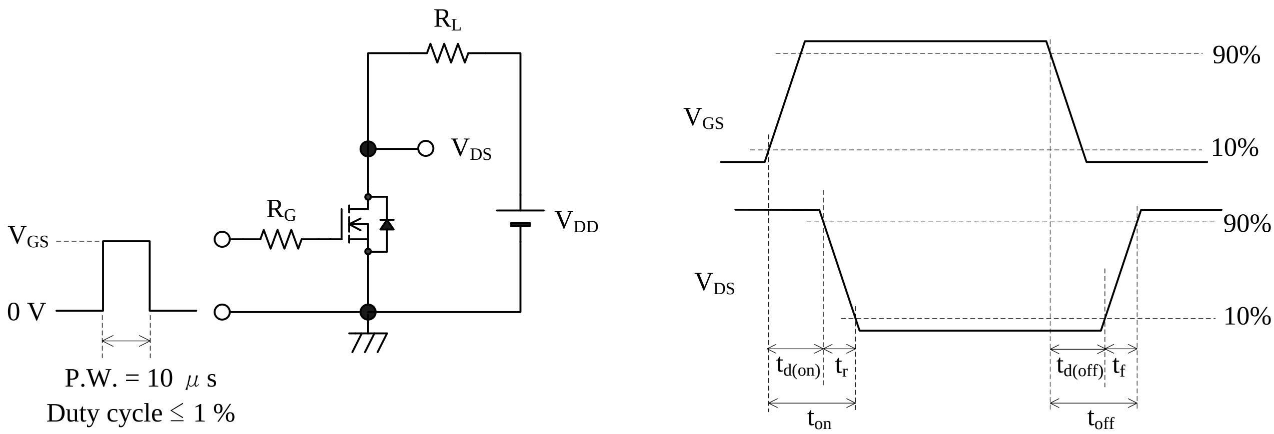
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Drain to Source Breakdown Voltage	$V_{(BR)DSS}$	I_D = 100 µA, V_{GS} = 0 V	40	–	–	V
Drain to Source Leakage Current	I_{DSS}	V_{DS} = 40 V, V_{GS} = 0 V	–	–	100	µA
Gate to Source Leakage Current	I_{GSS}	V_{GS} = ± 20 V	–	–	± 100	nA
Gate Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 650 µA	1.0	2.0	2.5	V
Static Drain to Source On-Resistance	$R_{DS(ON)}$	I_D = 42.8 A, V_{GS} = 10 V	–	4.1	5.2	mΩ
		I_D = 21.4 A, V_{GS} = 4.5 V	–	5.4	7.0	mΩ
Gate Resistance	R_G	f = 1 MHz	–	1.5	–	Ω
Input Capacitance	C_{iss}	V_{DS} = 25 V V_{GS} = 0 V f = 1 MHz	–	2410	–	pF
Output Capacitance	C_{oss}		–	395	–	
Reverse Transfer Capacitance	C_{rss}		–	190	–	
Total Gate Charge (V_{GS} = 10 V)	Q_{g1}	V_{DS} = 20 V I_D = 42.8 A	–	35.0	–	nC
Total Gate Charge (V_{GS} = 4.5 V)	Q_{g2}		–	16.0	–	
Gate to Source Charge	Q_{gs}		–	5.6	–	
Gate to Drain Charge	Q_{gd}		–	6.0	–	
Turn-On Delay Time	$t_{d(on)}$	V_{DD} = 20 V I_D = 42.8 A V_{GS} = 10 V, R_G = 4.7 Ω Refer to Figure 2	–	4.1	–	ns
Rise Time	t_r		–	5.6	–	
Turn-Off Delay Time	$t_{d(off)}$		–	19.7	–	
Fall Time	t_f		–	11.9	–	
Source to Drain Diode Forward Voltage	V_{SD}	I_S = 42.8 A, V_{GS} = 0 V	–	0.9	1.5	V
Source to Drain Diode Reverse Recovery Time	t_{rr}	I_F = 42.8 A di/dt = 100 A/µs Refer to Figure 3	–	32.9	–	ns
Source to Drain Diode Reverse Recovery Charge	Q_{rr}		–	30.3	–	nC

Test Circuits and Waveforms



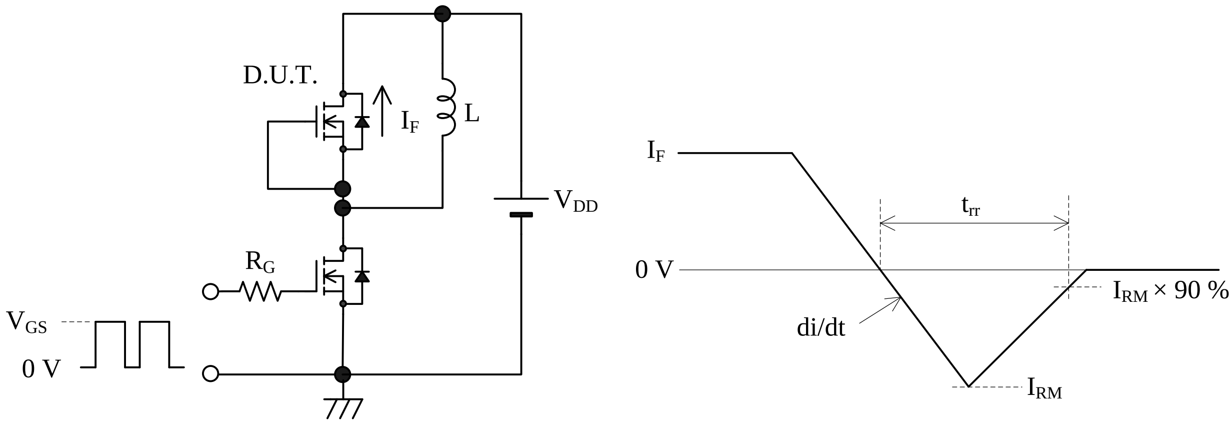
(a) Test Circuit (b) Waveform

Figure 1 Unclamped Inductive Switching



(a) Test Circuit (b) Waveform

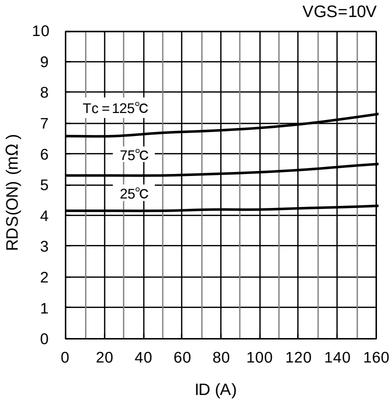
Figure 2 Switching Time



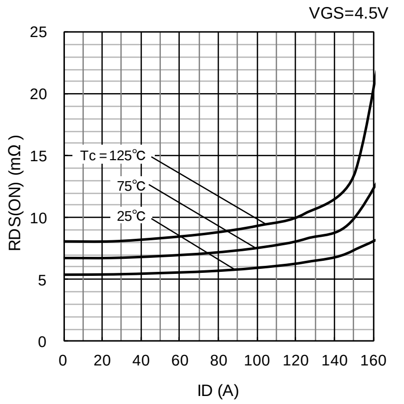
(a) Test Circuit (b) Waveform

Figure 3 Diode Reverse Recovery Time

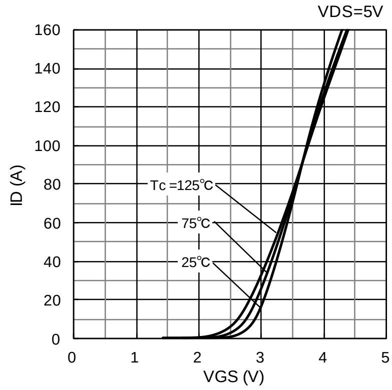
RDS(ON)-ID characteristics (typical)



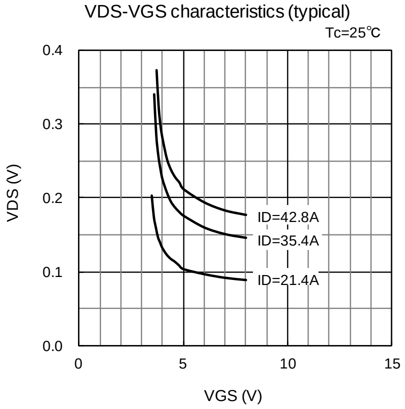
RDS(ON)-ID characteristics (typical)



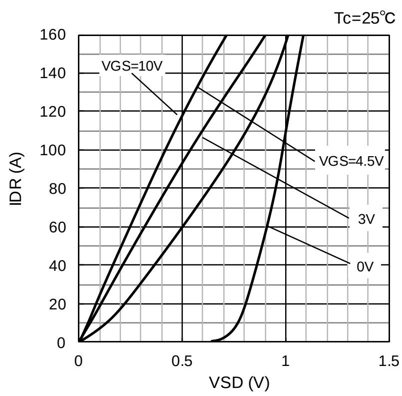
ID-VGS characteristics (typical)



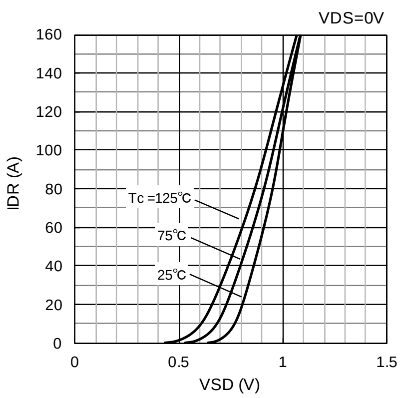
VDS-VGS characteristics (typical)



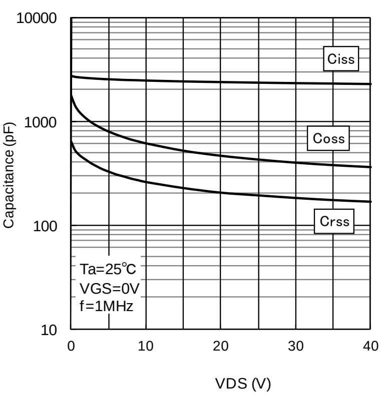
IDR-VSD characteristics (typical)



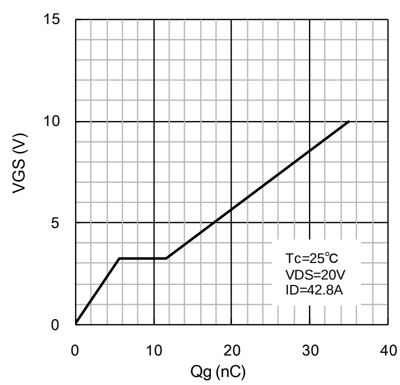
IDR-VSD characteristics (typical)



