

# Railway Current & Voltage Transducers



# Current and Voltage Transducers for Railway applications

## LEM solutions for traction electrical measurements

This catalogue summarizes the most common LEM product offerings for electrical railway measurements. It is our business to support you with both standard and customized products to optimize your application.

Please contact LEM in your region for assistance.

Today, high speed trains, city transit systems (metro, trams, and trolleybuses) and freight trains are the solutions against pollution and interstate traffic immobility and provide a significant energy savings.

Power electronics is essential to drive and control energy in these transportation systems.

LEM has been a main player in traction power electronics applications and development for the last 45 years and leverages this vast experience to supply solutions for isolated current and voltage measurements.

LEM transducers provide control and protection signals to power converters and inverters that regulate energy to the electric motors (for propulsion)

and to the auxiliaries (for air-conditioning, heating, lighting, electrical doors, ventilation, etc.). This includes the early monitoring of the voltage network (changing by crossing the European borders) to make the power electronics working accordingly.

Although this is true for on-board applications, LEM has also provided the same control and protection signals for wayside substations.

The rail industry is under constant changes and evolution. As a recent example, the privatization of the rail networks raised new requirements for which LEM provides: the on-board monitoring of power consumption (EM4T II Energy Meter), solutions to trackside applications, rail maintenance and the monitoring of points (switches) machines or signaling conditions with some new transducers families.

LEM is always available to assist in adapting to these evolving technical applications.

Four decades of railway

experience has contributed to establishing LEM as a market leader with worldwide presence to serve you and provide the efficient, safe and reliable operation of the railways.

With more than 2 500 current and voltage transducers in its portfolio, LEM offers a complete range of accurate, reliable and galvanically isolated devices for the measurement of currents from 0.01 A to 20000 A and voltages from 10 V to 6400 V in various technologies: Open Loop, Closed Loop, Isolating digital technology, etc.

LEM transducers for railway applications are designed according to the most demanding international standards (EN50155, EN50124-1, NFF 16101, 16102, etc) and carry CE marking. UL or UR is also available on selected models.

We have worldwide ISO 9000 and ISO TS 16949 and IRIS qualification and offer a 5-year warranty on all of our products. LEM constantly innovates and strives to improve the

performance, cost and sizes of its products.

LEM is a worldwide company with offices across the globe and production facilities in Europe (included Russia), Asia and America.

We hope you will find this catalogue as a useful guide for the selection of our products. Visit our website at [www.lem.com](http://www.lem.com) and contact our sales network for further assistance. Detailed datasheets and application notes are available. Sincerely,

Hans-Dieter Huber  
Vice President Industry Sales

Frank Rehfeld  
CEO LEM

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**LEM - At the heart of power electronics.**

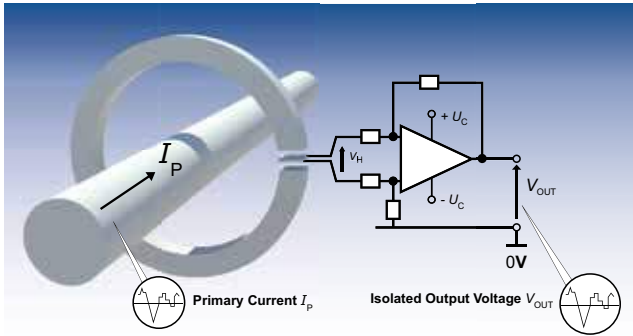


## Open Loop Current Transducers (O/L)

### Features

- Small package size
- Extended measuring range
- Reduced weight
- Low power consumption
- No insertion losses

### Operation principle O/L



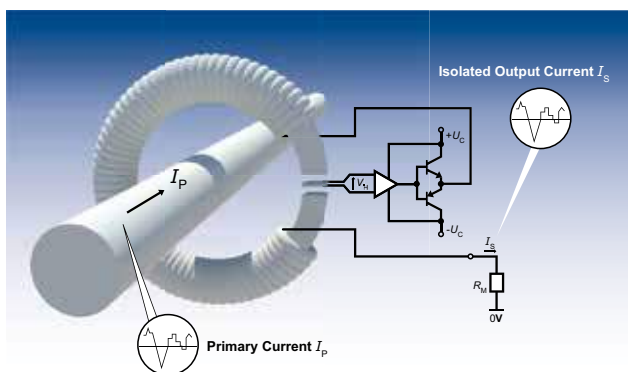
The magnetic flux created by the primary current  $I_P$  is concentrated in a magnetic circuit and measured in the air gap using a Hall device. The output from the Hall device is then signal conditioned to provide an exact representation of the primary current at the output.

## Closed Loop Current Transducers (C/L)

### Features

- Wide frequency range
- Good overall accuracy
- Fast response time
- Low temperature drift
- Excellent linearity
- No insertion losses

### Operation principle C/L



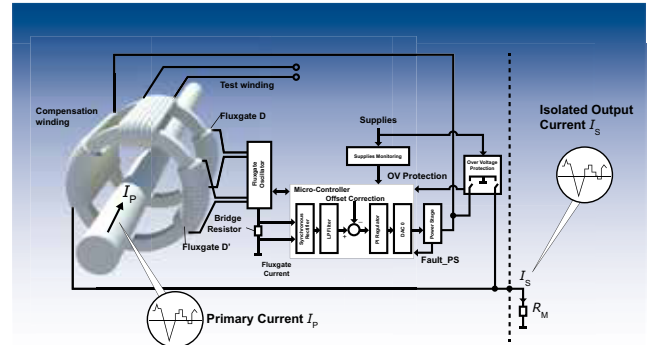
The magnetic flux created by the primary current  $I_P$  is balanced by a complementary flux produced by driving a current through the secondary windings. A hall device and associated electronic circuit are used to generate the secondary (compensating) current that is an exact representation of the primary current.

## Closed loop Fluxgate ITC type

### Features

- Excellent linearity
- Better than Class 0.5R according to EN 50463
- Outstanding long-term stability
- Low residual noise
- Very low sensitivity to high external DC and AC fields
- High temperature stability

### Operation principle



ITC current transducers are high accuracy transducers using fluxgate technology. This high sensitivity zero-flux detector uses a second wound core (D') for noise reduction. A difference between primary and secondary ampere turns creates an asymmetry in the fluxgate current.

This difference is detected by a microcontroller that controls the secondary current that compensates the primary ampere turns ( $I_P \times N_P$ ).

This results in a very good accuracy and a very low temperature drift.

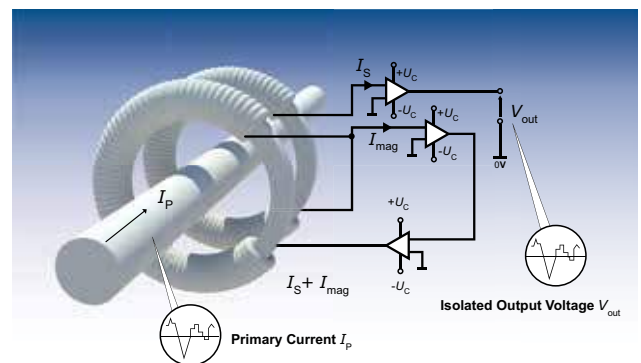
The secondary compensating current is an exact representation of the primary current.

## Closed Loop Fluxgate (C Type)

### Features

- High accuracy
- Very wide frequency range
- Reduced temperature drift
- Excellent linearity
- Measurement of differential currents (CD)
- Safety isolation (CV)
- Reduced loading on the primary (CV)

### Operation principle



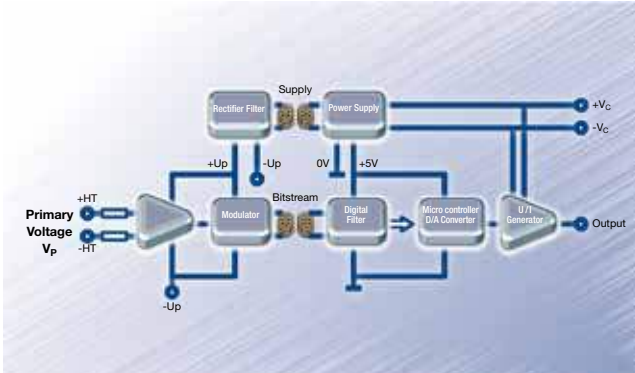
This technology uses two toroidal cores and two secondary windings and operates on a fluxgate principle of Ampere-turns compensation. For the voltage type a small (few mA) current is taken from the voltage line to be measured and is driven through the primary coil and the primary resistor.

## DV, DVL & DVM Type Voltage transducers

### Features

- Insulating digital technology
- Measurement of all types of signals: DC, AC, pulsed and complex
- Compact size, reduced volume
- High galvanic insulation
- Low consumption and losses
- Very high accuracy, Class 0.5R according to EN 50463 (DV Models)
- Low temperature drift

### Operation principle



The measuring voltage,  $V_p$ , is applied directly to the transducer primary connections through a resistor network allowing the signal conditioning circuitry to feed a Sigma-Delta modulator that allows to transmit data via one single isolated channel.

