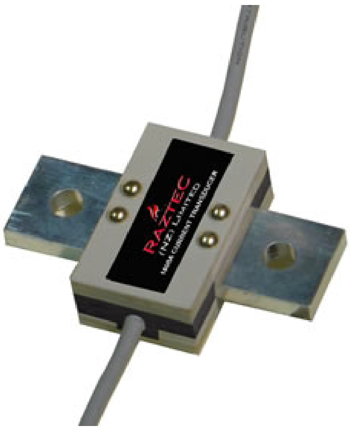
RAZTEC LINK CURRENT SENSOR
TECHNICAL INFORMATION



DESCRIPTION
The Raztec Link current sensor looks rather like a fuse or even a shunt but offers some very significant technical advantages over shunts when it comes to measuring current.

Additional benefits over current shunts:

- Galvanic isolation between the measured current and the output to 3000V.
- Negligible power loss
- 4500mV differential output voltage (no signal amplification required)
- Superior signal to noise ratio
- Physically smaller

Retained are:

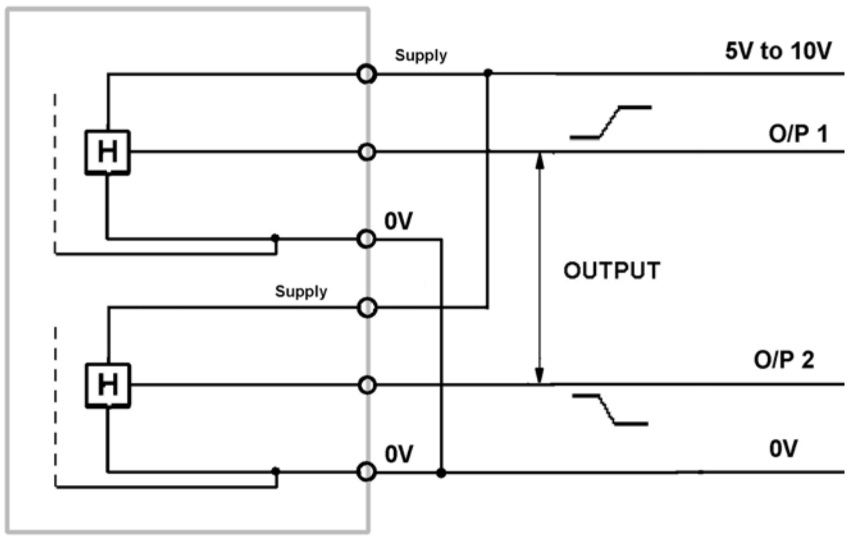
- Excellent frequency response to 350KHz
- Excellent linearity
- Very low drift of the null output voltage
- Competitive pricing
- Excellent immunity to stray electric and magnetic fields.
- 5V operation

The Raztec Link can measure currents to 1500A and practically resolve down to 1A or less.

OPERATING PRINCIPLE

The sensor incorporates two Hall effect magnetic field sensors arranged to give a bipolar output. This greatly improves the sensors immunity to common mode effects. The output signal is effectively the difference between the two sensor signals, these are then brought out separately to ensure better noise rejection.

Electrostatic and magnetic screening is employed to reduce the possible effects of noise from high voltage switching transients and nearby current carrying conductors.



** Note 1*
An optional interface board supplied from +/-15V can be included that converts the bipolar output to a conventional single ended output. The interface board also allows calibration of the gain and offset.

IMPORTANT SENSOR QUALITIES:

The following is a list of some of the more important qualities that should be considered when selecting a current sensor for a particular application.

EFFECTS OF TEMPERATURE:
Maintaining accuracy over say the automotive temperature range of -40C to +125C can be a challenge for a number of reasons. Just about everything drifts with temperature!

Additionally the failure rate of many components accelerates at high temperatures, particularly if there is significant self heating in the device.

Open-loop sensors, such as the Link, are prone to thermally induced drift of offset and gain but temperature stable devices <u>are</u> available and the Link can be provided with selected sensors to assure stability when the application demands this.
(Effects are quantified in the section on accuracy.)

