Application Note 32
Issue 1 January 2000

Features and Applications of the ZDS1009 Current Mirror/Level Translator

Neil Chadderton

Introduction

The ZDS1009 current mirror has been developed specifically for high side, current sense plus level translation applications and as such will find a broad applications base including battery charge management, DC motor control and over current monitoring functions. It is of particular interest for current sense applications for feedback purposes in fast battery chargers for Li-Ion cell based systems. The device functions by sensing the voltage developed across an external (user defined) high side current sense resistor, and by an arrangement of current mirrors refers this sensed voltage, with or without multiplication, to a low side referenced signal. This signal can then be used to close the control loop to the controller IC, for the DC-DC converter providing the charge to the battery.

Features and Benefits

- High side Current Sense and Referencing to Low Side
- Signal Multiplication
- Excellent Temperature Tracking Characteristic
- Compact, Cost Effective Solution
- Only Four Connections Required
- Low Component Count
- Simplifies Circuit Implementation
- Broad Application Base from Single cell Li-Ion chargers to Multi-cell Lead-Acid systems
- DC Motor Control
- Over Current Monitors

Typical End Products

- Battery chargers, particularly Li-Ion based systems, for either stand alone units or support units for portable systems including: Cellphones, GPS systems, POS terminals, medical monitors, dataloggers, test equipment and instrumentation
- DC motor controller systems
- Over current monitors
- Battery conditioning and monitoring systems

Description

The part is supplied in an eight lead package, the SM8, (see Appendix B) and requires only four connections into the circuit and four external resistors to effect a complete, accurate and cost effective current sense plus level translation circuit. The maximum operating ratings of the part are 30V and 1A, though in practice the operating current is likely to be of the order of a few mA at most.

The part is connected into the circuit using the E1, E2, E3 and E4 pins, corresponding to the Emitter nodes on the functional diagram shown in Figure 1. The other pins of the ZDS1009 are normally unused, though some applications may use the X2 or Y2 nodes (see Applications considerations later). For most applications all pins other than the E1-4 pins are left open circuit.

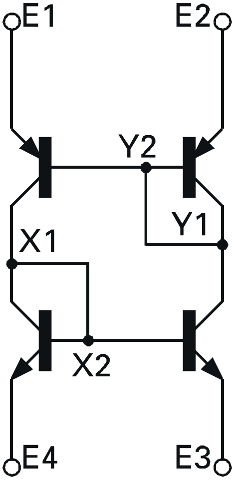


Figure 1
Functional Diagram

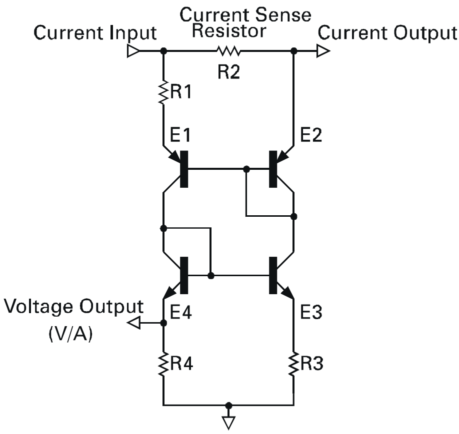


Figure 2
Typical Application Circuit.

The device operates by current mirror action. The voltage developed across the current sense resistor (R2 in Figure 2) for example, by the charging current in a battery charging system,is also developed across R1 due to the inherent matching of the PNPs (defining the same I_C for a given V_{BE}). As the current flowing through R1 also flows through R4 (less the base current of E3 and E1) then if R4 equals R1, R4 will also develop the same voltage across it as R2, but referenced to the low side of R3 and R4. Therefore the high side sensed voltage (representing the current) has been referred to the low side. By adjustment of the R1 and R4 ratio, multiplication factors can be introduced into the loop, to provide the scaled value as required for a controller IC for example.

Typical Application Circuit

The part is used as shown in the typical application circuit of Figure 2.
For example, with R2=200mΩ and R1=R3=R4=100Ω, this circuit would provide a current to voltage sensitivity of 200mV/A.

The components used with the ZDS1009 are detailed below:

1. R2 is an high side current sense resistor through which the current to be sensed is passed. In the case of a fast battery charger, R2 would be placed after the switching regulator that provides the constant current/voltage as required by the battery chemistry being employed. For other applications, the power supply input would be applied to the junction of R1 and R2. The junction of R2 and E2 being connected to the load/battery.