The signal is then transmitted to the secondary over an insulating transformer ensuring the insulation between the high voltage side (primary) and the low voltage side (secondary).

The signal is reshaped on the secondary side, then decoded and filtered through a digital filter to feed a micro-controller using a Digital/Analog (D/A) converter and a voltage to current generator.

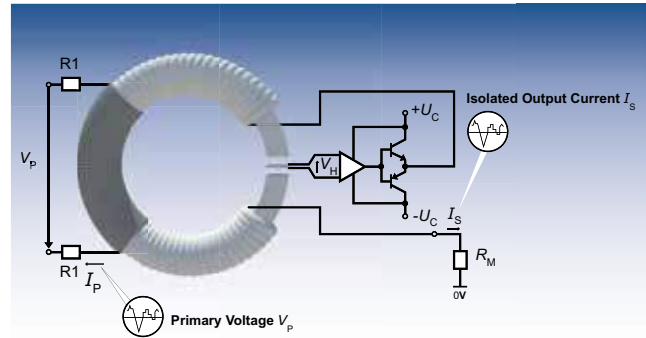
The recovered output signal is completely insulated against the primary and is an exact representation of the primary voltage.

## Closed Loop Voltage Transducers (C/L)

### Features

- Measurement of high voltages
- Safety isolation
- Good overall accuracy
- Low temperature drift
- Excellent linearity

### Operation principle C/L



A very small current limited by a series resistor is taken from the voltage to be measured and is driven through the primary coil. The magnetic flux created by the primary current  $I_p$  is balanced by a complementary flux produced by driving a current through the secondary windings. A hall device and associated electronic circuit are used to generate the secondary (compensating) current that is an exact representation of the primary voltage. The primary resistor ( $R_1$ ) can be incorporated or not in the transducer.

\* For further information, refer the brochure "Characteristics - Applications - Calculations" or [www.lem.com](http://www.lem.com)

## On-Board Applications

The electrical power is supplied to the trains via the catenaries. So, depending on the country and also to the applications (Subway, trolleybuses, high speed train, heavy traction...) the locomotives can operate at different voltage levels and under different systems.

### 1. Rolling Stock Heavy Traction

Heavy traction means high speed, or long distances, or heavily loaded cars (freight trains). For new lines, not part of an already existing network, AC voltage is often the choice. Heavy traction rolling stocks are made up of (figure 1):

in different countries with various electrical railway catenary voltages, it has been possible due to advances in modern power electronics. Eurostar, for example, is able to run over four different voltages, 25 kV/AC/50 Hz, 3 kV DC, 1.5 kV DC and 750 V DC.

The **DVM** or **DV** series used at this level allows the detection of the voltage network, informing about the country where is running the locomotive (N°:1c in the figure 2).

To ensure the protection of the whole system, the earth leakage current to the wheels is also monitored thanks to special current transducers called **CD** series dedicated for that function (N°:1b in the figure 2). They are responsible for measuring

measurement.

Multi winding transformers convert the catenary voltage to a voltage compatible with the power converters.

To get the best efficiency of the energy provided by the network, accurate and reliable measurement is required. LEM proposes the adapted measurement tool "**EM4T II**", adapted to various European networks (please see section dedicated to **EM4T II**). One of the secondary windings of this transformer is used to build a four-quadrant controller.

### Main Rectifier

This is generally made up by a four quadrant controller to be connected to the DC link.

A four quadrant controller can regulate the flow of energy from the AC line to the DC link and from the DC link back to the AC line. It allows to have the power, taken from the catenaries, nearly close to the maximum theoretical value for a given current and this over a large range of speed and traction effort. In simple terms, this is an active rectifier.

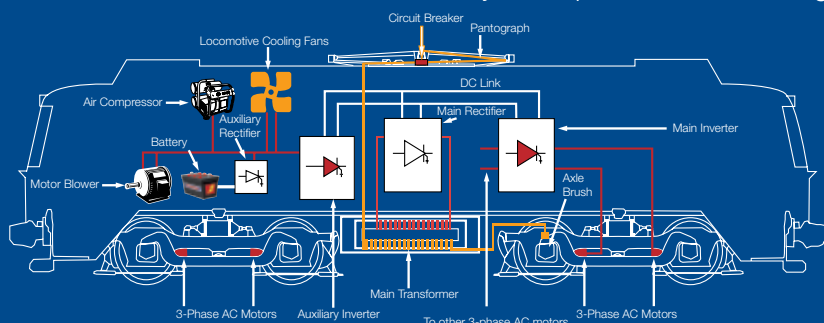


Figure 1: Various parts of an AC electric locomotive

- Main transformer,
- Main rectifier,
- DC link to make the connection to the Main Inverter and Auxiliary Inverter,
- Main Inverter,
- Auxiliary Inverter.

### Main Transformer

Power from the catenaries route through the main circuit breaker before reaching the main transformer. This is the first place where a current transducer can be advantageous: The control of the input current (N°1a in the figure 2). The **LT 2005** & **4000** models bring the necessary advantages for that job: a large aperture for cable pass-through of the primary conductor as well as high isolation voltage.

Although it is a complex undertaking to design a train capable of operating

differential current between 2 or 3 conductors and detecting possible leakage between these conductors. It is also possible to accomplish this measurement by using 2 typical traction current transducers like the **HAR 1000** or **LT 2005** families.

This step is necessary for the 15 kV/AC/16Hz 2/3 and 25 kV/AC/50Hz networks, in order to decrease the voltage level, and, also, to convert the voltage to a DC value, which has been defined as the best compromise for the voltage/current supplied to today's semiconductors. 2000 V is a typical value at this stage

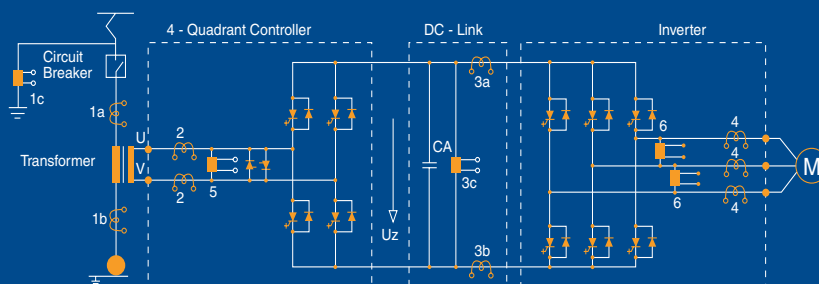


Figure 2: Where is the current and voltage measurement on the traction drive system ?

No contact and galvanically isolated differential measurement with a large aperture for multiple primary conductors result in safety-friendly transducers and accurate

of the voltage transformation. The control of the input voltage (main transformer output) is ensured by **DVM** or **DV Voltage** transducers (N°:5 in the figure 2).



SMA Technologie AG



Copyright ALSTOM

500 A

LTC FAMILY

1000 A

200 A

350 A

400 A

500 A

Mounting **flexibility** horizontal or vertical

Multiple options for a full **modularity**

Various secondary connections

Various busbars

Various feet





One current transducer may be used for the input current measurement to control and protect the four quadrant controller (N°:2 in the figure 2) such as models derived from **LTC 1000** or **LT 1005** Series.

## DC Link

This is the link between the main rectifier output and the propulsion inverter input and the auxiliary inverter.

Its goal is to smooth the DC signal, limit the voltage (overloads), and/or filter the perturbations coming from the source (catenary/transformer) to the inverter or vice-versa.

A voltage transducer derived from the **DVM** family can be used for these functions (there are many models available for 2000 V measurement which is a typical value at this level) (N°:3c in the figure 2). **DVL** Series transducers can also be a solution. The polarity on the DC link is also a controlled parameter.

Current overloads and polarity are also monitored by some current transducers to avoid power semiconductor damage (N°:3a in the figure 2): **LT 1005**, **2005**, **LTC 1000**, **LF 2005** and **LF 2010** families.

In the case of a direct DC voltage supplied by the catenaries (no transformer, no rectifier) (for subways, or trolleybuses for example, voltage line between 600 to 900 V DC), the DC link could then be made up of a simple inductance and some capacitors (**DVM** transducers range covers also these values as well as the **LV 25-Voltage** models) (N°:3c in the figure 2).

As for measurement of differential leakage currents at this level, the **CD** series transducers would satisfy the requirement (N°:3b in the figure 2).

## Main Inverter or Drive Propulsion Inverter

In the past, some other propulsion principles were running using series DC current motors. Initially, the adjustment of the motor speed and torque was controlled by switched series resistors (figure 3).