The Link does have a finite resistance, so there is a small amount of self-heating at high currents. If very high (>500A) mean currents are anticipated, the mounting structure should be designed to provide some heat-sinking.

Since the sensor does not have a ferromagnetic core, there is little possibility of heating due to high frequency currents.

OFFSET STABILITY:
The suitability of a sensor to measure small currents accurately (as well as high currents) is very much dependant on the stability of the offset voltage.
As mentioned above, temperature changes cause offset shift but a significant contributor is shifts due to remanence effects in the magnetic circuit of the sensor. Reasonably good material can cause a 0.5% shift of output after a significant current excursion. *'The greater the excursion, the greater the shift of output'.* Very special material may be twice as good and leave 0.25% of remanent shift. Both open and closed-loop sensors are equally affected by remanence.
Only an air circuit exhibits zero remanence.
HOWEVER!
Sensors that don't use flux concentrators without suitable shielding are very vulnerable to stray magnetic fields. Even the Earth's magnetic field can look like 0.4A, and shifts due to nearby solenoids can be very large, as will the influence of nearby current carrying conductors.
The Raztec Link addresses both these issues by firstly, not using a ferromagnetic flux concentrator and, by the addition of shielding to protect the sensor from stray magnetic and electric fields.
This results in a sensor with very low hysteresis errors <u>and</u> excellent immunity to stray fields.

PRACTICAL SPAN (dynamic range):
Open-loop sensor span may be limited by either core saturation or magnetic field sensor saturation.
Since the Link does not have a core its peak span is limited by sensor saturation however the sensor does have a finite resistance, so the practical long-term maximum is limited by sensor heating or the ability to cool the sensor.
A dynamic range of 200:1 is very practical for most open and closed-loop sensors. The Link has an exceptional 700:1 dynamic range

Also in practice, the dynamic range of a sensor is governed by the signal to noise ratio. This is especially true in high frequency circuits where noise filtering could kill the frequency response. For example if a 1000:1 dynamic range was required and the maximum voltage swing was 2V, 2mV must be sensed reliably. This could well be a challenge in a practical environment where noise levels could be in the order of 100s of millivolts.

FREQUENCY RESPONSE:
The frequency response of open-loop sensors has been traditionally limited to about 20 KHz, but this does not have to be the case. It is possible to manufacture sensors that respond to far higher frequencies. The limitation is normally the hall element buffer amplifier.

The normal Link frequency response is an excellent 120KHz but this can be extended to 350KHz by use of the optional interface module – see ** Note 1*
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DESTRUCTIVE OVERLOAD CAPABILITY:
Normal open-loop current sensors excel with this quality. The rating is purely the rating of the conductor passing through the device. The provision of adequate apertures is not a significant design challenge.

The Link does have a limitation for i^2t overload as it is constructed somewhat like a fuse therefore suitable fuse protection is recommended by a fuse with a lesser i^2t rating.

SIZE:
High current sensors generally become quite bulky.
It was an objective with the Link to make it as compact as possible. A face-mounted option is available for even greater compactness.