2. The scaling resistors R1 and R4 are used to set the multiplication factor required, to provide the full scale input voltage as defined by the charge current I, R2 and the sensitivity of the controller's feedback pin. The transfer equation is:

V_{sense}=I x R2 x R4/R1 (R4=R3)

3. R3 is used for balancing purposes, to ensure that the current passing through each limb of the device is equal, thereby reducing the offset voltage at the output pin. The offset voltage produced by the part potentially introduces inaccuracies into the control loop, so an appreciation of the likely magnitude of the offset voltage is important to gauge the effects on a particular circuit. The chart shown in Figure 3 shows the offset voltage obtained at the output pin (E4) with zero current flowing through R2. This is for a circuit configured similarly to that of Figure 2, but with R2 having a value of 330mΩ, providing a sensitivity of 330mV/A. R1, R3 and R4 are again equal to 100Ω. This shows that 71% of parts have an offset less than 300µV, and 89% have an offset less than 1.48mV. Internal process changes have reduced the percentage of parts with higher offset values such that the internal test limit used at Production Test is now set to guarantee a 4mV maximum for this parameter.

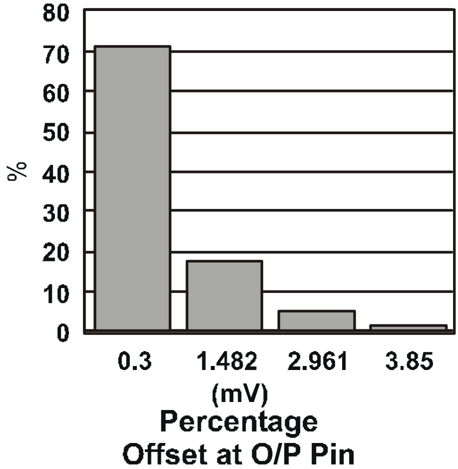


Figure 3
Offset Voltage Obtained at the Output Pin (E4) with Zero Current Flowing Through R1.

4. A suggested layout for an evaluation PCB with suggested components is given in Appendix A.

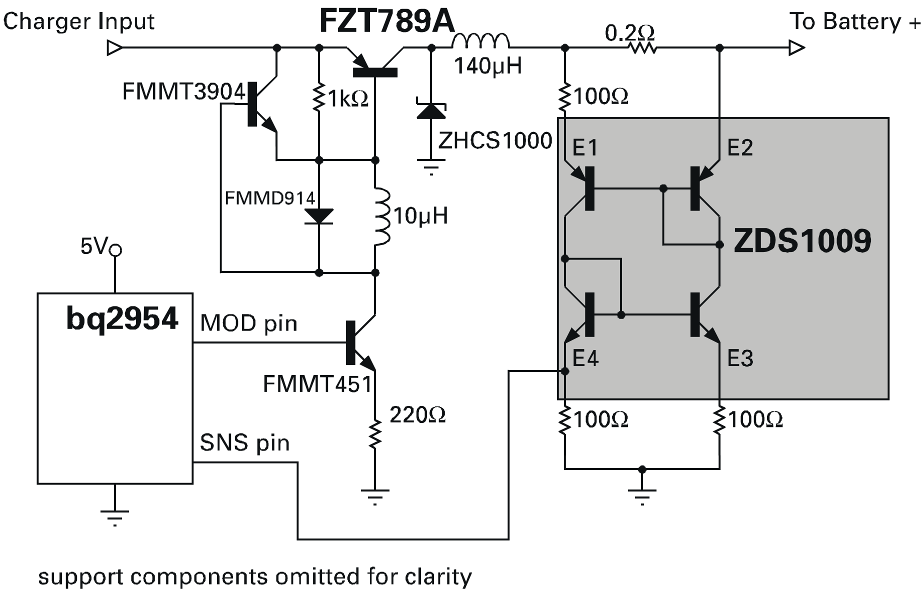


Figure 4
The ZDS1009 Supporting the Benchmarq bq2954 Charge Management IC.

Li-Ion Charger Circuit

Figure 4 shows the ZDS1009 supporting the Benchmarq bq2954 Charge Management IC. Most of the support components for the bq2954 are omitted for clarity. This design also uses the Zetex FZT789A high current Super-β PNP as the switching transistor in the DC-DC step down converter and the FMMT451 as the drive NPN for the FZT789A. The evaluation circuit as presented in reference 2 Appendix C, can be configured to charge up to four Li-Ion cells at a charge current of 1.25A. Charge can be terminated on maximum voltage, selectable minimum current, or maximum time out. Switching frequency of the PWM loop is approximately 120kHz. Complete details of the bq2954 and its supporting evaluation board can be found via the references given in Appendix C.