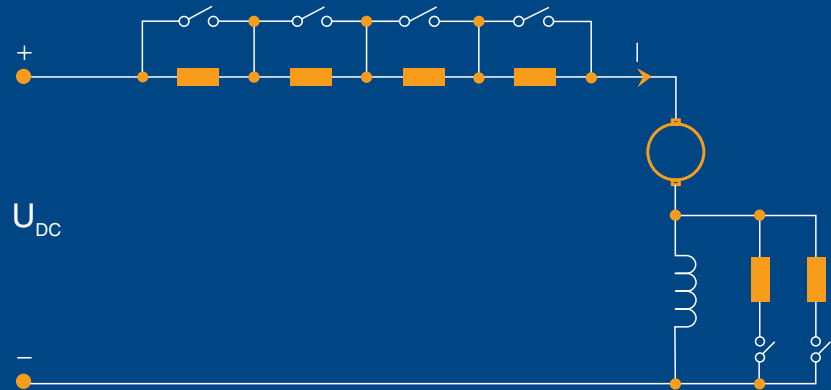


Figure 3 : DC motor control per resistors adjustment

Years later, choppers appeared with the use of the semiconductors (thyristors, then GTO thyristors or IGBT transistors). This last propulsion system is still often used today for railway traction (figure 4).

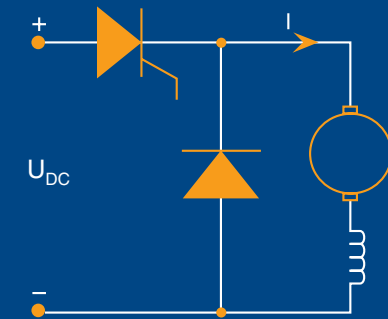


Figure 4 : DC motor control per chopper

Today, however, the most popular way to propel the train is the asynchronous motor where the power is supplied by inverters.

Indeed, asynchronous motors bring advantages such as compactness, robustness, less expensive for maintenance, and increased productivity.

(Synchronous motors are also

often used for TGV propulsion for example).

The inverter is transforming the DC voltage supplied by the DC link into an AC voltage for a three phase system.

The frequency and amplitude of the root (base) signal can then be adjusted.

The most used inverter today is the PWM (Pulse Width Modulation) inverter. This is made up of six electronic switches (initially GTOs followed by IGBTs) as represented in figure 5.

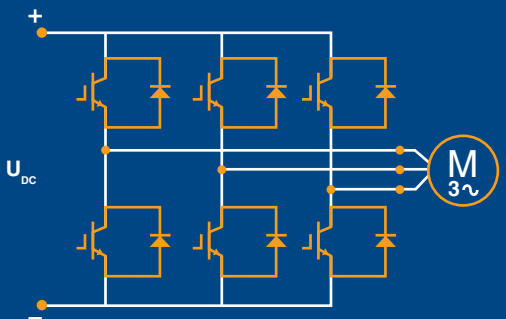


Figure 5 : AC motor control per PWM inverter

The switching frequency is normally as high as possible.

The motor voltage follows a sinusoidal profile and the fundamental frequency of the current and the voltage supplied are functions of the required motor speed. Depending on the required torque, voltage and current amplitudes fluctuate with the frequency.

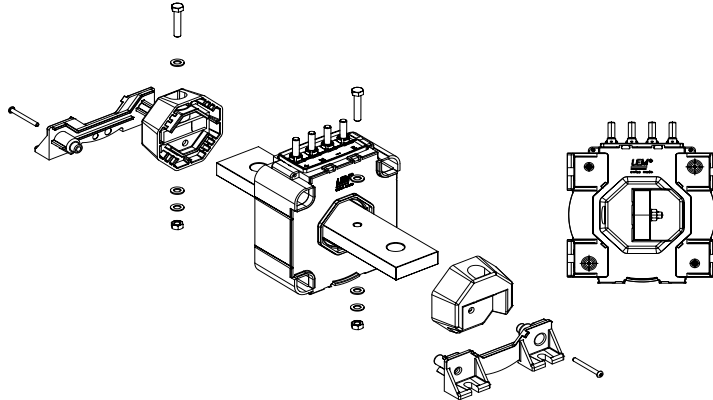
To control these motor current



# LTC series : Modular Current transducers

- ▶ Measures DC, AC, pulsed ... currents with galvanic isolation
- ▶ Mountable in 4 positions : 0°, 90°, 180°, 270°
- ▶ Different accessories : mounting feet, clamps, bus bars  
more details on page 4 of each -S data sheet

200...1000 A<sub>RMS</sub>  
Closed loop  
Hall cell



LTC 600 & 1000 Transducer /  
Mechanical adaptation accessories  
(same possibilities for LTC 200,  
350, 400 and 500 models)

**Technical data** in short form. For more details please see data sheet

				Without accessories	LTC 200-S	LTC 350-S	LTC 400-S	LTC 500-S	LTC 600-S	LTC 1000-S
				With clamps	1)	1)	1)	1)	1)	1)
				With feet	1)	LTC 350-SF	1)	LTC 500-SF	LTC 600-SF	LTC 1000-SF
				With clamps and feet	1)	1)	1)	1)	LTC 600-SFC	LTC 1000-SFC
				With bus bar	1)	LTC 350-T	1)	LTC 500-T	LTC 600-T	LTC 1000-T
				With bus bar and feet	1)	LTC 350-TF	1)	LTC 500-TF	LTC 600-TF	LTC 1000-TF
				Other types: contact sales	<	<	<	<	<	<
				Special features : contact sales	<	<	<	<	<	<
				Different bus bars are available	yes	yes	yes	yes	yes	yes
Parameter	Description	Condition	unit							
I <sub>PN</sub>	Primary nominal current		A <sub>RMS</sub>	<b>200</b>	<b>350</b>	<b>400</b>	<b>500</b>	<b>500</b>	<b>1000</b>	
I <sub>P</sub>	Measuring range, primary	@ ±24V	A peak	±400 <sup>2)</sup>	±1200 <sup>2)</sup>	±1000 <sup>2)</sup>	±1200 <sup>2)</sup>	±1200 <sup>2)</sup>	±1500 <sup>2)</sup>	±2400 <sup>2)</sup>
I <sub>P</sub>	Max. not measurable overload		kA / ms	10 / 10	10 / 10	10 / 10	10 / 10	10 / 10	10 / 10	10 / 10
R <sub>Mmax</sub>	Max. Measuring resistance	@ ±24V	Ω	31	60	33	110	150	50	
R <sub>Mmax</sub>	Max. Measuring resistance	@ ±15V	Ω	9	30	6	50	70	15	
R <sub>Mmin</sub>	Min. Measuring resistance	@ ±24V	Ω	10	10	0	0	0	0	
R <sub>Mmin</sub>	Min. Measuring resistance	@ ±15V	Ω	0	0	0	0	0	0	
K <sub>N</sub>	Conversion ratio			1 : 1000	1 : 2000	1 : 5000	1 : 4000	1 : 5000	1 : 5000	
I <sub>SN</sub>	Secondary nominal current		mA	200	175	80	125	100	200	
V <sub>C</sub>	Supply voltage	±5%	V	±15...24	±15...24	±15...24	±15...24	±15...24	±15...24	
I <sub>C</sub>	Current consumption	@ ±24V	mA	< 35 + I <sub>S</sub>	< 35 + I <sub>S</sub>	< 35 + I <sub>S</sub>	< 35 + I <sub>S</sub>	< 30 + I <sub>S</sub>	< 30 + I <sub>S</sub>	
V <sub>d</sub>	Dielectric strength	50Hz 1min.	kV <sub>RMS</sub>	12	12	12	12	13.4	13.4	
X <sub>G</sub>	Overall accuracy	@ I <sub>PN</sub> , T <sub>A</sub> = 25°C @ I <sub>PN</sub> , T <sub>A</sub> = -40...+85°C	%	≤ ± 0.5	< ± 0.5	≤ ± 0.6	< ± 0.6	< ± 0.7 < ± 1.6	< ± 0.4 < ± 1	
ε <sub>L</sub>	Linearity error		%	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	
I <sub>O</sub>	Offset current	@ I <sub>P</sub> =0, T <sub>A</sub> =25°C	mA	≤ ±0.5	≤ ±0.5	≤ ±0.5	≤ ±0.5	≤ ±0.5	≤ ±0.5	
I <sub>OT</sub>	Thermal drift of I <sub>O</sub>	-40...+85°C	mA	≤ ±0.8 <sup>3)</sup>	≤ ±0.8	≤ ±0.8	≤ ±0.8	≤ ±1	≤ ±1	
t <sub>r</sub>	Response time	@90% of I <sub>PN</sub>	μs	< 1	< 1	< 1	< 1	< 1	< 1	
di/dt	accurately followed		A/μs	> 100	> 100	> 100	> 100	> 100	> 100	
BW	Frequency bandwidth	-1dB	kHz	DC...100	DC...100	DC...100	DC...100	DC...100	DC...100	
T <sub>A</sub>	Ambient operating temperature		°C	-40...+70	-40...+85	-40...+85	-40...+85	-40...+85	-40...+85	
T <sub>S</sub>	Ambient storage temperature		°C	-45...+85	-45...+90	-45...+90	-45...+90	-45...+90	-45...+90	
R <sub>S</sub>	Secondary coil resistance	@ T <sub>A</sub> = +85°C	Ω	20 <sup>4)</sup>	15	70	47	44	44	
m	Mass	-S model	g	300	400	385	400	750	750	
Standards				EN50155	yes	yes	yes	yes	yes	yes
Secondary connection				Faston	yes	M5, Faston	yes	M5, Faston	yes	M5, Faston
Shield between primary and secondary				yes	yes	yes	yes	yes	yes	yes

1) order separately

2) more details: see data sheet

3) -40 ... +70°C

4) +70°C

parameters, **LTC** current transducers located on each phase of the asynchronous motor, fulfill all the railway requirements for 200 to 1000 A nominal current measurements (N°:4 in the figure 2): The **LTC** is modular, compact, designed for traction, many possibilities of secondary connections, and fully approved for traction.