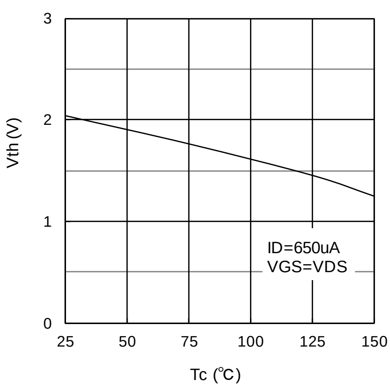
Capacitance-VDS characteristics (typical)



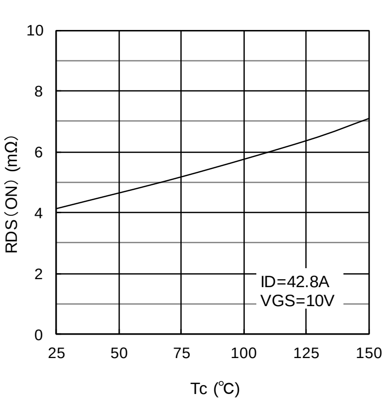
VGS - Qg characteristics (typical)



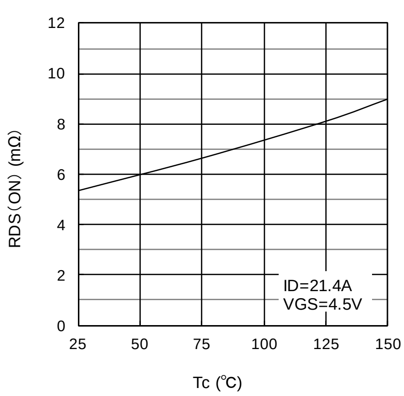
Vth-Tc characteristics (typical)



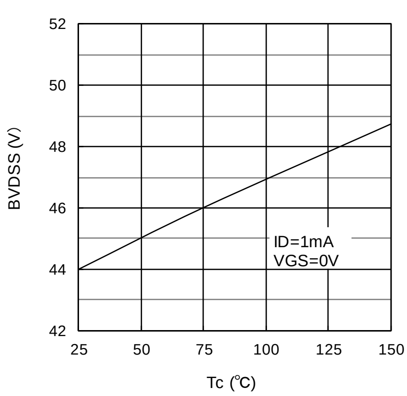
RDS(ON)-Tc characteristics (typical)

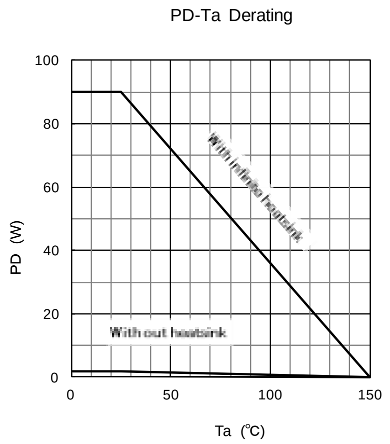


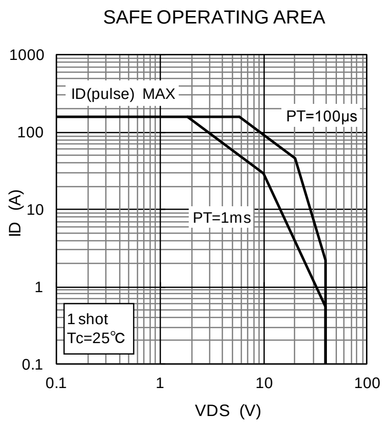
RDS(ON)-Tc characteristics (typical)

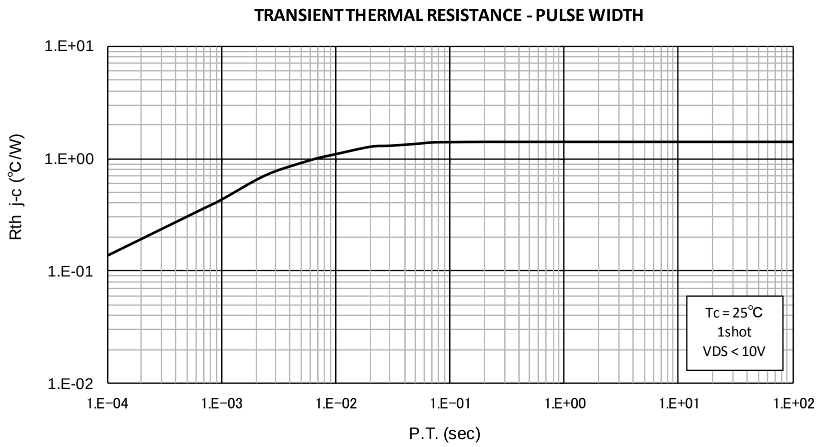


BVDSS-Tc characteristics (typical)



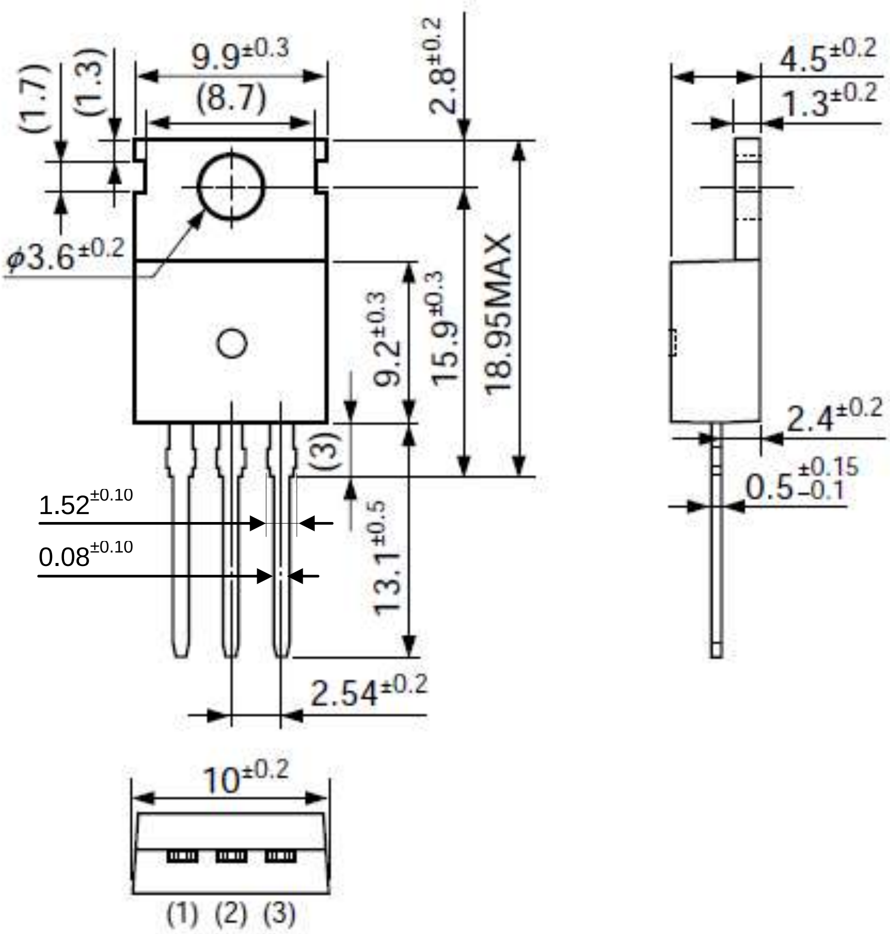

PD-Ta Derating
100
80
60
40
20
0
PD (W)
0
50
100
150
Ta (℃)
With infinite heatsink
With out heatsink


SAFE OPERATING AREA
1000
100
10
1
0.1
ID (A)
0.1
1
10
100
VDS (V)
ID(pulse) MAX
PT=100μs
PT=1ms
1 shot
Tc=25℃


TRANSIENT THERMAL RESISTANCE - PULSE WIDTH
1.E+01
1.E+00
1.E-01
1.E-02
Rth j-c (℃/W)
1.E-04
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
P.T. (sec)
Tc = 25℃
1shot
VDS < 10V

Package Outline

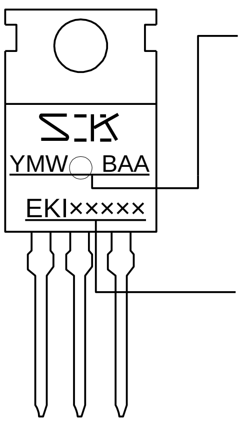
TO-220



NOTES:

1) Dimension is in millimeters
2) Pb-free. Device composition compliant with the RoHS directive

Marking Diagram



Lot Number
Y is the Last digit of the year (0 to 9)
M is the Month (1 to 9, O, N or D)
W is the Week (1st to 5th week of every month)
B expresses Pb free pins
A is the suffix No.

Part Number

OPERATING PRECAUTIONS

In the case that you use Sanken products or design your products by using Sanken products, the reliability largely depends on the degree of derating to be made to the rated values. Derating may be interpreted as a case that an operation range is set by derating the load from each rated value or surge voltage or noise is considered for derating in order to assure or improve the reliability. In general, derating factors include electric stresses such as electric voltage, electric current, electric power etc., environmental stresses such as ambient temperature, humidity etc. and thermal stress caused due to self-heating of semiconductor products. For these stresses, instantaneous values, maximum values and minimum values must be taken into consideration. In addition, it should be noted that since power devices or IC’s including power devices have large self-heating value, the degree of derating of junction temperature affects the reliability significantly.

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

Cautions for Storage

- Ensure that storage conditions comply with the standard temperature (5 to 35°C) and the standard relative humidity (around 40 to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of the products that have been stored for a long time.

Cautions for Testing and Handling

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between the product pins, and wrong connections. Ensure all test parameters are within the ratings specified by Sanken for the products.

Remarks About Using Thermal Silicone Grease

- When thermal silicone grease is used, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce excess stress.
- The thermal silicone grease that has been stored for a long period of time may cause cracks of the greases, and it cause low radiation performance. In addition, the old grease may cause cracks in the resin mold when screwing the products to a heatsink.
- Fully consider preventing foreign materials from entering into the thermal silicone grease. When foreign material is immixed, radiation performance may be degraded or an insulation failure may occur due to a damaged insulating plate.
- The thermal silicone greases that are recommended for the resin molded semiconductor should be used. Our recommended thermal silicone grease is the following, and equivalent of these.