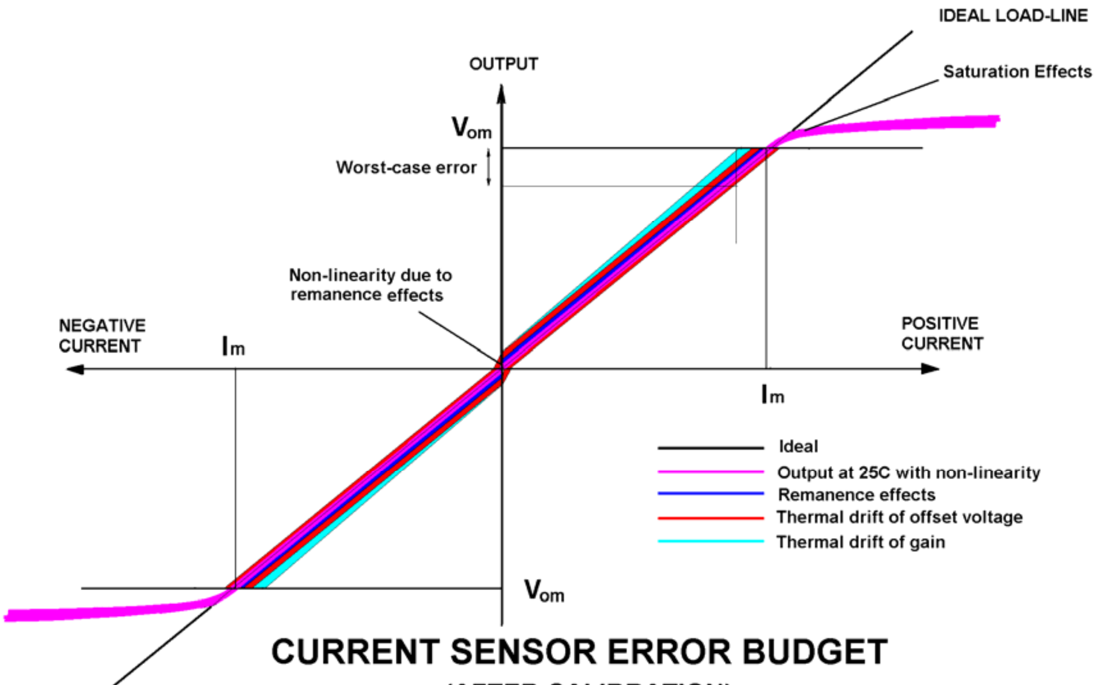
ACCURACY:

In summary, sensors have the following contributors to error:

Null output voltage stability as a function of temperature
Null output voltage as a function of current (hysteresis or remanence effects)
Transfer function calibration (mV/A)
Linearity of transfer function as a function of current
Transfer function as a function of temperature
Saturation of transfer function at limit of current range
Cross-talk or stray magnetic field interference
Errors induced by finite frequency response
Errors induced by noise from capacitive coupling of primary voltages.
Hall sensor noise limiting small signal resolution

For each application, the influence of the above error contributors should be assessed.

In order to minimise cost and size, the Raztec Link current sensor is designed for in-process calibration of gain and offset. Once this process is performed, the link has remarkable accuracy for an open-loop current sensor.
(a calibrated version of the Link will be available 4th quarter 2008)



CURRENT SENSOR ERROR BUDGET
(AFTER CALIBRATION)

EXPLANATIONS:

Null Offset

The null offset voltage is the difference between the two outputs with zero primary current flowing. Ideally it should be zero volts but in practice it is within 150mV of zero.
It is normally necessary to calibrate out any offset.

There is some drift of offset voltage with temperature of up to 0.8mV/K. For demanding applications, this can be tightened on request to less than 0.08mV/K.
If the nominal transfer function for the 1500A link is 2.7mV/A,
the drift in current error = 0.08/2.7 A/K
= 30mA/K

All current sensors that include a magnetic circuit are subjected to errors due to remanence in the magnetic circuit which severely limit their low current accuracy. The magnetic circuit in the link is designed to minimise this effect at 0.05% (<1A) after a full current excursion. This is an exceptionally low figure.

Transfer Function

The nominal 1500A link transfer function is 2.7mV/A.
The production variability is +/-0.3mV/A.
Because of this variability, it probably will be necessary to do production calibration of gain, but once calibrated, the gain stays linear and constant over a wide dynamic range.
Note that the transfer function bears a linear and proportional relationship to the supply voltage.

Key to accuracy is linearity of response. Linearity can be measured by deviation from an ideal linear response, normally expressed as a percentage of full scale. Full scale requires specifying, as saturation is inevitable.
The 1500A link has better than 1% linearity over +/-1000A.

Open-loop sensors are vulnerable to drifts of transfer function with temperature. Raztec link sensors are configured to assure negligible negative drift with increasing temperature. With most current control circuits it is advisable that the output indicates high with increasing temperature, thus improving safety and reliability.
Typical drift for the Link is <+0.01%/K

Current sensors based on magnetic field sensing are vulnerable to some degree to stray external magnetic fields. The Link is specifically configured using magnetic screening amongst other techniques to minimize these effects. For the 1500A Link a conductor carrying 1000A, 25mm from the link in the worst orientation could cause up to 0.3% error. The more uniform the magnetic field, the less will be its effect.