The **LT 505**, **1005**, and **2005** series are also recognized for this function, and have been used for several years in these applications.

The higher the chopping frequency, the more sinusoidal is the current waveform.

The choice of a Closed Loop Hall effect based transducer is justified:

- to get a fast response time (for protection purpose),
- to “see” and support high frequency signals of the current (ripple on the fundamental) from the high switching frequency of the inverter,
- and to achieve accurate control of the speed.

Several propulsion motors can be connected in parallel at the inverter output.

Depending on the equipment manufacturer, some techniques are possible to improve the voltage waveform applied to the motor or to decrease the motor harmonic currents.

The PWM inverter output phase voltages can also be controlled with help from two voltage transducers derived from the **DVM-Voltage**, **DV Voltage** or **DVL Voltage** or **CV-Voltage** families for speed control (N°:6 in the figure 2).

## Auxiliary Inverter

Auxiliary inverters are the systems supplying other on-board loads. Although, not as popular, they are essential to the auxiliary loads needed for the propulsion and for the passengers' comfort.

Depending on the catenary voltages on the applied loads at the output, on the constraints dictated by the car itself (where it will be mounted : On the roof, into

the floor...) or by the application (environment)..., the electronic schematics for the auxiliary inverters are various, and, they use in all the cases all the last innovations of the power electronics.

They have to bring the following advantages to the application:

- Compact,
- Light weight,
- High yield, low cost and low maintenance,
- High performance.

For DC power, auxiliary inverters can be fed directly from the catenaries and for AC power, they can be connected to the main transformer through a secondary winding, but can also be connected to the main or intermediate rectifier output.

By converting the voltage and current under various waveforms (DC, AC, different frequencies, stable or variable frequency), they have the responsibility to supply systems such as:

- Batteries: The DC voltage provides charge to the battery at different values depending on the country and the traction vehicle (24, 48, 72 or 110 V being the most widely used). The batteries are used to provide start-up current, for emergency lighting when the line supply fails, or to supply power to other auxiliary circuits. Charging and discharging of the batteries are monitored by voltage transducers. Depending on the accuracy needed for this type of monitoring, various models are available. The **CV 3** models are designed for high accurate measurement throughout their measuring ranges followed by the **DV Voltage**, **DVL Voltage** and **DVM-Voltage** models.
- Resistances and windings,
- Motors: DC or even AC motors operating under three phases 380-400 V/50-60 Hz for car ventilation, traction motors fans and traction compartment fans, blowers, pumps, compressors,

etc. The start-up and shutdown of these motors are automatically controlled by other on-board systems but still require current overload support from the auxiliary inverter.

- Various electronics: AC single-phase power supplies control power, power plugs, lighting, etc. These voltages have to be filtered and stabilized since the catenary voltages can fluctuate. The auxiliary inverter must sustain any high transient overvoltages that may occur.
- Transformers...

Additionally, these systems support the operation of HVAC heating and doors openers while having to operate from several possible voltage networks for European cars.

The passenger's comfort is represented more and more in these systems and consequently increases the overall energy requirements. The auxiliary inverters have to rationalize the best energy consumption by using the latest power electronics technology and take advantage of any possible energy savings.

For the previous mentioned reasons (protection and control), monitoring the DC or AC currents and voltages at the input and output of the inverter is needed. This is also essential for successful loop control. Again, depending on the regulation accuracy required, the choices for voltage and current transducers are various. Furthermore, auxiliary inverters are subject to cost pressures and often the least expensive measuring solutions are the final preferences. In this context, the best compromise of the price/performance ratio for the voltage measurement is the **LV 25-Voltage** family (200 V to 1200 V) and for current measurements, models derived from the **LTC** and **LAC** families are typically the best solutions. All use the Closed Loop Hall effect technology providing high bandwidth, overall accuracy at + 25°C between 0.4 and 0.8 % of nominal current (or voltage)

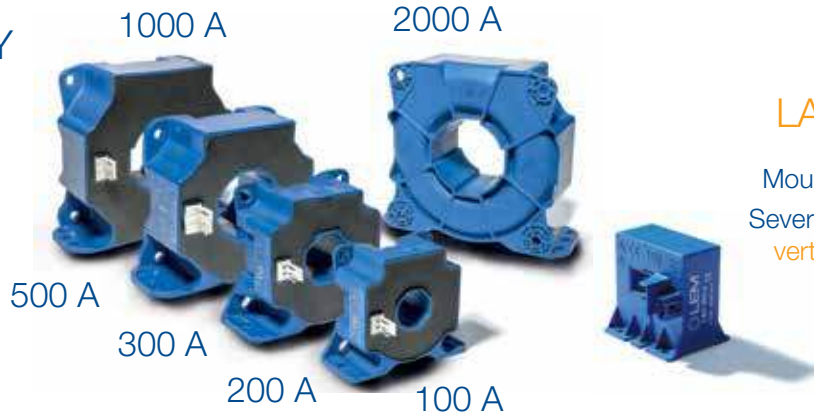
# LF series : Compact Current transducers

- ▶ Measures DC, AC, pulsed ... currents with galvanic isolation
- ▶ Choice between different electrical parameters
- ▶ Choice between different output connectors, studs, cables

100...2000 A<sub>RMS</sub>  
Closed loop  
Hall cell

## LF xx10 FAMILY

Very compact packages



## LAC 300-S

Mounting versatility  
Several horizontal or vertical mountings

**Technical data** in short form. For more details please see data sheet

				LF 210-S/SP5	LF 210-S/SP11	LF 310-S/SP20	LAC 300-S
Other types: contact sales				<	<	<	<
Special features : contact sales				<	<	<	<
Parameter	Description	Condition	unit				
$I_{PN}$	Primary nominal current		A <sub>RMS</sub>	<b>100</b>	<b>200</b>	<b>300</b>	<b>400</b>
$I_P$	Measuring range, primary	@ ±12...15V	A peak	±200 <sup>1</sup>	±420 <sup>1</sup>	±500 <sup>1</sup>	±650 <sup>1</sup>
$R_{Mmax}$	Max. Measuring resistance	@ ±15V	Ω	54.6	27.2	24.15	15
$R_{Mmax}$	Max. Measuring resistance	@ ±12V	Ω	40.35	13.6	12.75	
$R_{Mmin}$	Min. Measuring resistance	@ ±15V	Ω	47	23	0	0
$R_{Mmin}$	Min. Measuring resistance	@ ±12V	Ω	15	0	0	
$K_N$	Conversion ratio			1 : 1000	1 : 2000	1 : 2000	1 : 4000
$I_{SN}$	Secondary nominal current		mA	100	100	150	100
$V_C$	Supply voltage	±5%	V	±12...15	±12...15	±12...20	±15
$I_C$	Current consumption	@ ±15V	mA	35 + $I_S$	35 + $I_S$	38 + $I_S$	25 + $I_S$
$V_d$	Dielectric strength	50Hz 1min.	kV <sub>RMS</sub>	3.5	3.5	3.8	5.5
$X_G$	Overall accuracy	@ $I_{PN}$ , $T_A$ = 25°C @ $I_{PN}$ , $T_A$ = -40...+85°C	%	< ± 0.2 < ± 0.2	< ± 0.2 < ± 0.2	< ± 0.2 < ± 0.2	< ± 1 < 0.1
$\varepsilon_L$	Linearity error		%	< 0.05	< 0.05	< 0.05	< 0.1
$I_O$	Offset current	@ $I_P=0$ , $T_A=25^\circ\text{C}$	mA	≤ ±0.15	≤ ±0.075	≤ ±0.1	≤ ±0.15
$I_{OM}$	Residual current @ $I_P$ after overload 3 x $I_{PN}$		mA	≤ ±0.2	≤ ±0.1	≤ ±0.1	≤ ±0.15
$I_{OT}$	Thermal drift of $I_O$	-40...+85°C	mA	typ. ±0.2	typ. ±0.12	typ. ±0.1	typ. ±0.2
$t_{ra}$	Reaction time	@ 10% of $I_{PN}$	ns	< 500	< 500	< 500	
$t_r$	Response time	@ 90% of $I_{PN}$	μs	< 0.5	< 0.5	< 0.5	< 1
$di/dt$	accurately followed		A/μs	> 100	> 100	> 100	> 50
$BW$	Frequency bandwidth	-1dB -3dB	kHz kHz	DC...100	DC...100	DC...100	DC...50
$T_A$	Ambient operating temperature		°C	-40...+85	-40...+85	-40...+85	-40...+85
$T_S$	Ambient storage temperature		°C	-50...+90	-50...+90	-50...+90	-45...+90
$R_S$	Secondary coil resistance	@ $T_A$ = +25°C	Ω	8.5	27	22.5	
"	"	@ $T_A$ = +85°C	Ω	11.05	35.1	29.25	67
$m$	Mass		g	75	78	107	137
Standards				yes	yes	yes	yes
Secondary connection				Molex Minif.5566	Molex Minif.5566	Molex Minif.5566	Molex 70543-0003
Shield between primary and secondary				no	no	no	no

1) more details: see data sheet

and fast response time for current transducers (less than 1  $\mu$ s @ 90 % of I<sub>pn</sub>).