Type	Suppliers
G746	Shin-Etsu Chemical Co., Ltd.
YG6260	Momentive Performance Materials Japan LLC
SC102	Dow Corning Toray Co., Ltd.

Cautions for Mounting to a Heatsink

- When the flatness around the screw hole is insufficient, such as when mounting the products to a heatsink that has an extruded (burred) screw hole, the products can be damaged, even with a lower than recommended screw torque. For mounting the products, the mounting surface flatness should be 0.05mm or less.
- Please select suitable screws for the product shape. Do not use a flat-head machine screw because of the stress to the products. Self-tapping screws are not recommended. When using self-tapping screws, the screw may enter the hole diagonally, not vertically, depending on the conditions of hole before threading or the work situation. That may stress the products and may cause failures.
- Recommended screw torque:

Package	Recommended Screw Torque
TO-220, TO-220F	0.490 to 0.686 N・m (5 to 7 kgf・cm)
TO-3P, TO-3PF, TO-247	0.686 to 0.882 N・m (7 to 9 kgf・cm)
SLA	0.588 to 0.784 N・m (6 to 8 kgf・cm)

- For tightening screws, if a tightening tool (such as a driver) hits the products, the package may crack, and internal stress fractures may occur, which shorten the lifetime of the electrical elements and can cause catastrophic failure. Tightening with an air driver makes a substantial impact. In addition, a screw torque higher than the set torque can be applied and the package may be damaged. Therefore, an electric driver is recommended.
  When the package is tightened at two or more places, first pre-tighten with a lower torque at all places, then tighten with the specified torque. When using a power driver, torque control is mandatory.
- Please pay special attention about the slack of the press mold. In case that the hole diameter of the heatsink is less than 4 mm, it may cause the resin crack at tightening.

Soldering

- When soldering the products, please be sure to minimize the working time, within the following limits:
  - 260 ± 5 °C 10 ± 1 s (Flow, 2 times)
  - 380 ± 10 °C 3.5 ± 0.5 s (Soldering iron, 1 time)
- Soldering should be at a distance of at least 1.5 mm from the body of the products.

Electrostatic Discharge

- When handling the products, the operator must be grounded. Grounded wrist straps worn should have at least 1MΩ of resistance from the operator to ground to prevent shock hazard, and it should be placed near the operator.
- Workbenches where the products are handled should be grounded and be provided with conductive table and floor mats.
- When using measuring equipment such as a curve tracer, the equipment should be grounded.
- When soldering the products, the head of soldering irons or the solder bath must be grounded in order to prevent leak voltages generated by them from being applied to the products.
- The products should always be stored and transported in Sanken shipping containers or conductive containers, or be wrapped in aluminum foil.

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付録 J

ハーフブリッジドライバのデータシート

参考資料

Data Sheet No. PD60207 Rev.A

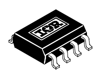
IR2302(S) & (PbF)

HALF-BRIDGE DRIVER

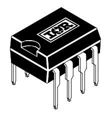
Features

- Floating channel designed for bootstrap operation
  Fully operational to +600V
  Tolerant to negative transient voltage
  dV/dt immune
- Gate drive supply range from 5 to 20V
- Undervoltage lockout for both channels
- 3.3V, 5V and 15V input logic compatible
- Cross-conduction prevention logic
- Matched propagation delay for both channels
- High side output in phase with IN input
- Logic and power ground +/- 5V offset.
- Internal 540ns dead-time
- Lower di/dt gate driver for better noise immunity
- Shut down input turns off both channels
- 8-Lead SOIC also available LEAD-FREE (PbF).

Packages



8-Lead SOIC
IR2302(S)
(Also available LEAD-FREE (PbF))



8-Lead PDIP
IR2302

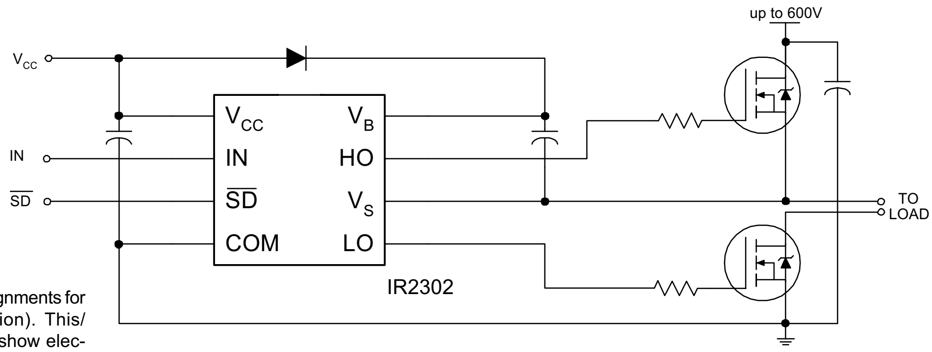
2106/2301//2108//2109/2302/2304 Feature Comparison

Part	Input logic	Cross-conduction prevention logic	Dead-Time	Ground Pins
2106/2301	HIN/LIN	no	none	COM
21064				VSS/COM
2108	HIN/$\overline{LIN}$	yes	Internal 540ns	COM
21084			Programmable 0.54~5µs	VSS/COM
2109/2302	IN/$\overline{SD}$	yes	Internal 540ns	COM
21094			Programmable 0.54~5µs	VSS/COM
2304	HIN/LIN	yes	Internal 100ns	COM

Description

The IR2302(S) are high voltage, high speed power MOSFET and IGBT drivers with dependent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. The logic input is compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 600 volts.

Typical Connection



(Refer to Lead Assignments for correct configuration). This/ These diagram(s) show electrical connections only. Please refer to our Application Notes and DesignTips for proper circuit board layout.

参考資料

Absolute Maximum Ratings

Absolute maximum ratings indicate sustained limits beyond which damage to the device may occur. All voltage parameters are absolute voltages referenced to COM. The thermal resistance and power dissipation ratings are measured under board mounted and still air conditions.

Symbol	Definition		Min.	Max.	Units
V_B	High side floating absolute voltage		-0.3	625	V
V_S	High side floating supply offset voltage		V_B - 25	V_B + 0.3	
V_{HO}	High side floating output voltage		V_S - 0.3	V_B + 0.3	
V_{CC}	Low side and logic fixed supply voltage		-0.3	25	
V_{LO}	Low side output voltage		-0.3	V_{CC} + 0.3	
V_{IN}	Logic input voltage (IN & $\overline{SD}$)		COM - 0.3	V_{CC} + 0.3	
dV_S/dt	Allowable offset supply voltage transient		—	50	V/ns
P_D	Package power dissipation @ $T_A \le +25°C$	(8 Lead PDIP)	—	1.0	W
		(8 Lead SOIC)	—	0.625	
Rth_{JA}	Thermal resistance, junction to ambient	(8 Lead PDIP)	—	125	°C/W
		(8 Lead SOIC)	—	200	
T_J	Junction temperature		—	150	°C
T_S	Storage temperature		-50	150	
T_L	Lead temperature (soldering, 10 seconds)		—	300	

Recommended Operating Conditions

The input/output logic timing diagram is shown in figure 1. For proper operation the device should be used within the recommended conditions. The V_S offset rating is tested with all supplies biased at 15V differential.

Symbol	Definition	Min.	Max.	Units
VB	High side floating supply absolute voltage	V_S + 5	V_S + 20	V
V_S	High side floating supply offset voltage	Note 1	600	
V_{HO}	High side floating output voltage	V_S	V_B	
V_{CC}	Low side and logic fixed supply voltage	5	20	
V_{LO}	Low side output voltage	0	V_{CC}	
V_{IN}	Logic input voltage (IN & $\overline{SD}$)	COM	V_{CC}	
T_A	Ambient temperature	-40	150	°C

Note 1: Logic operational for V_S of -5 to +600V. Logic state held for V_S of -5V to $-V_{BS}$. (Please refer to the Design Tip DT97-3 for more details).

Dynamic Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}) = 15V, C_L = 1000 pF, and T_A = 25°C unless otherwise specified.

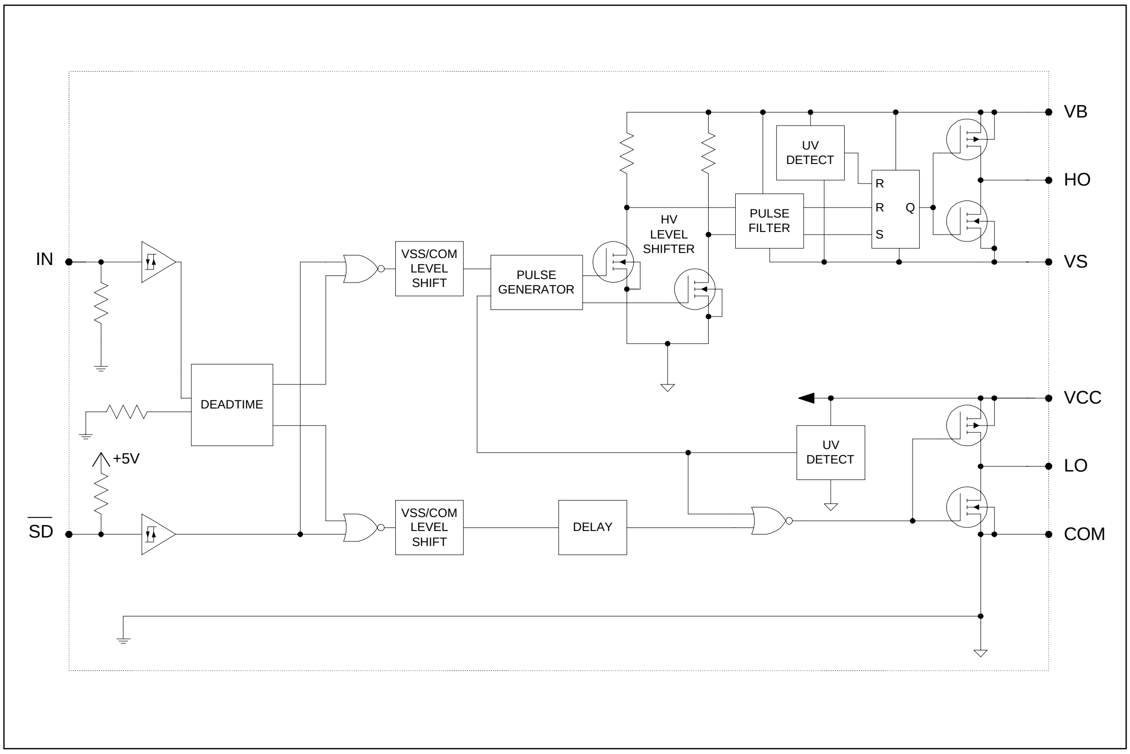
Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
t_{on}	Turn-on propagation delay	550	750	950	nsec	V_S = 0V
t_{off}	Turn-off propagation delay	—	200	280		V_S = 0V or 600V
t_{sd}	Shut-down propagation delay	—	200	280		
MT	Delay matching, HS & LS turn-on/off	—	0	50		
t_r	Turn-on rise time	—	130	220		V_S = 0V
t_f	Turn-off fall time	—	50	80		V_S = 0V
DT	Deadtime: LO turn-off to HO turn-on(DT_{LO-HO}) & HO turn-off to LO turn-on (DT_{HO-LO})	400	540	680		
MDT	Deadtime matching = DT_{LO-HO} - DT_{HO-LO}	—	0	60		