If high frequency current signals are to be accurately sensed, the sensor requires an adequate frequency response. The Link has a very good 120KHz capability which can be extended to 350KHz on application to Raztec.

Noise on the primary voltage can be capacitively coupled through to the sensor output – normally as spikes which can be significantly large. The coupling effect can be mitigated by providing electrostatic screening between the primary voltage and the magnetic field sensors. Sensor installers must also ensure that screened output cables are routed away from noisy potentials. Another technique to avoid noise effects when sensing via an A to D to a microcomputer is to not attempt to measure the current during current switching thus avoiding the noise spike.
The Link superimposes a voltage less than 1V for a primary transient of 10^8V/s.

The Link uses Hall sensors that have an insignificant noise output compared with useful output voltages.

SUMMARY
The Raztec Link has a performance that matches or betters the very best open loop current sensors yet is extremely compact and economically priced. Some typical applications where high current measurement, fast response and more importantly; small physical size, ease of mounting – both electrically and physically – galvanic isolation and excellent signal/noise ratio is required include

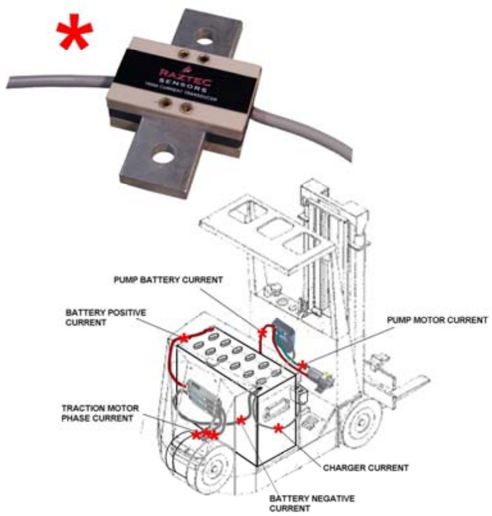
- Electric vehicles
    - Electric automobiles/cars/rail transport
    - Fork-lift, pallet truck, electric cart
    - Earth-moving

- IGBT / Inverters
- Power modules
- Variable speed drives

A particularly demanding current measurement application is electric vehicles, and in particular, the electric fork-lift truck. Whilst possibly not as high-profile as, say, the electric or hybrid car application, the electric fork-lift truck demands all of the same technology, but more so in almost every area.

As shown (fig 4) thanks to it's small physical size and superior performance in electrically noisy environments, the RAZL1500 is well suited for mounting in the most convenient location, irrespective of concerns regarding traditional current shunts such as physical size, generated heat, electrical noise etc . . .

RAZTEC LINK



COMPLETE FLEXIBILITY WHERE THE LINK IS MOUNTED

TECHNOLOGY COMPARISONS

TECHNOLOGY	OFFSET STABILITY	GAIN STABILITY	SPAN	HYSTER-ESIS ERROR	QUIESCENT CURRENT	H.F. PERFORM-ANCE	AMBIENT TEMP RANGE	OVERLOAD CAPABILITY	SIZE	PRICE
Ferrite core open-loop	P to G	M	G	G	VG	G to Ex	VG	Ex	Ex	VG
Iron core open-loop	P to G	M	VG	VG	VG	G to VG	Ex	Ex	VG	VG
Raztec Link sensor	G	G	Ex	Ex	G	Ex	Ex	VG	VG	G
Closed-loop	VG	Ex	VG	VG	P	VG	M	VG	G	M
Low current shunt	Ex	Ex	Ex	Ex	Ex	Ex	Ex	G	VG	Ex
High current shunt	VG	Ex	Ex	Ex	Ex	VG	VG	M	M	VG

NOTE 1: Grading is relative to competing technology and assumes mass-produced but quality devices.
NOTE 2: Shunted performance is recorded assuming no galvanic isolation. The inclusion of galvanic isolation would alter the table ratings.

GRADING

Excellent	Ex
Very Good	VG
Good	G
Modest	M
Poor	P