If mounting constraints or overall dimensions restrictions are relevant then other models can be used for this function, such as the **LA 205 / 305** series or **LT** and **LF 510 / 1010 / 2010-S** families for example.

However, if the price is the main issue and if overall accuracy of 1 % of I<sub>pn</sub> at +25°C, a slightly longer response time (between 3 and 10  $\mu$ s @ 90 % of I<sub>pn</sub>) and a shorter bandwidth (10 to 50 kHz) are acceptable in the application then, the solution might be an Open Loop Hall effect based current transducer: the **HTA**, **HAR** or **HTC** series.

## 2. Rolling Stock Light Rail Cars (Trolleybus/Tramways)

In principle, there is no major difference between the diagrams of heavy traction and light rail traction systems.

Both are mainly propelled by asynchronous motors. As for the heavy traction, the chopper technology is still often used to supply a series DC current traction motor.

They operate mainly from DC voltages supplied by the catenaries with typical values such as: 600 V, 750 V, 900 V, 1200 V or 1500 V at the maximum.

The main transformer and rectifier are then not needed.

Auxiliary inverters are also used, as for the heavy traction, to generate either three phase AC 380 V voltage or DC voltage (24, 48 V or more) for battery chargers. Both voltages (DC and AC three phase output voltages) can be isolated from the auxiliary inverter with an intermediate transformer.

Trolleybuses as well as tramways are becoming more and more important in cities to reduce the local air pollution. Trolleybuses are however more abundant than tramways, as they require less significant infrastructure and also, as they are more convenient for steep grades (where

tramways are not possible).

Often combined with a diesel engine (bi-mode), the rail network can be extended outside cities by using the diesel mode. Also, the trolleybuses and tramways, with their batteries charged via the auxiliary inverter or through wheel inertia or "Sup Cap," ensure their electrical propulsion in places where electrical networks are not possible for architectural reasons for example: High flexibility.

## 3. Rolling Stock Underground (Subways)

At one time, subways propulsion systems were based on resistor control to control a series DC current traction motor then, chopper control was progressively introduced in the 70's to reduce the power losses and finally, combined with the regenerative braking to reduce overheating in tunnels and to save energy. Most of the recent deliveries are now based on inverters controlling asynchronous motors.

They operate mainly from DC voltages supplied by the rails (third rail or 2 lateral rails) or by a catenary (for suburban lines) with typical values: 600 V, 750 V up to 1500 V at the maximum.

Subway systems also use auxiliary inverters for auxiliary functions such as ventilation, air-conditioning, doors openers, etc., similar to heavy traction, trolleybuses and tramways.

## 4. Rolling Stock Heavy Traction Diesel-Electric :

In the past, locomotives operating where no electrical networks exist had only a couple of options:

The diesel engine drives:

1. DC current generator,
2. or, a three phase alternating-current generator.

Both scenarios need to supply power to DC motors for the propulsion.

The three phase alternating-current generator must use a rectifier at the output to convert back to DC.

Current control from the generators is accomplished by a rheostat or a group of contactors.

Traction power is controlled by adjusting the rotational speed setting of the diesel engine.

DC voltages generated can be from 400 to 1500 V with currents from 500 A to 2500 A DC.

But as for all the other rolling stock, the trend is asynchronous motors. Today, we see that the share is 80 % with AC and 20 % DC.

This trend can also be justified by the requirement to reduce the fuel consumption.

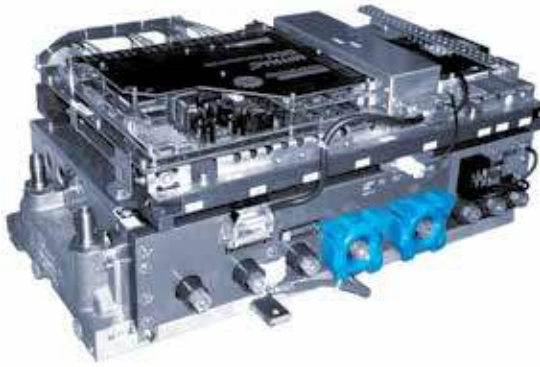
Indeed, asynchronous motors provide better yield than DC in the same application.

The whole electrical system is similar to the one used for the heavy traction except that the initial AC power is generated by the AC generator (alternator).

The needs in current and voltage measurements are the same as previously detailed in the other rolling stocks.







Auxiliary Inverter  
Copyright Bombardier



Copyright ALSTOM



Copyright ALSTOM

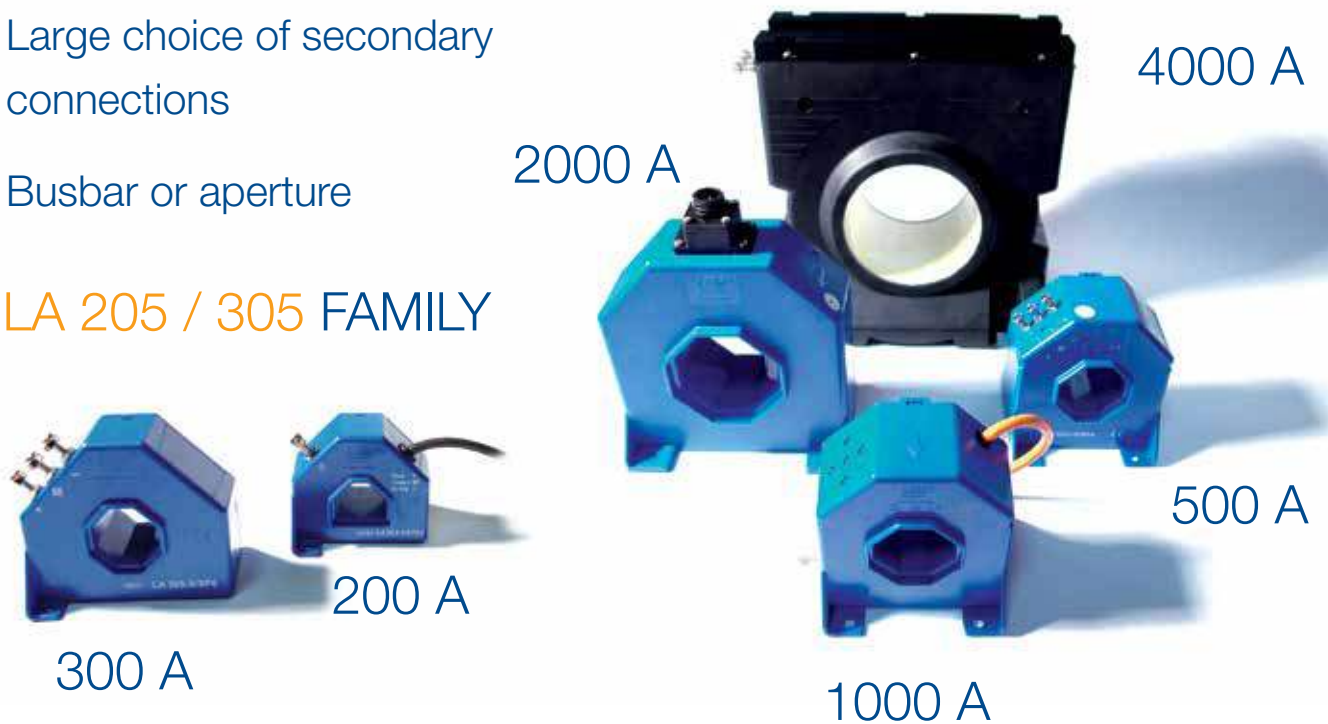
Large current range capability up to 4000 A

LT FAMILY

Large choice of secondary connections

Busbar or aperture

LA 205 / 305 FAMILY



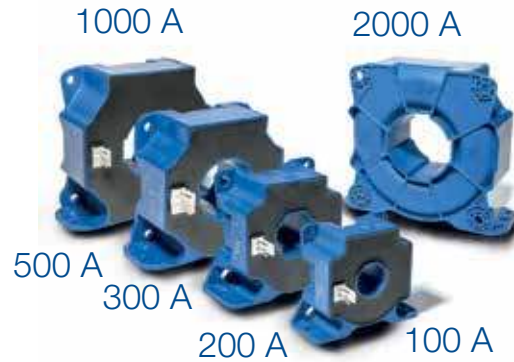
## LF series : Compact Current transducers

- ▶ Measures DC, AC, pulsed ... currents with galvanic isolation
- ▶ Choice between different electrical parameters
- ▶ Choice between different output connectors, studs, cables