Static Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}) = 15V and T_A = 25°C unless otherwise specified. The V_{IL}, V_{IH} and I_{IN} parameters are referenced to COM and are applicable to the respective input leads: IN and $\overline{SD}$. The V_O, I_O and Ron parameters are referenced to COM and are applicable to the respective output leads: HO and LO.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
V_{IH}	Logic "1" input voltage for HO & logic "0" for LO	2.9	—	—	V	V_{CC} = 10V to 20V
V_{IL}	Logic "0" input voltage for HO & logic "1" for LO	—	—	0.8		V_{CC} = 10V to 20V
$V_{SD,TH+}$	$\overline{SD}$ input positive going threshold	2.9	—	—		V_{CC} = 10V to 20V
$V_{SD,TH-}$	$\overline{SD}$ input negative going threshold	—	—	0.8		V_{CC} = 10V to 20V
V_{OH}	High level output voltage, V_{BIAS} - V_O	—	0.8	1.4		I_O = 20 mA
V_{OL}	Low level output voltage, V_O	—	0.3	0.6		I_O = 20 mA
I_{LK}	Offset supply leakage current	—	—	50	µA	V_B = V_S = 600V
I_{QBS}	Quiescent V_{BS} supply current	20	60	100		V_{IN} = 0V or 5V
I_{QCC}	Quiescent V_{CC} supply current	0.4	1.0	1.6	mA	V_{IN} = 0V or 5V
I_{IN+}	Logic "1" input bias current	—	5	20	µA	IN = 5V, SD = 0V
I_{IN-}	Logic "0" input bias current	—	—	2		IN = 0V, $\overline{SD}$ = 5V
V_{CCUV+} V_{BSUV+}	V_{CC} and V_{BS} supply undervoltage positive going threshold	3.3	4.1	5	V	
V_{CCUV-} V_{BSUV-}	V_{CC} and V_{BS} supply undervoltage negative going threshold	3	3.8	4.7		
V_{CCUVH} V_{BSUVH}	Hysteresis	0.1	0.3	—		
I_{O+}	Output high short circuit pulsed vurrent	120	200	—	mA	V_O = 0V, PW ≤ 10 µs
I_{O-}	Output low short circuit pulsed current	250	350	—		V_O = 15V,PW ≤ 10 µs

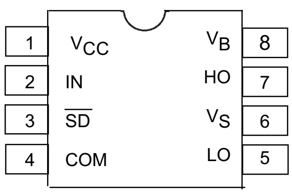
Functional Block Diagrams



Lead Definitions

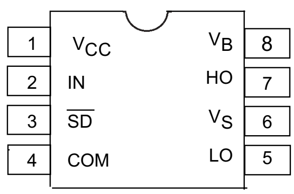
Symbol	Description
IN	Logic input for high and low side gate driver outputs (HO and LO), in phase with HO
$\overline{SD}$	Logic input for shutdown
V_B	High side floating supply
HO	High side gate drive output
V_S	High side floating supply return
V_{CC}	Low side and logic fixed supply
LO	Low side gate drive output
COM	Low side return