Application Considerations

1. It is desirable to minimize the current through the two limbs of the mirror to prevent internal temperature differentials and to maintain the desired output current - the output current can be reduced by the ZDS1009 (outer) limb current depending on resistor values, and so this may introduce a slight error. This can be corrected if desired with an additional offset.

2. Observe the minimum operation voltage, (termed Output cut-off voltage on the datasheet). This should not be problem in the majority of circuits as this minimum is lower than common single cell voltages.

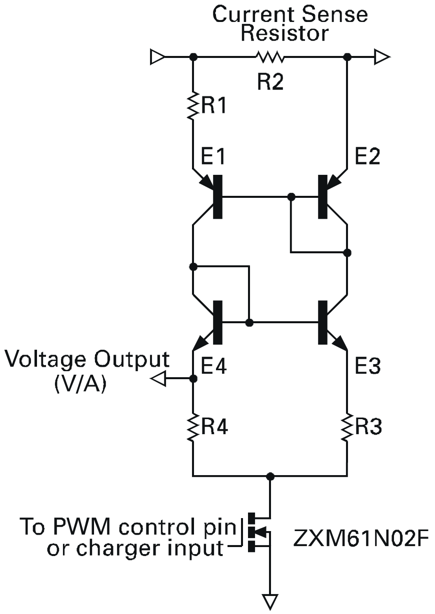


Figure 5
Minimising Quiescent Current.

3. In some battery life critical applications, the quiescent current of the ZDS1009 (~50µA for the circuit shown in Figure 2 and when the charger is not operating) may be considered an undesirable current drain on the system battery. In these circumstances, an N Channel MOSFET may be used to disconnect the low side terminals of the mirror, when the current sense function is not required. See Figure 5.

4. For operation at very low temperatures (<-20°C), it may be necessary to include an additional resistor connected between Y2 and ground. See Figure 6. This is to kick-start the normal self feeding (initiated by transistor leakage current) current mirror action - at low temperatures, the transistor leakage may be reduced below the value where the current mirrors can self-start.

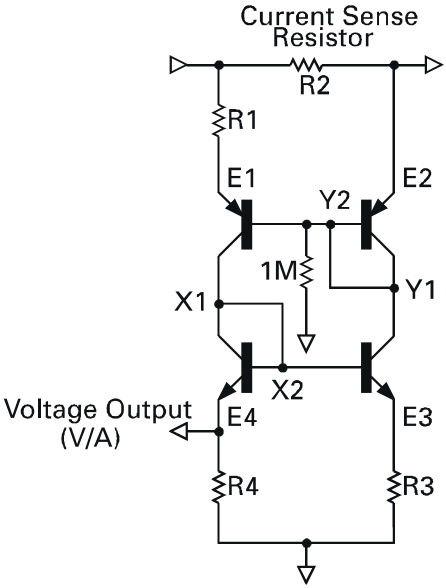


Figure 6
Operation at Low Temperature.

Suggested Evaluation PCB.

A suggested PCB layout to permit evaluation of the ZDS1009 is shown in Figure 8 (derived from the schematic of Figure 7). Of course it is likely that this subcircuit would likely be reproduced as part of the intended system, but is included here for interest.

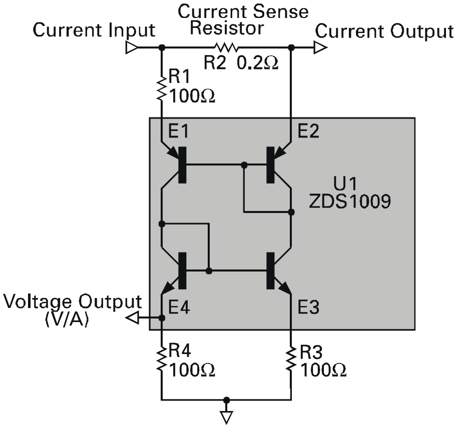


Figure 7
Typical Application Circuit for the ZDS1009.

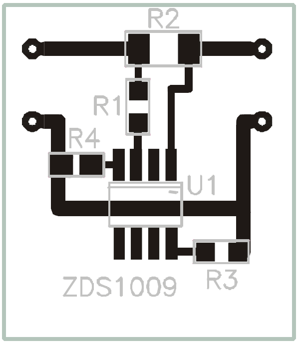


Figure 8
Suggested PCB Layout to Allow Evaluation of the ZDS1009 Current Mirror and Level Translator.