100...2000 A<sub>RMS</sub>  
Closed loop  
Hall cell

### LF xx10 FAMILY

Very compact  
packages



**Technical data** in short form. For more details please see data sheet

				LF 510-S/SPA2	LF 1010-S/SPA2	LF 2010-S/SP1	LT 4000-S/SP34
Other types: contact sales				<	<	<	<
Special features : contact sales				<	<	<	<
Different bus bars are available				no	no	yes	yes
Parameter	Description	Condition	unit				
$I_{PN}$	Primary nominal current		A <sub>RMS</sub>	<b>500</b>	<b>1000</b>	<b>2000</b>	<b>4000</b>
$I_P$	Measuring range, primary	@ ±24V	A peak	±1920 <sup>1</sup>	±2720 <sup>1</sup>	±3500 <sup>1</sup>	±6000 <sup>1</sup>
$R_{Mmax}$	Max. Measuring resistance	@ ±24V	Ω	2.06	1.2	6.5	10
$R_{Mmax}$	Max. Measuring resistance	@ ±15V	Ω	1.44 <sup>2)</sup>	0.64 <sup>3)</sup>	0.72 <sup>4)</sup>	
$R_{Mmin}$	Min. Measuring resistance	@ ±24V	Ω	0	0	0	2
$R_{Mmin}$	Min. Measuring resistance	@ ±15V	Ω	0	0	0	
$K_N$	Conversion ratio			1 : 4000	1 : 5000	1 : 5000	1 : 5000
$I_{SN}$	Secondary nominal current		mA	125	200	400	800
$V_C$	Supply voltage	±5%	V	±15...24	±15...24	±15...24	±24
$I_C$	Current consumption	@ ±24V	mA	49 + $I_S$	49 + $I_S$	48 + $I_S$	35 + $I_S$
$V_d$	Dielectric strength	50Hz 1min.	kV <sub>RMS</sub>	4.6	6	10	12
$X_G$	Overall accuracy	@ $I_{PN}$ , $T_A = 25^\circ\text{C}$	%	< ± 0.5	< ± 0.2	< ± 0.2	< ± 0.5
		@ $I_{PN}$ , $T_A = -40...+85^\circ\text{C}$	%	< ± 0.6	< ± 0.4	< ± 0.3	
$\varepsilon_L$	Linearity error		%	< 0.1	< 0.15	< 0.1	< 0.1
$I_O$	Offset current	@ $I_P=0$ , $T_A=25^\circ\text{C}$	mA	≤ ±0.25	≤ ±0.2	≤ ±0.2	≤ ±0.8
$I_{OM}$	Residual current @ $I_P$ after overload 3 x $I_{PN}$		mA	0.175	0.2	≤ ±0.2	
$I_{OT}$	Thermal drift of $I_O$		mA	typ. ±0.15	typ. ±0.12	typ. ±0.2	typ. ±0.6
$t_{ra}$	Reaction time	@10% of $I_{PN}$	ns	< 500	< 500	< 500	
$t_r$	Response time	@90% of $I_{PN}$	μs	< 0.5	< 0.5	< 0.5	< 1
$di/dt$	accurately followed		A/μs	> 100	> 100	> 100	> 50
$BW$	Frequency bandwidth	-3dB	kHz	DC...200	DC...200	DC...150	DC...100
$T_A$	Ambient operating temperature		°C	-40...+85	-40...+85	-40...+85	-25...+70
$T_S$	Ambient storage temperature		°C	-50...+90	-50...+90	-50...+90	-40...+85
$R_S$	Secondary coil resistance	@ $T_A = +25^\circ\text{C}$	Ω	33.3	29.9	18.6	15
		@ $T_A = +85^\circ\text{C}$	Ω	43.29	38.87	24.18	
$m$	Mass		g	240	435	1500	6000
Standards				yes	yes	yes	yes
Secondary connection				Molex Minifit 5566	Molex Minifit 5566	Lemo EEJ...CYC	M5 studs
Shield between primary and secondary				yes	yes	yes	no

1) more details: see data sheet

2)  $I_{Pmax} = 1200\text{ A}$

3)  $I_{Pmax} = 1700\text{ A}$

4)  $I_{Pmax} = 2600\text{ A}$

# DV, DVM and DVL series : Voltage transducers

- ▶ Measures DC, AC, pulsed ... Voltages with galvanic isolation
- ▶ Choice between different electrical parameters
- ▶ Choice between different output connectors, studs, cables

50 V...6400 V<sub>RMS</sub>  
Isolation Amplifier  
Insulating Digital  
Technologies



**Technical data** in short form. For more details please see data sheet

				DVL 1000	DVM 2000	DV 1200/SP2	DV 4200/SP4	DV 6400
Other types: contact sales				<	<	<	<	<
Special features : contact sales				<	<	<	<	<
Parameter	Description	Condition	unit					
V <sub>PN</sub>	Primary nominal voltage		V <sub>RMS</sub>	<b>1000</b>	<b>2000</b>	<b>1200</b>	<b>4200</b>	<b>6400</b>
V <sub>PM</sub>	Measuring range, primary	@ ±24V	V	±1500 <sup>1)</sup>	±3000 <sup>1)</sup>	±1800 <sup>1)</sup>	±6000 <sup>1)</sup>	±9050 <sup>1)</sup>
R <sub>Mmax</sub>	Max. Measuring resistance	@ ±24V	Ω	133	244	28	140	133
R <sub>Mmax</sub>	Max. Measuring resistance	@ ±15V	Ω	133	135	7		133
R <sub>Mmin</sub>	Min. Measuring resistance	@ ±24V	Ω	100	0	0	60	0
R <sub>Mmin</sub>	Min. Measuring resistance	@ ±15V	Ω	0	0	0	0	0
I <sub>SN</sub>	Secondary nominal current		mA	50	50	50	50	50
V <sub>C</sub>	Supply voltage	±5%	V	±15...24	±15...24	±15...24	±15...24	±13.5...26.4
I <sub>C</sub>	Current consumption	@ ±24V	mA	20 + I <sub>S</sub>	30 + I <sub>S</sub>	20 + I <sub>S</sub>	20 + I <sub>S</sub>	25 + I <sub>S</sub>
V <sub>e</sub>	Partial discharge extinction voltage RMS@ 10pC		kV	2.7	5	5	5	7.05
V <sub>d</sub>	Dielectric strength	50Hz 1min.	kV <sub>RMS</sub>	8.5	12	18.5	18.5	18.5
X <sub>G</sub>	Overall accuracy	@ V <sub>PN</sub> , T <sub>A</sub> = 25°C	%	< ± 0.5	< ± 0.5	< ± 0.3	< ± 0.3	< ± 0.3
		@ V <sub>PN</sub> , T <sub>A</sub> = -40...+85°C	%	< ± 1	< ± 1	< ± 1,2	< ± 1	< ± 1 <sup>2)</sup>
ε <sub>L</sub>	Linearity error		%	< 0.5	< 0.5	< 0.1	< 0.1	< 0.1
I <sub>O</sub>	Offset current	@ V <sub>P</sub> =0, T <sub>A</sub> =25°C	mA	≤ ±0.05	≤ ±0.05	≤ ±0.5	≤ ±0.5	≤ 0.05
I <sub>OT</sub>	Thermal drift of I <sub>O</sub>	-40 ... +85°C	mA	max ±0.15	max ±0.12	max ±0.3	max ±0.1	max ±0.1 <sup>2)</sup>
t <sub>r</sub>	Response time	@90% of V <sub>PN</sub>	μs	< 50	< 50	<48	< 48	< 48
BW	Frequency bandwidth	-3dB	kHz	DC...14	DC...13	DC...12	DC...12	DC...12
T <sub>A</sub>	Ambient operating temperature		°C	-40...+85	-40...+85	-40...+85	-40...+85	-40...+70
T <sub>S</sub>	Ambient storage temperature		°C	-50...+90	-50...+90	-50...+90	-50...+90	-50...+85
m	Mass		g	270	375	620	620	620
Standards				yes	yes	yes	yes	yes
Secondary connection				M5, Faston	M5, Faston	M5, Faston	M5	M5, Faston
Shield between primary and secondary				no	no	no	no	no

1) more details: see data sheet

2) -40 to +70°C

## Substations

Most of the trains are powered electrically. The necessary power to energize the electrical motors for locomotive propulsion is generated at the railway substations.

Power substations convert the high voltage provided by the utility company's distribution lines to the low voltage (AC or DC) and supply it with direct current needed to operate railway vehicles.

Once generated, the voltage and current are distributed to the locomotives or rolling stocks via the catenaries or rails (for urban underground railway for example). The voltages generated by the substations are various, due to the different possible voltage networks existing, according to the country where the rolling stocks are running. All the following voltage networks exist in Europe:

- 1.5 kV DC : in south of France, Netherlands...
- 3 kV DC : in Spain, Italia, Latvia, Slovenia, Estonia, Poland, Belgium, Croatia, Moldavia... representing about 30 % of the worldwide railway electrical lines,
- 15 kV / AC / 16.7 Hz: in Germany, Switzerland, Austria, Norway, Sweden...
- 25 kV/AC/50 Hz : Portugal, North of France, North of UK, Finland, Belarus, Yugoslavia, Bosnia & Herzegovina, Macedonia, Greece, Romania, Bulgaria, Hungary, Lithuania, Denmark...
- 3 kV DC and 25 kV/AC/50 Hz : Czech Republic, Slovakia, Ukraine, Russia...
- 750 V DC : UK...