Lead Assignments



8 Lead PDIP

IR2302



8 Lead SOIC
(Also available LEAD-FREE (PbF)

IR2302S

参考資料

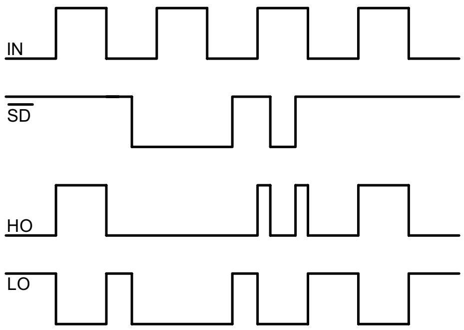


Figure 1. Input/Output Timing Diagram

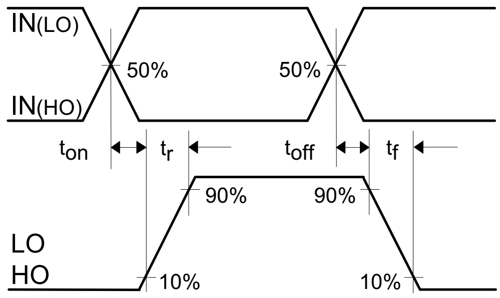


Figure 2. Switching Time Waveform Definitions

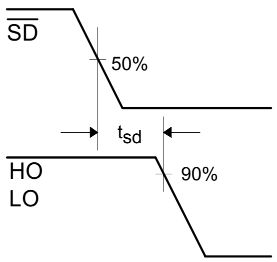


Figure 3. Shutdown Waveform Definitions

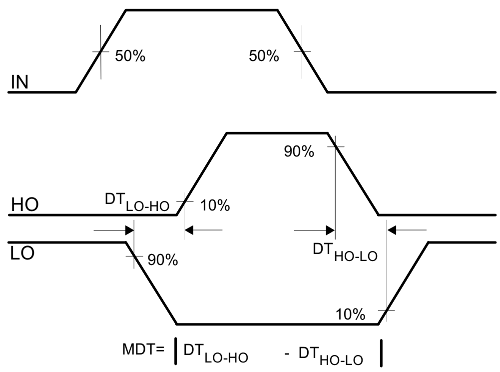


Figure 4. Deadtime Waveform Definitions

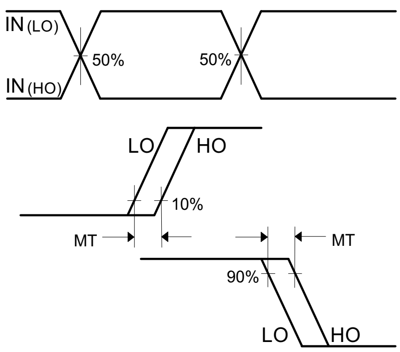


Figure 5. Delay Matching Waveform Definitions

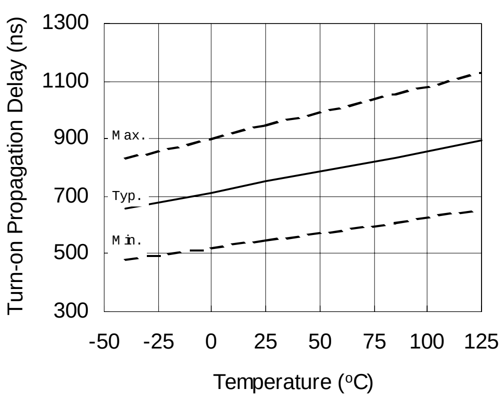


Figure 6A. Turn-on Propagation Delay vs. Temperature

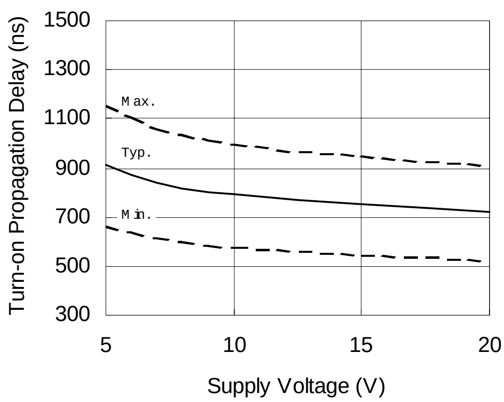


Figure 6B. Turn-on Propagation Delay vs. Supply Voltage

参考資料

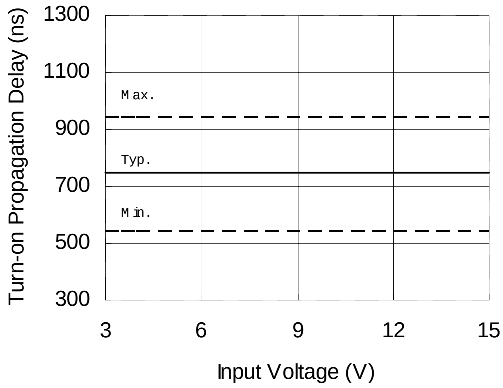


Figure 6C. Turn-on Propagation Delay vs. Input Voltage

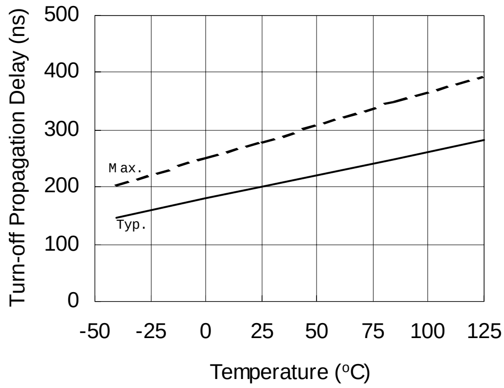


Figure 7A. Turn-off Propagation Delay vs. Temperature

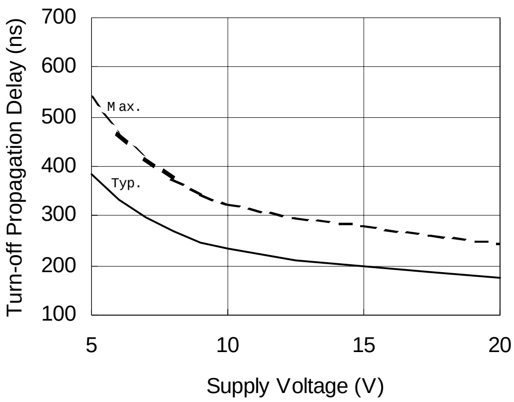


Figure 7B. Turn-off Propagation Delay vs. Supply Voltage

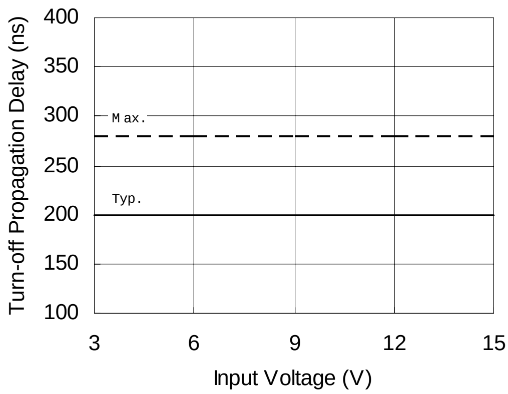


Figure 7C. Turn-off Propagation Delay vs. Input Voltage

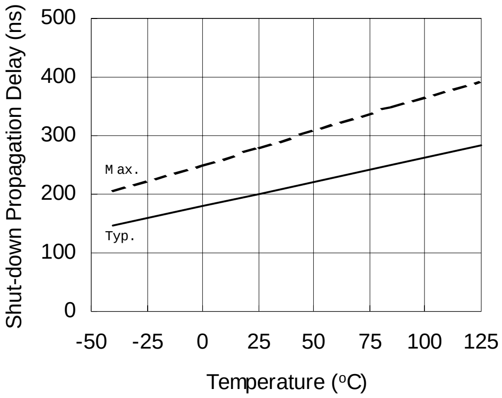


Figure 8A. Shut-down Propagation Delay vs. Temperature

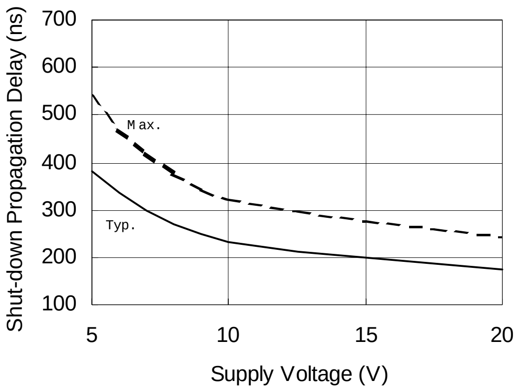


Figure 8B. Shut-down Propagation Delay vs. Supply Voltage

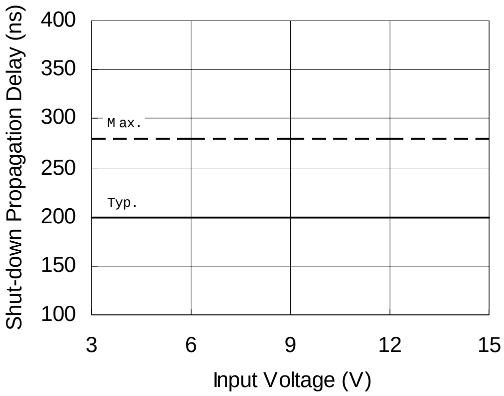


Figure 8C. Shut-down Propagation Delay vs. Input Voltage

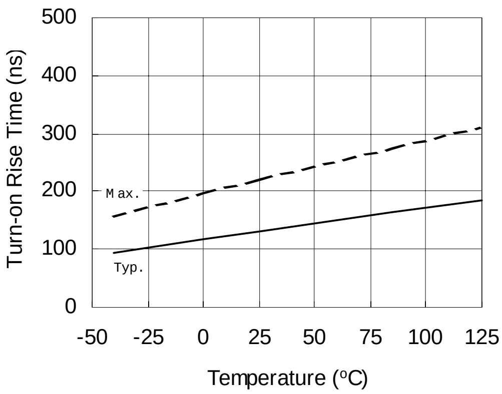


Figure 9A. Turn-on Rise Time vs. Temperature

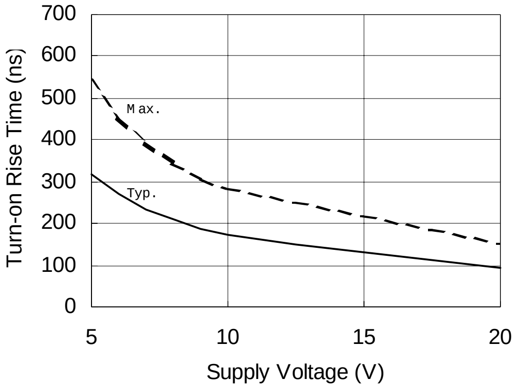


Figure 9B. Turn-on Rise Time vs. Supply Voltage

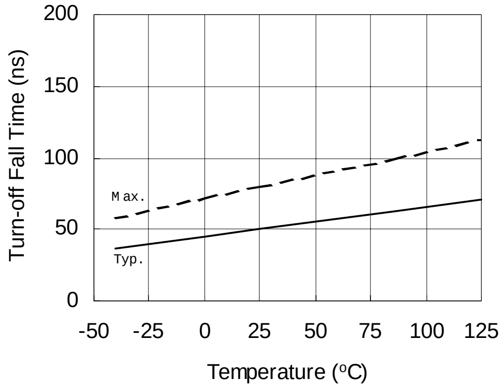


Figure 10A. Turn-off Fall Time vs. Temperature

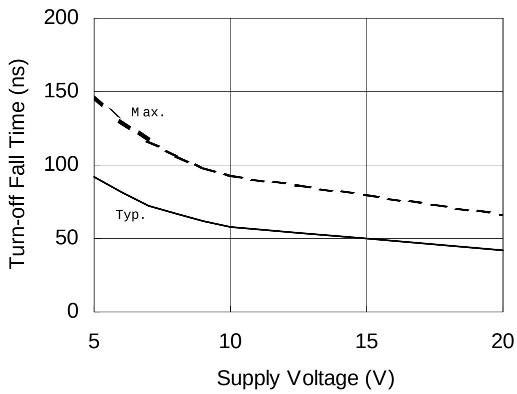


Figure 10B. Turn-off Fall Time vs. Supply Voltage

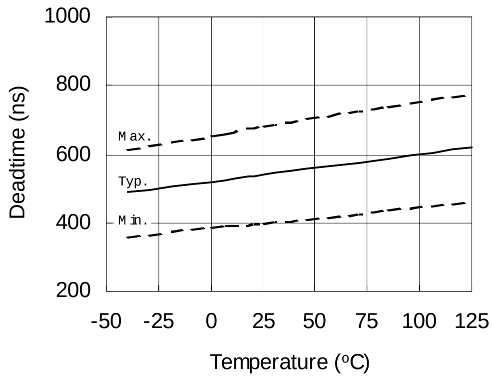


Figure 11A. Deadtime vs. Temperature

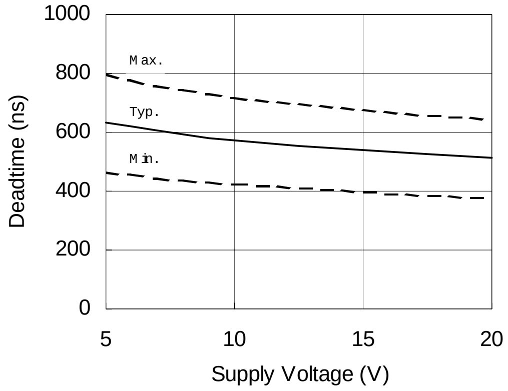


Figure 11B. Deadtime vs. Supply Voltage

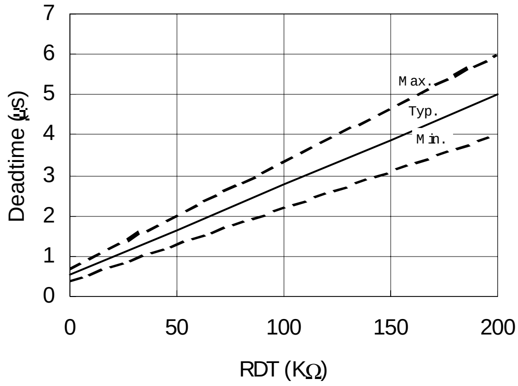