Designation	Quantity	Description	Package	Source
U1	1	ZDS1009 Current Mirror + Level Translator	SM8	Zetex
R2	1	LR2010-01-R200-F 200mΩ, 1%	2010	IRC
R1,R3,R4	3	PCF-W1206R-03-1000-B 100Ω, 0.1%	1206	IRC

Component Suppliers
Resistors

IRC, Corpus Christi, TX 78411
Tel: (361)-992-7900 FAX: (361)-992-3377
http://www.irctt.com

ZDS1009

SM-8 COMPLEMENTARY CURRENT MIRROR

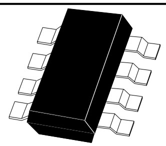
DESCRIPTION

The ZDS1009 current mirror has been developed specifically for high side, current sense plus level translation applications and as such will find a broad applications base including battery charge management, DC motor control and over current monitoring functions. It is of particular interest for current sense applications for feedback purposes in fast battery chargers for Li-Ion cell based systems.

The device functions by sensing the voltage developed across an external (user defined) high side current sense resistor, and by an arrangement of current mirrors refer this sensed voltage, with or without multiplication, to a low side referenced signal. This signal can then be used, for example, to close the control loop to a controller IC, for a DC-DC converter providing charge to a battery.

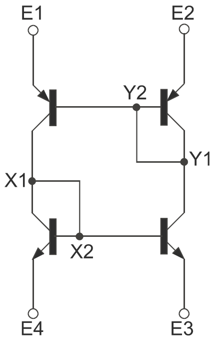
FEATURES

- Excellent Temperature Tracking Characteristics
- Compact Cost Effective Solution
- Simplifies Circuit Implementation
- Broad application base from Single Cell Li-ion High Side Current sense chargers to Multi-cell Lead-Acid systems
- Only 4 Connections required



SM-8
(8 LEAD SOT223)

SCHEMATIC DIAGRAM



TYPICAL APPLICATION CIRCUIT

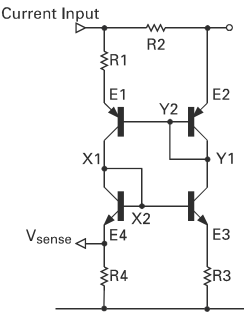
$$V_{sense} = IR_2 \frac{R_4}{R_1}$$

For balance R3=R4

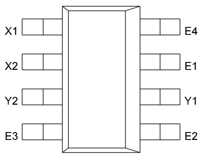
eg

R2=100mΩ
R1=R3=R4=100Ω

V_{sense} sensitivity = 100mV/A



CONNECTION DIAGRAM



ZDS1009

ABSOLUTE MAXIMUM RATINGS.

PARAMETER	SYMBOL	VALUE	UNIT
Maximum Operating Voltage	V_{y1-x1}	120	V
Maximum Voltage (E1-E2,E3-E4)	$V_{E-E'}$	10	V
Peak Pulse Current	I_M	4	A
Continuous Current (E1-E4,E2-E3)	I_C	1	A
Total Power Dissipation at T_{amb} = 25°C*	P_{tot}	2	W
Operating and Storage Temperature Range	T_j:T_{stg}	-55 to +150	°C

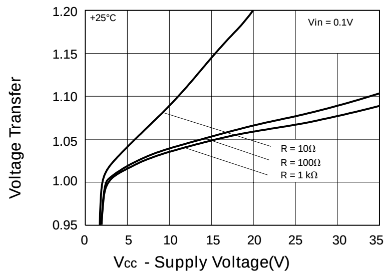
* The power which can be dissipated assuming the device is mounted in a typical manner on a PCB with copper equal to 2 inches square.

ELECTRICAL CHARACTERISTICS (at T_{amb}=25°C)