Today, the trend is to have more and more heavy rolling stocks powered with voltage lines under AC voltage.

For the subways, trolleybuses, or tramways the voltage line is typically between 600 to 900 V DC (600, 750 and 900 Volt).

The substations then supply these various voltages to the rolling stocks. The supplied voltage type (AC or DC) and levels make the substations different in their building. These substations are located as close as possible to the tracks to maintain a consistent power level. The number of substations all along the track is dependent on the power supply requirement (subway or high speed trains for example) and also of the traffic.

Generally, they are made up of (figure 6):

- AC switchgear,
- Power transformers,
- Power rectifiers,
- DC switchgear.

Initially, the substation has an input voltage of 10.5 kV/AC/50 (60) Hz up to 66 kV/AC/50 (60)Hz, as an example, and can convert it into different levels of AC or DC voltages depending on the network supply requirement.

transformers may have additional windings for metering and protection purposes.

Some relays are protecting the transformer and also contribute to the rectifier protection.

### Rectifiers

Most of the rectifiers are in 3-phase bridge connection.

These rectifiers shall withstand a full short circuit until the opening of the AC breakers; this is rather common in traction networks.

It is not unusual to find current transducers measuring earth leakage current from the rectifier to the rail (as represented in figure 6).

### DC switchgear

DC switchgear is used to connect the rectifier DC busbar and the catenary (DC line).

Its aim is to open the circuit:

- During low impedance short circuits, the DC switchgear must

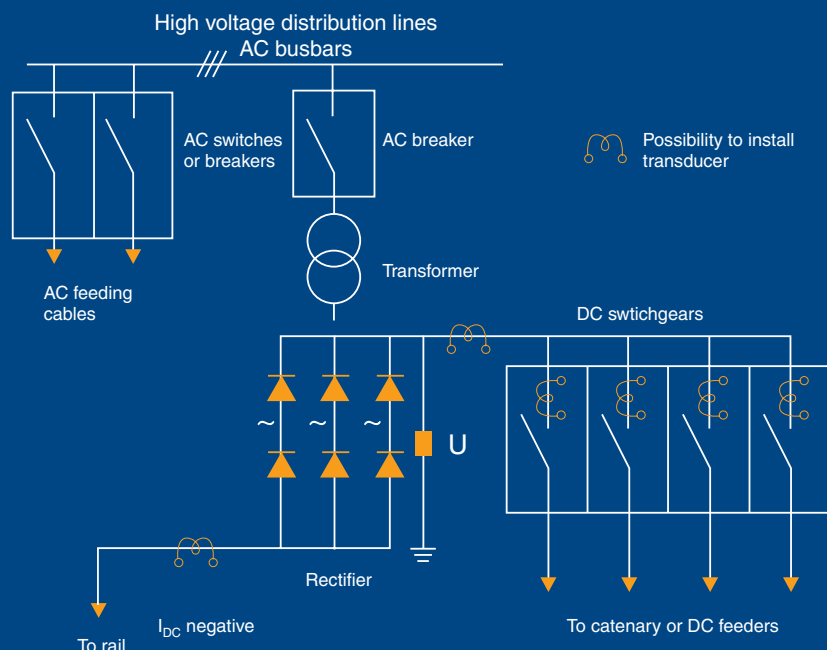


Figure 6: Typical Substation layout.

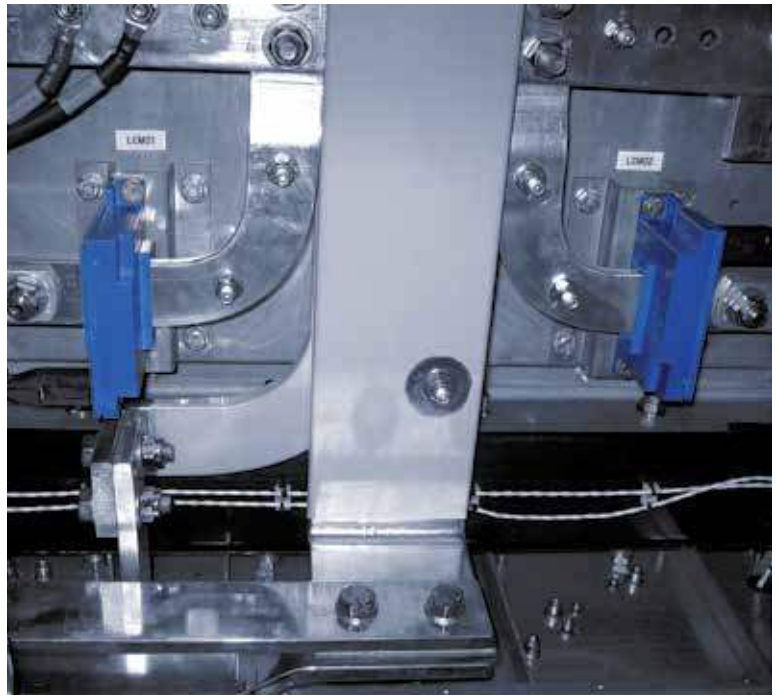
### AC switchgear and Power transformers

AC switchgear is similar to the ones installed in AC distribution stations. In a general way, the AC current

open within milliseconds to prevent overcurrent levels exceeding breaking capacity.

You will find current transducers accurately measuring and monitoring these short circuit overcurrents while feeding relays





Copyright ALSTOM



## DVL VOLTAGE

Voltage measurement  
from 50 to 2000 V

## HAR 1000-S

Small size for 1000 A measured



## DVM-VOLTAGE

Voltage measurement  
from 600 to 4200 V

with defined trigger levels to open the switchgear without delay (as represented figure 6).

- During medium to high impedance short circuits, the DC switchgear must open within a few hundred milliseconds. Again, the combination of the current transducer and relay will trigger the switchgear to open, however, electronic analysis of the transducer output waveform would allow further consideration and decision making (as represented figure 6).

Typical nominal currents in DC switchgear range from 1000 to 10000 A DC and voltages from 600 to 3000 VDC.

Current transducers **LT 4000-S/SP32, SP34, LT 4000-T/SP42**, or **HAZ 4000...20000** models can measure and detect these required levels and are especially useful due to their large apertures allowing wide primary conductors as this is often the case in this kind of application.

The protection can also be ensured by measuring the current at the rectifier output using the same current transducers previously indicated, and represented in figure 6.

The voltage at the DC switchgear or the DC busbar (rectifier output) is often monitored to ensure the right voltage supplied to the catenary (The **DV Voltage** transducers are possible voltage transducers solutions as represented figure 6).

Many times, when DC circuit breakers interrupt the circuit, a reverse voltage is generated at about 2 times higher than its nominal value. This reverse voltage is generated by the arc splitting process. This arc is split into small arcs in series within the arc chute and each individual arc generates a reverse voltage (20 to 25 V). These small arcs are contained

between arc splitting plates. The sum of all these individual small voltages makes the total reverse voltage.

After the interrupt (up to 80 to 150 kA peak), the current then decreases with a time constant L/R while the breaker reverse voltage is higher than the busbar DC voltage. The arc stops when the current is at a zero value.

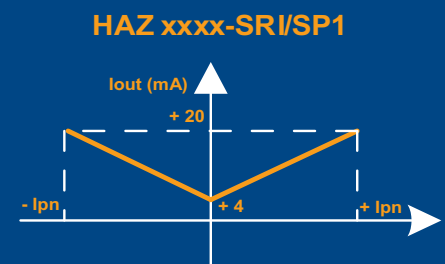
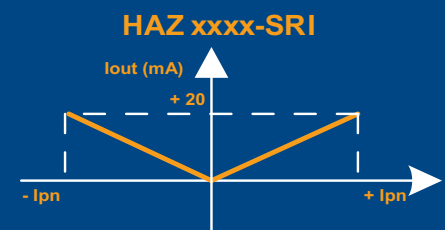
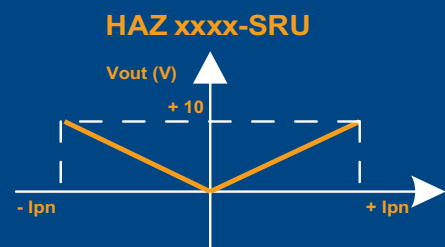
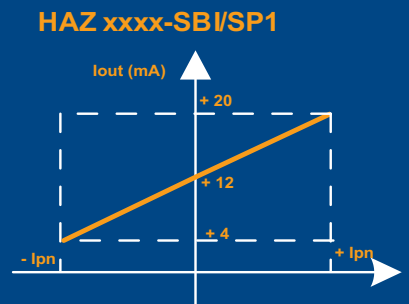
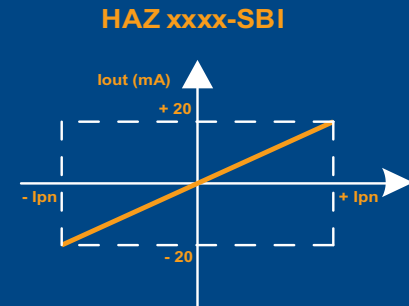
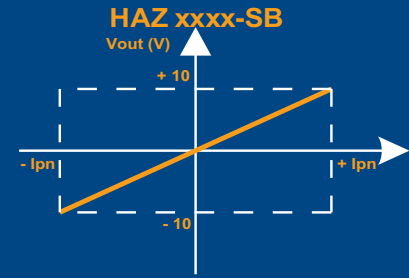
The current transducers installed must support these high over-currents (representing sometimes 20 times their nominal value) and voltages.