Figure 11C. Deadtime vs. RDT

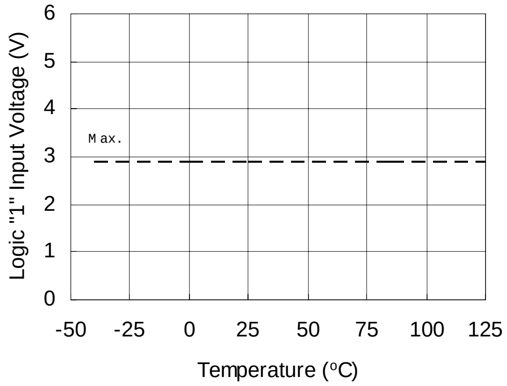


Figure 12A. Logic "1" Input Voltage vs. Temperature

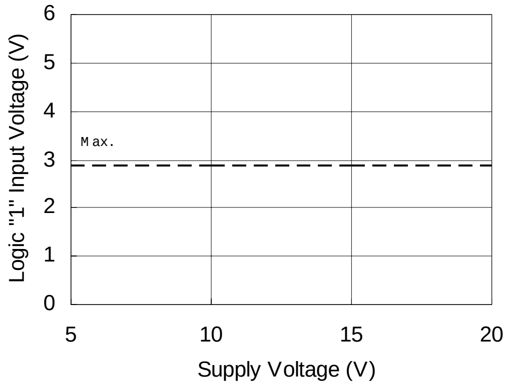


Figure 12B. Logic "1" Input Voltage vs. Supply Voltage

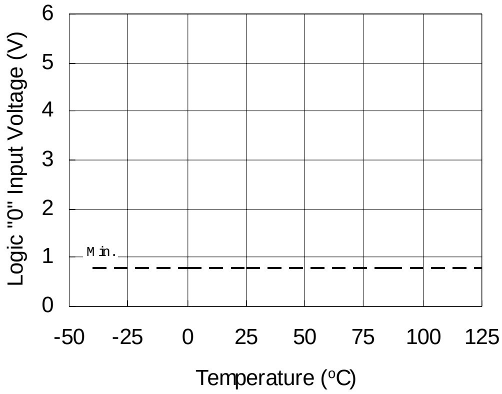


Figure 13A. Logic "0" Input Voltage vs. Temperature

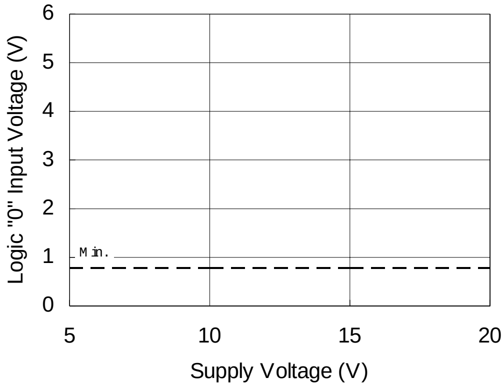


Figure 13B. Logic "0" Input Voltage vs. Supply Voltage

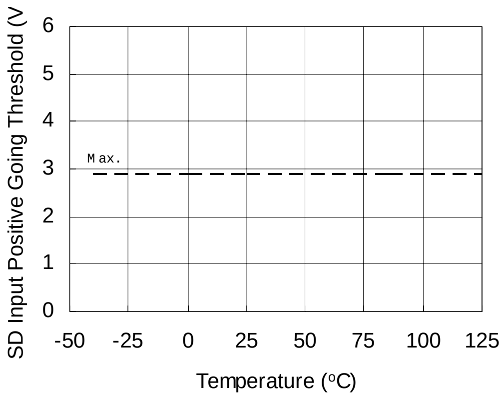


Figure 14A. SD Input Positive Going Threshold vs. Temperature

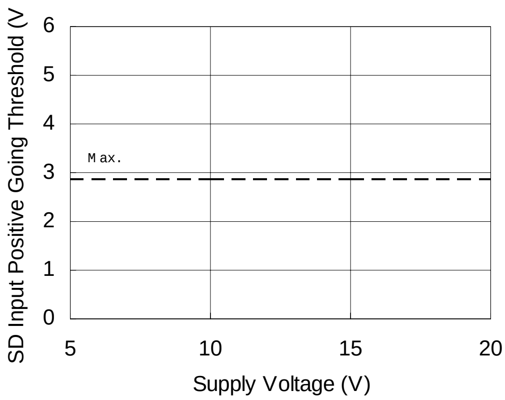


Figure 14B. SD Input Positive Going Threshold vs. Supply Voltage

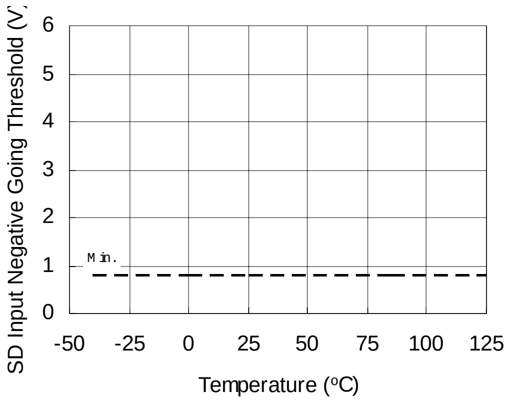


Figure 15A. SD Input Negative Going Threshold vs. Temperature

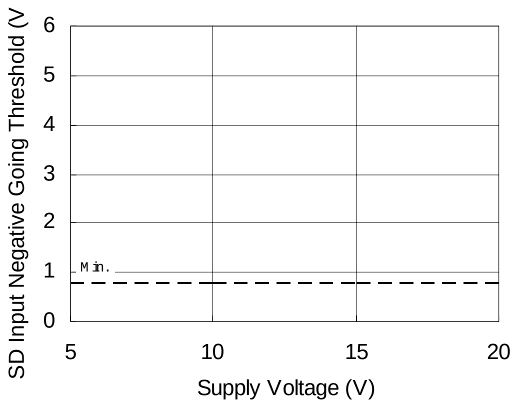


Figure 15B. SD Input Negative Going Threshold vs. Supply Voltage

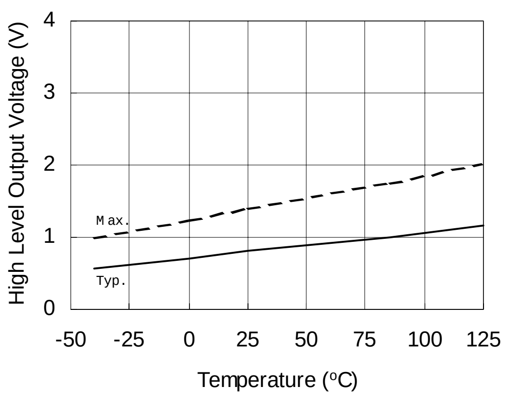


Figure 16A. High Level Output Voltage vs. Temperature

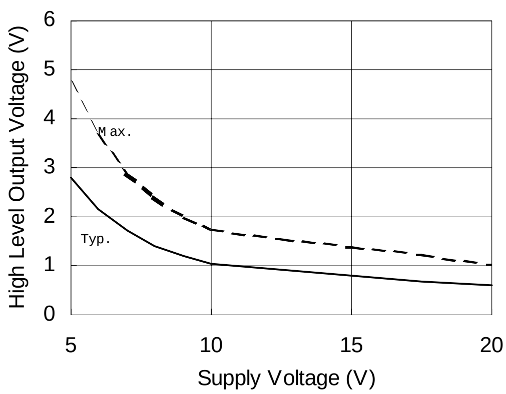


Figure 16B. High Level Output Voltage vs. Supply Voltage

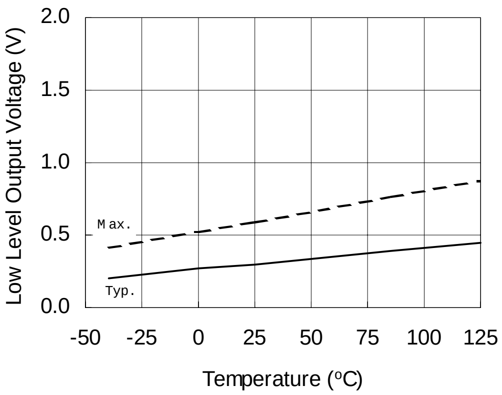


Figure 17A. Low Level Output Voltage vs. Temperature

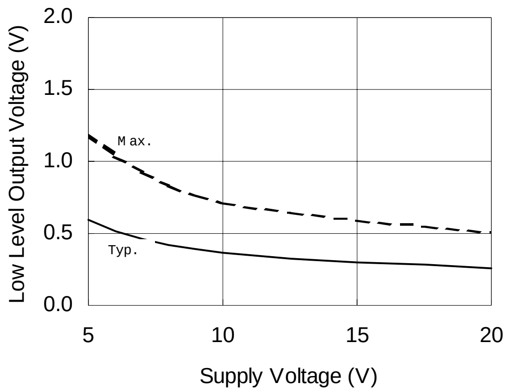


Figure 17B. Low Level Output Voltage vs. Supply Voltage

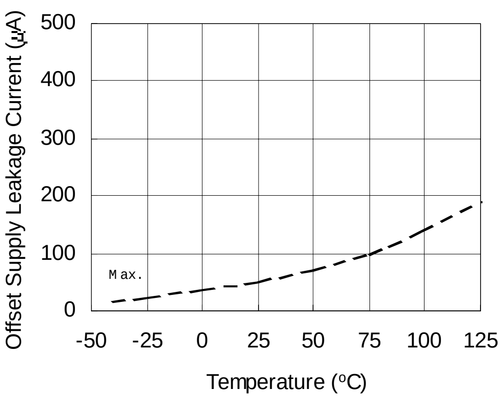


Figure 18A. Offset Supply Leakage Current vs. Temperature

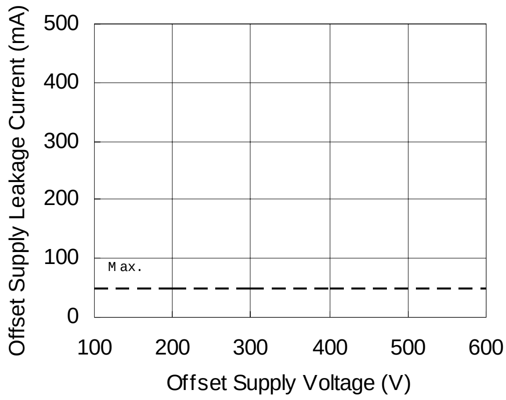


Figure 18B. Offset Supply Leakage Current vs. Offset Supply Voltage

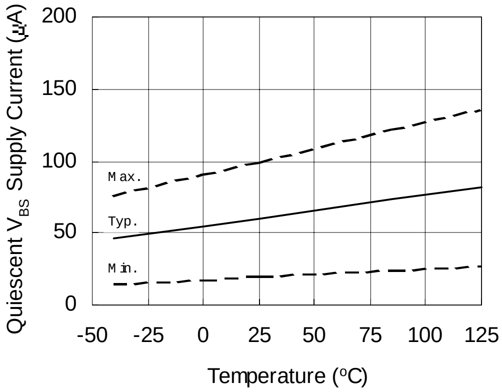


Figure 19A. Quiescent V_{BS} Supply Current vs. Temperature

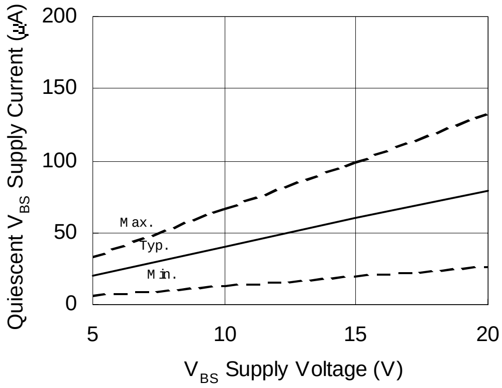


Figure 19B. Quiescent V_{BS} Supply Current vs. V_{BS} Supply Voltage

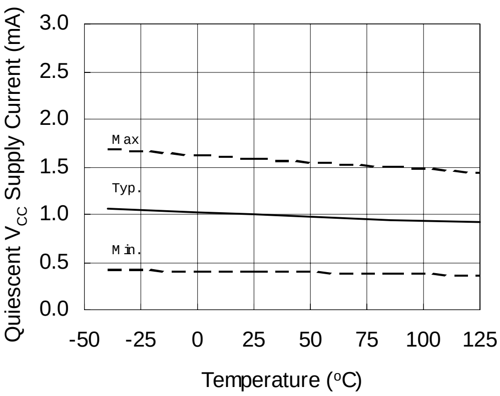


Figure 20A. Quiescent V_{CC} Supply Current vs. Temperature

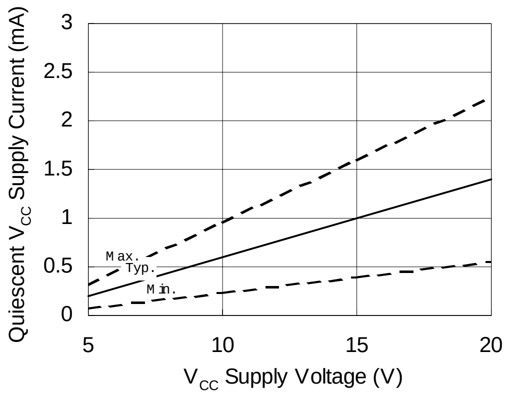


Figure 20B. Quiescent V_{CC} Supply Current vs. V_{CC} Supply Voltage

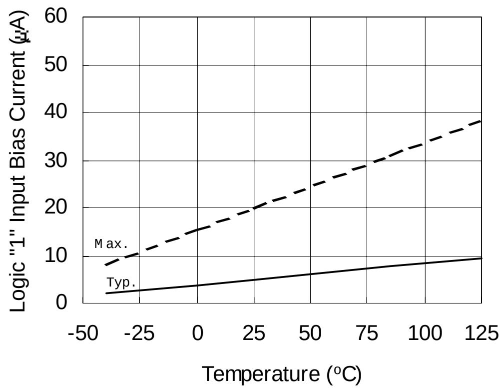


Figure 21A. Logic "1" Input Bias Current vs. Temperature