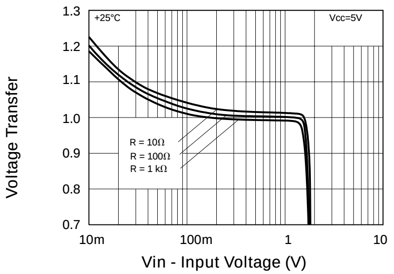
Parameter	Symbol	Min	Max	Unit	Conditions
Breakdown Voltage	BV_{Y1-X1}	120		V	I_{Y1}=100µA
Breakdown Voltage	BV_{X1-E1}	-30		V	I_{X1}=-10mA
Breakdown Voltage	BV_{Y1-E3}	30		V	I_{Y1}=10mA
Breakdown Voltage	BV_{E1-Y1}	-12		V	I_{E1}=-100µA
Breakdown Voltage	BV_{E2-Y1}	-6		V	I_{E2}=-100µA
Breakdown Voltage	BV_{E3-X1}	12		V	I_{E3}=100µA
Breakdown Voltage	BV_{E4-X1}	6		V	I_{E4}=100uA
Leakage	I_{Y1}		50	nA	V_{Y1-X1}=100V
Leakage	I_{X1}		-10	µA	V_{X1-E1}=-30V, V_{y1}=V_{E1}
Leakage	I_{Y1}		10	µA	V_{Y1-E3}=30V,V_{X1}=V_{E3}
Leakage	I_{E1}		-100	nA	V_{E1-Y1}=-8V
Leakage	I_{E2}		-100	nA	V_{E2-Y1}=-4V
Leakage	I_{E3}		100	nA	V_{E3-X1}=8V
Leakage	I_{E4}		100	nA	V_{E4-X1}=4V
Input Voltage	V_{Y1-E2}	-1.45	-1.65	V	I_{Y1}=-1A
Input Voltage	V_{Y1-E3}	1.45	1.75	V	I_{Y1}=1A,V_{X1}=V_{Y1}
Input Voltage	V_{X1-E1}	-1.45	-1.75	V	I_{X1}=-1A,V_{X1}=V_{Y1}
Input Voltage	V_{X1-E4}	1.45	1.65	V	I_{X1}=1A
Transfer Characteristic	V_{OUT}	0.99	1.01	V	See Fig 1.V_{CC}=5V R1=R3=R4=100Ω, V_{IN}=1V
Transfer Characteristic	V_{OUT}	1		mV	See Fig 1.V_{CC}=5V R1=R3=R4=100Ω, V_{IN}=5mV
Output Zero-Offset Voltage	V_{OFFSET}		4	mV	See Fig 2.V_{CC}=5V,R_2<1Ω R1=R3=R4=100Ω

ZDS1009

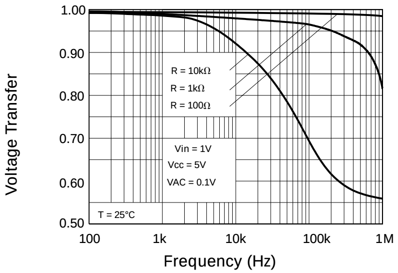
TYPICAL CHARACTERISTICS



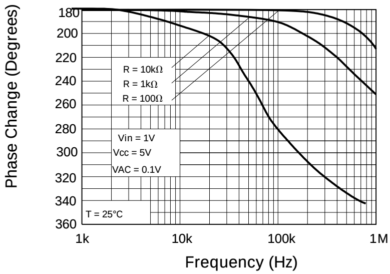
Voltage Transfer v Supply Voltage



Voltage Transfer v Input Voltage



Voltage Transfer v Frequency Response



Phase Change v Frequency Response

TEST CIRCUITS

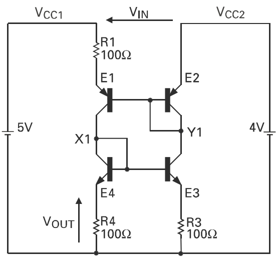


Figure 1
Transfer Characteristic Test Circuit

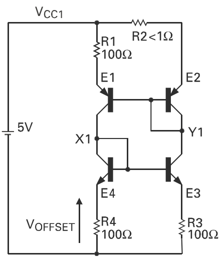


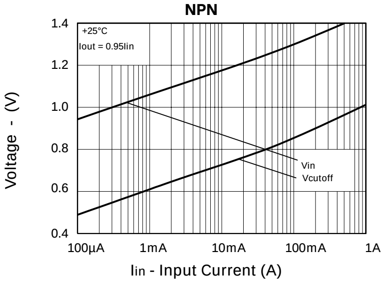
Figure 2
Output Zero-Offset Voltage Test Circuit