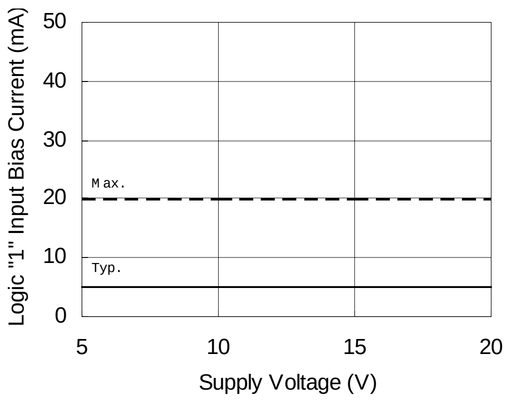


Figure 21B. Logic "1" Input Bias Current vs. Supply Voltage

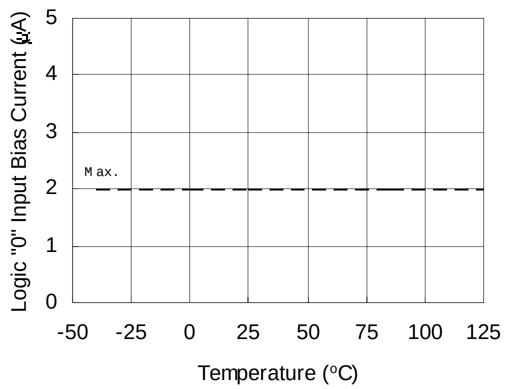


Figure 22A. Logic "0" Input Bias Current vs. Temperature

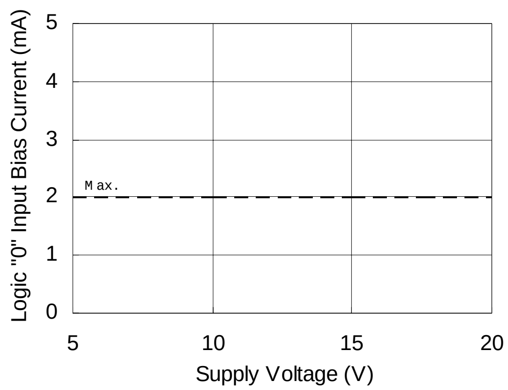


Figure 22B. Logic "0" Input Bias Current vs. Supply Voltage

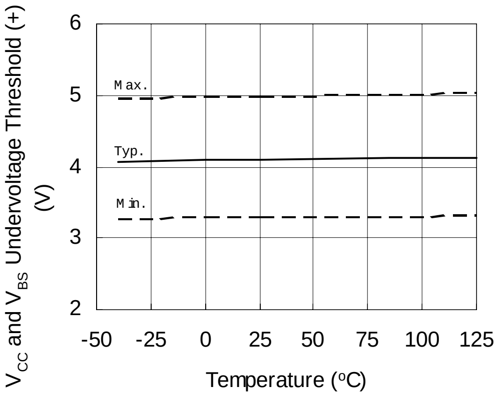


Figure 23. V_{CC} and V_{BS} Undervoltage Threshold (+) vs. Temperature

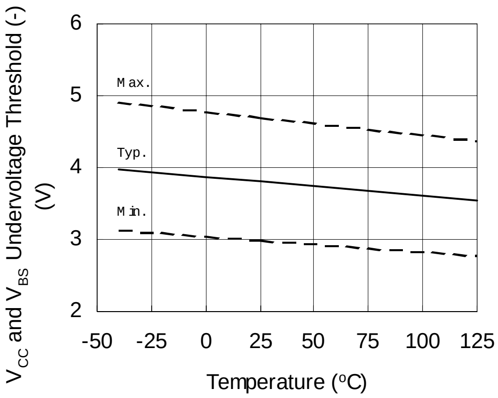


Figure 24. V_{CC} and V_{BS} Undervoltage Threshold (-) vs. Temperature

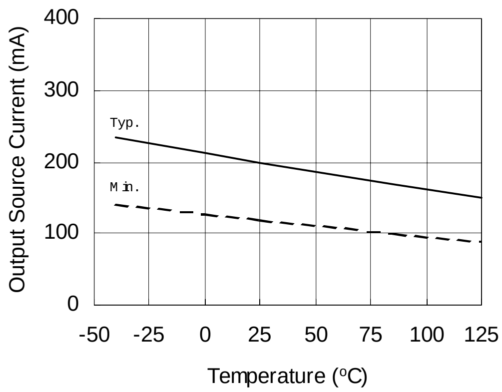


Figure 25A. Output Source Current vs. Temperature

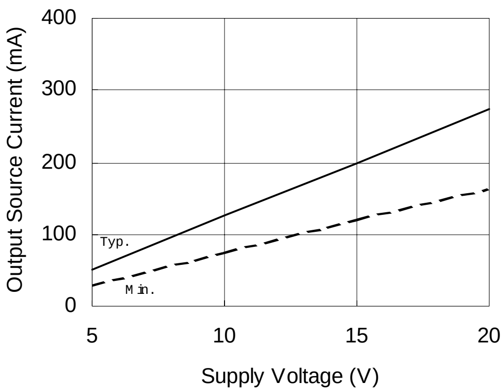


Figure 25B. Output Source Current vs. Supply Voltage

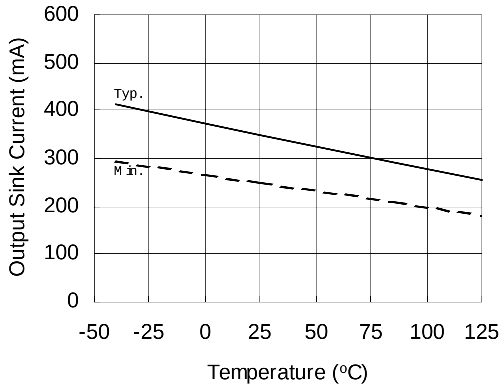


Figure 26A. Output Sink Current vs. Temperature

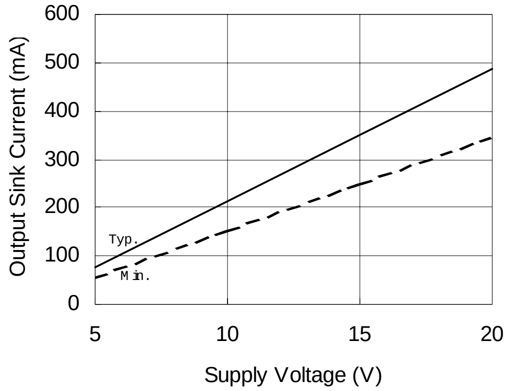


Figure 26B. Output Sink Current vs. Supply Voltage

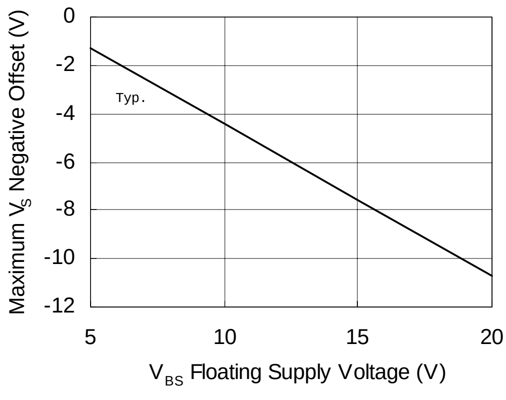


Figure 27. Maximum V_S Negative Offset vs. V_{BS} Floating Supply Voltage

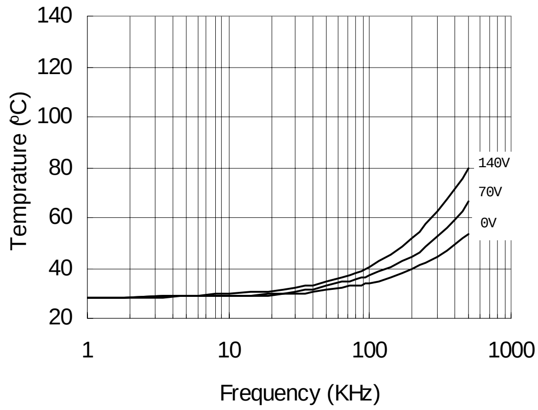


Figure 28. IR2302 vs. Frequency (IRFBC20), R_{gate}=33Ω, V_{CC}=15V

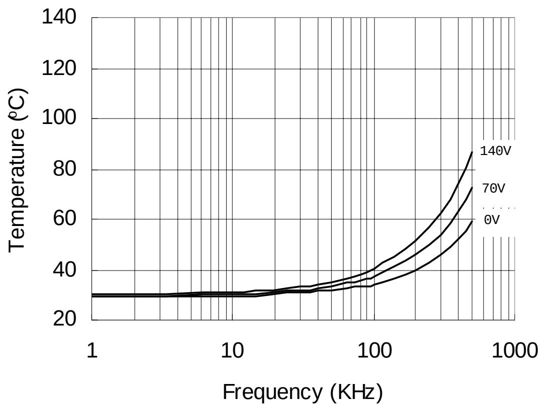


Figure 29. IR2302 vs. Frequency (IRFBC30), R_{gate}=22Ω, V_{CC}=15V

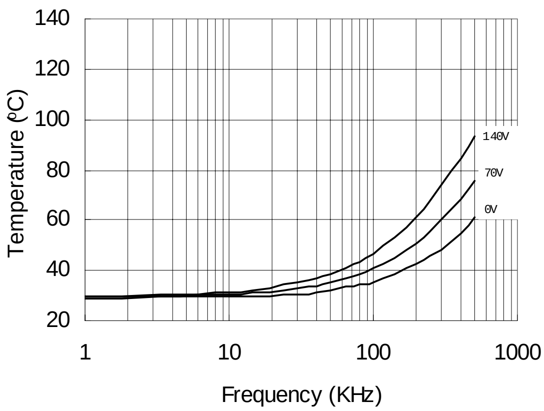


Figure 30. IR2302 vs. Frequency (IRFBC40), R_{gate}=15Ω, V_{CC}=15V

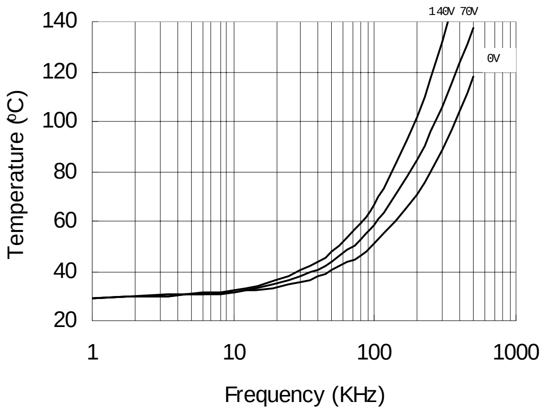


Figure 31. IR2302 vs. Frequency (IRFPE50), R_{gate}=10Ω, V_{CC}=15V

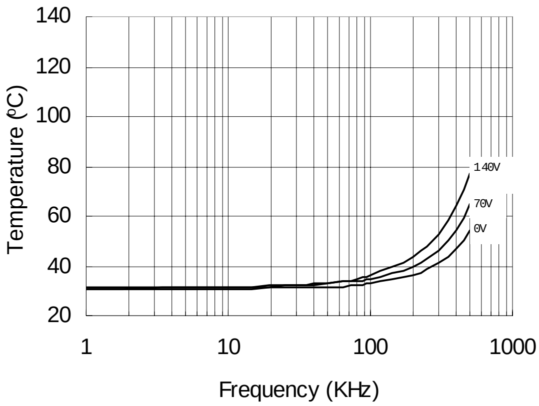


Figure 32. IR2302S vs. Frequency (IRFBC20), R_{gate}=33Ω, V_{CC}=15V

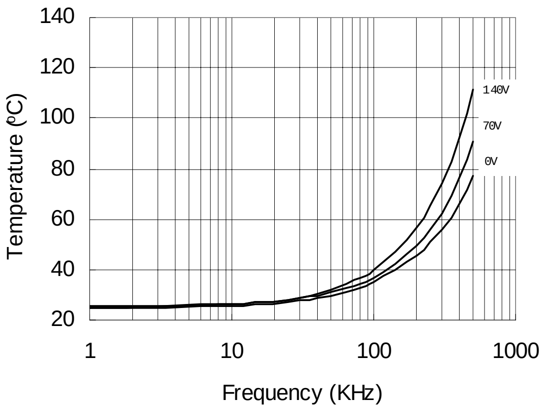


Figure 33. IR2302S vs. Frequency (IRFBC30), R_{gate}=22Ω, V_{CC}=15V

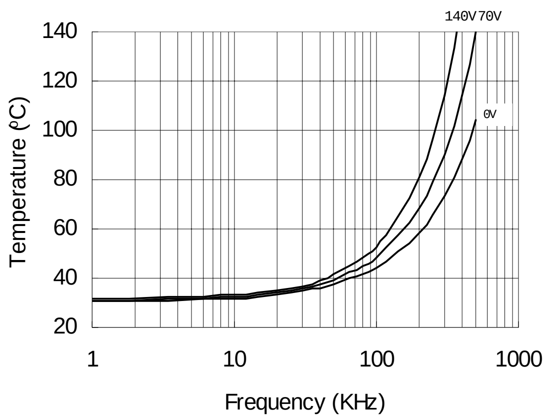


Figure 34. IR2302S vs. Frequency (IRFBC40), R_{gate}=15Ω, V_{CC}=15V

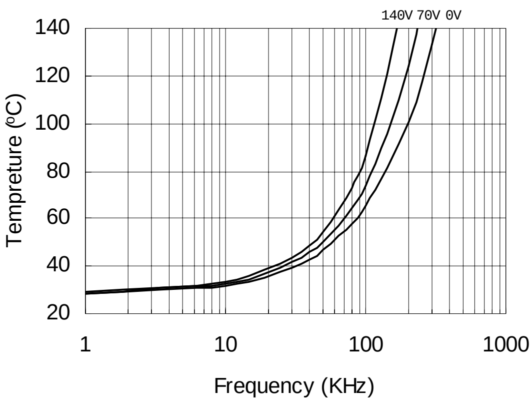
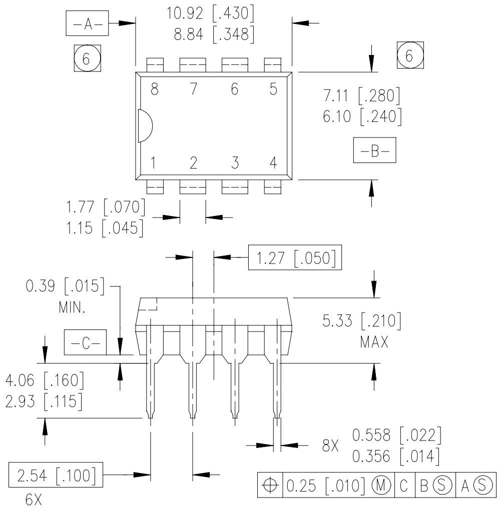
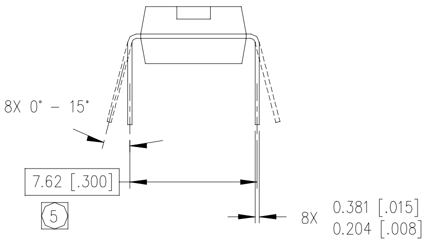


Figure 35. IR2302S vs. Frequency (IRFPE50), R_{gate}=10Ω, V_{CC}=15V

Case Outlines

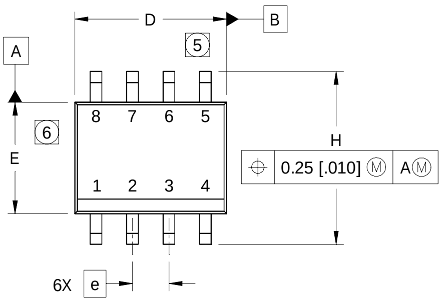


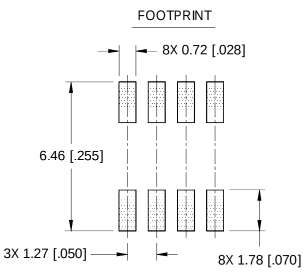
NOTES:
1. DIMENSIONING & TOLERANCING PER ANSI Y14.5M-1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSIONS ARE SHOWN IN MILLIMETERS [INCHES].
4. OUTLINE CONFORMS TO JEDEC OUTLINE MS-001AB.
5. MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO DATUM PLANE C.
6. DIMENSION DOES NOT INCLUDE MOLD PROTUSIONS. MOLD PROTUSIONS SHALL NOT EXCEED 0.25 [.010].



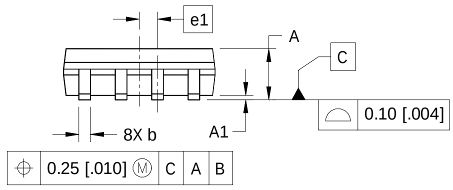
8 Lead PDIP

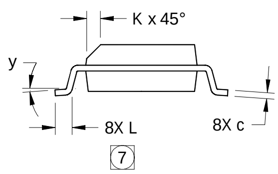
01-6014
01-3003 01 (MS-001AB)





DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.0532	.0688	1.35	1.75
A1	.0040	.0098	0.10	0.25
b	.013	.020	0.33	0.51
c	.0075	.0098	0.19	0.25
D	.189	.1968	4.80	5.00
E	.1497	.1574	3.80	4.00
e	.050 BASIC		1.27 BASIC	
e 1	.025 BASIC		0.635 BASIC	
H	.2284	.2440	5.80	6.20
K	.0099	.0196	0.25	0.50
L	.016	.050	0.40	1.27
y	0°	8°	0°	8°





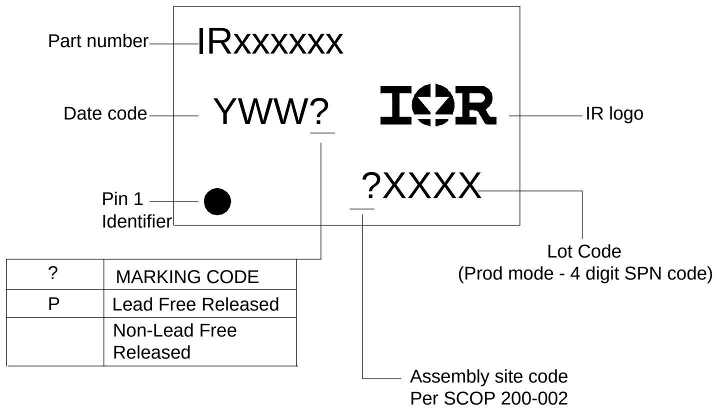
NOTES:
1. DIMENSIONING & TOLERANCING PER ASME Y14.5M-1994.
2. CONTROLLING DIMENSION: MILLIMETER
3. DIMENSIONS ARE SHOWN IN MILLIMETERS [INCHES].
4. OUTLINE CONFORMS TO JEDEC OUTLINE MS-012AA.
5. DIMENSION DOES NOT INCLUDE MOLD PROTRUSIONS. MOLD PROTRUSIONS NOT TO EXCEED 0.15 [.006].
6. DIMENSION DOES NOT INCLUDE MOLD PROTRUSIONS. MOLD PROTRUSIONS NOT TO EXCEED 0.25 [.010].
7. DIMENSION IS THE LENGTH OF LEAD FOR SOLDERING TO A SUBSTRATE.

8 Lead SOIC

01-6027
01-0021 11 (MS-012AA)

参考資料

LEADFREE PART MARKING INFORMATION



ORDER INFORMATION

Basic Part (Non-Lead Free)
8-Lead PDIP IR2302 order IR2302
8-Lead SOIC IR2302S order IR2302S

Leadfree Part
8-Lead PDIP R2302 not available
8-Lead SOIC IR2302S order IR2302SPbF

International
IOR Rectifier

Thisproduct has been designed and qualified for the Industrial market.
Qualification Standards can be found on IR's Web Site *http://www.irf.com*
Data and specifications subject to change without notice.
IR WORLD HEADQUARTERS: 233 Kansas St., El Segundo, California 90245 Tel: (310) 252-7105
8/16/2004