ISSUE 2 - JANUARY 2000

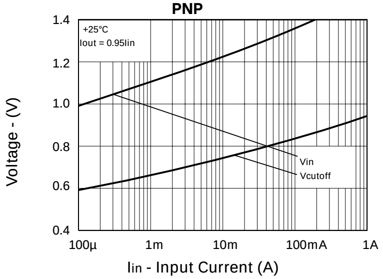
ZETEX

ZDS1009

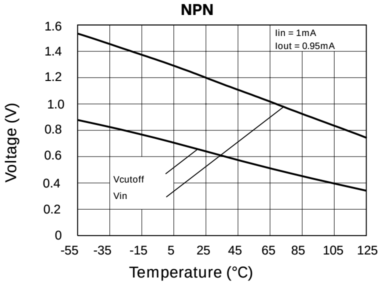
TYPICAL CHARACTERISTICS



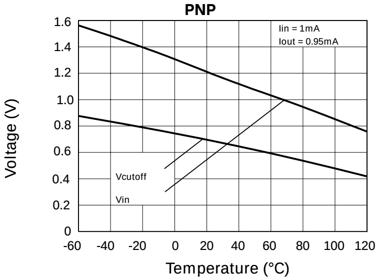
Input/Cutoff Voltage v Iin



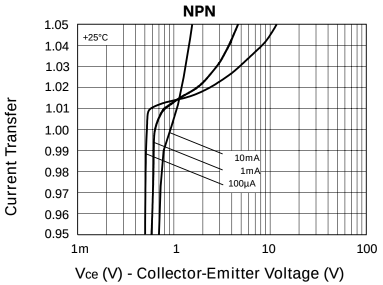
Input/Cutoff Voltage v Iin



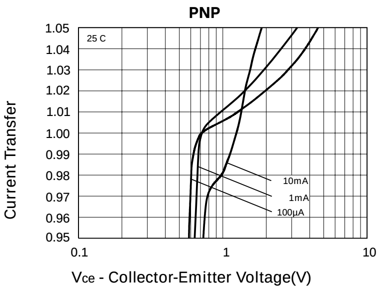
Input/Output Voltage v Temperature



Input/Output Voltage v Temperature



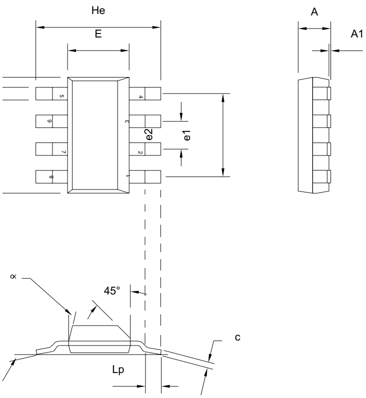
Current Transfer v Vce



Current Transfer v Vce

ZDS1009

PACKAGE DIMENSIONS



DIM	Millimetres			Inches		
	Min	Typ	Max	Min	Typ	Max
A	-	-	1.7	-	-	0.067
A1	0.02	-	0.1	0.0008	-	0.004
b	-	0.7	-	-	0.028	-
c	0.24	-	0.32	0.009	-	0.013
D	6.3	-	6.7	0.248	-	0.264
E	3.3	-	3.7	0.130	-	0.145
e1	-	4.59	-	-	0.180	-
e2	-	1.53	-	-	0.060	-
He	6.7	-	7.3	0.264	-	0.287
Lp	0.9	-	-	0.035	-	-
α	-	-	15°	-	-	15°
β	-	10°	-	-	10°	-

ORDERING INFORMATION

DEVICE	PARTMARKING
ZDS1009	S1009

REFERENCES

1. Unitrode/Benchmarq bq2954 datasheet - “Lithium Ion Charge Management IC with Integrated Switching Controller”

2. Unitrode/Benchmarq bq2954 demonstration PCB support literature - “DV2954S1H: Li-Ion Charger Development System - Control of On-board PNP Switch Mode Regulator with High Side Current Sensing”.

ZETEX

Zetex plc.
Fields New Road, Chadderton, Oldham, OL9-8NP, United Kingdom.
Telephone: (44)161 622 4422 (Sales), (44)161 622 4444 (General Enquiries)
Fax: (44)161 622 4420

Zetex GmbH
Streitfeldstraße 19
D-81673 München
Germany
Telefon: (49) 89 45 49 49 0
Fax: (49) 89 45 49 49 49

Zetex Inc.
47 Mall Drive, Unit 4
Commack NY 11725
USA
Telephone: (631) 543-7100
Fax: (631) 864-7630

Zetex (Asia) Ltd.
3510 Metroplaza, Tower 2
Hing Fong Road,
Kwai Fong, Hong Kong
Telephone:(852) 26100 611
Fax: (852) 24250 494

These are supported by agents and distributors in major countries world-wide

Internet:http://www.zetex.com