When bare or semi-isolated busbars are used for the primary current feed into the substations, then the isolation for transducers is required (12 kV<sub>RMS</sub>/50 Hz/1 min as isolation test voltage as an example).

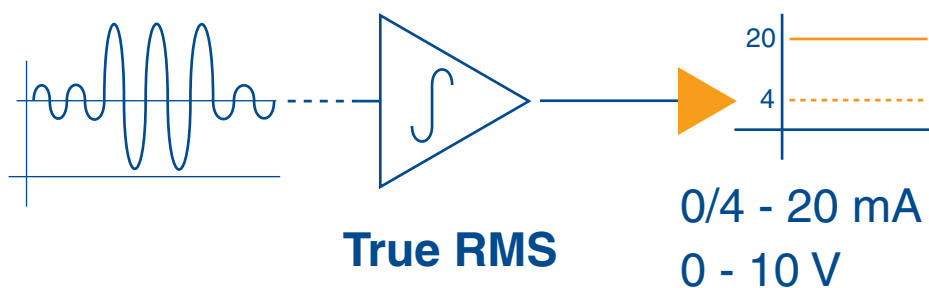
On the other hand, if the primary conductor is isolated, this will typically result in a large conductor requiring current transducers with a large aperture. The **LT 4000-S** and **HAZ** models provide the oversized aperture for large isolated primary conductors.

**HAZ** models are designed for various nominal current measurements from 4000 up to 20000 A and can supply various output signals such as :

- +/- 10 Volt instantaneous: **HAZ xxxxx-SB** models,
- +/- 20 mA instantaneous: **HAZ xxxxx-SBI** models,
- + 4 to + 20 mA instantaneous: **HAZ xxxxx-SBI/SP1** models,
- + 20 mA DC TRUE RMS: **HAZ xxxxx-SRI** models,
- + 4 to + 20 mA DC TRUE RMS: **HAZ xxxxx-SRI/SP1** models,
- + 10 Volt DC TRUE RMS: **HAZ xxxxx-SRU** models.



## Signal Conditioning or Instantaneous Output



Output \ Model	Instantaneous	DC True RMS
Voltage 0 - 10 Volt	- SB	- SRU
Current 0 - 20 mA	- SBI	- SRI
Current 4 - 20 mA	- SBI / SP1	- SRI / SP1



Measurement from 4000 A to 20000 A<sub>RMS</sub>

with the same compact size

## Energy Measurement for On-Board Applications: EM4T II

With the liberalization and/or privatization of some of the major rail networks, the opportunity for traction units to cross national boundaries now exists, using both the installed base of rail and planned rail networks.

This gave train designers the daunting task to develop multi-system locomotives to be used on the different existing networks.

These prime movers would be needed to operate on the different supply networks of bordering countries along the route without requiring an equipment exchange at the regional or network supply border.

Today, it is therefore technically possible to transfer people or goods throughout Europe, from Norway to Sicily for example, without any physical exchange of the locomotive (Picture 1).

Changes in the Energy Markets in the form of deregulation and increased competition for large user contracts brought potential benefits for those willing to negotiate for their electrical traction supply requirements.

This negotiation however requires greater knowledge and understanding of the load profile of bulk supply points in one of the harshest electrical environments – the traction supply.

With the energy meter from LEM, the data for the precise calculation of both supplied and regenerated energy for billing purposes can be accomplished on the train, independently of the energy supplier.

**The second generation of universal energy meters for traction especially designed for on-board applications**

With the **EM4T II energy meter**, LEM introduced the second

generation of universal energy meters for electric traction units with the authorization for billings. Thanks to the advanced capability (such as input channels to connect any actual available current and voltage transducer or transformer) of the **EM4T II**, it is used both in new multi-system locomotives and for retrofitting to all types of electrical rail vehicles already in operation. Recently, the new EN 50463 standards define characteristics of energy measurement function (EMF) as well as transducers for current and voltage DC or AC measurement used for EMF. This evolution led LEM to upgrade EM4T to the latest model: **EM4T II**.

### EM4T II - the load profile provider

**EM4T II** is a single energy meter complying to all the requirements of EN 50463-x & EN 50155 standards for metering and On-Board use, and thus satisfies the requirements of EC Decision 2011/291/EC (TSI “Locomotives and passenger rolling stock”).

**EM4T II** processes signals from the transformer and electronic converter systems for current and voltage to calculate energy values which are stored as load profile information.

In this load profile (set and stored in intervals of 1, 2, 3, 5, 10 or 15 minutes period length according to the user), the primary energy (delta) values are recorded together with data such as:

- Date and time stamp
- Events
- Train identification numbers
- Absolute energy values for consumption and regeneration of active and reactive energy
- Frequency of the network (16.7 Hz, 50 Hz, 60 Hz or DC)

- Additional “user” load profile like the voltage with a shorter time interval (feature coming in a second design step)
- Position of the train at the time the load profile was stored and/or the event arose
- Further functions, such as voltage detection can be set.

The measured energy information includes separately the consumed and regenerated active and reactive energy and is stored in the load profile memory (at 5 minutes period length) for at least 300 days.

The input variables - current and voltage - are connected to the measuring circuits of the **EM4T II** via differential inputs (Picture 2 and 3), designed for connection of all current and voltage transducers/transformers currently available on the market.

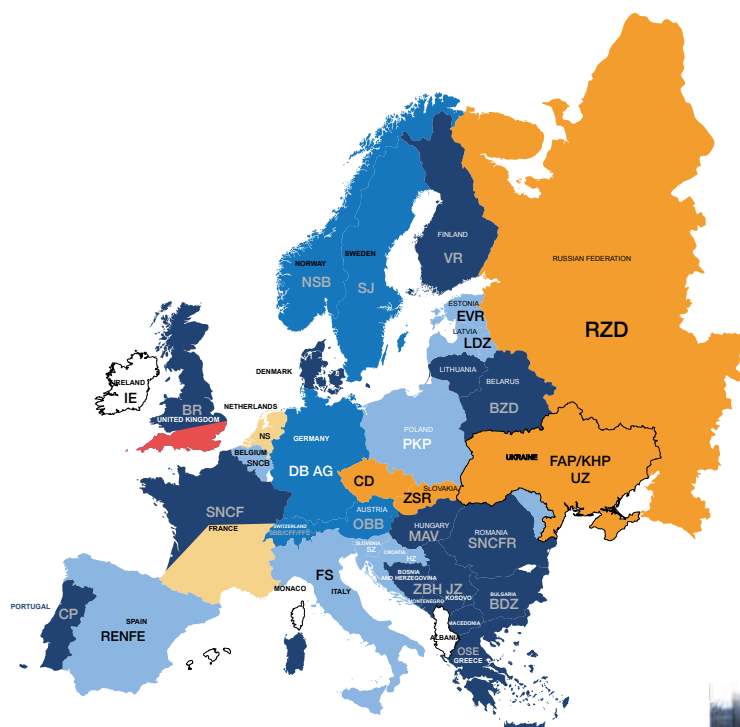
Four input channels are proposed for metering of both DC and AC signals of any existing traction network (see chart 1).

The **EM4T II** is suitable for usage in multi-system vehicles. Supply systems 25 kV 50/60 Hz and 15 kV 16.7 Hz, or either 600 V DC, 750 V DC, 1.5 kV DC or 3 kV DC are covered. A system change is detected by the energy meter and stored in the load profile.

The requirements for current measurement at this level can be diverse.

A large aperture transducer is appropriate when the primary conductor is highly isolated to support the high level of voltage (15 to 25 kV AC as nominal level); LEM's **ITC Transducer Series** is of this category.





Picture 1 :  
European rail networks

- not electrified
- electrified (DC) tracks
- 1.5 kV DC
- 3 kV DC
- 15 kV 16.7 Hz
- 25 kV 50 Hz
- 3 kV DC / 25 kV 50Hz

## EM4T II

### Energy meter for electrical traction unit railways

- Data recording according to EN 50463-x
- Accuracy 0.5R according to EN 50463-2
- Multi-System capability for DC, 16.7 Hz, 50 Hz, 60 Hz
- Supply systems according to EN50163: 25 kV 50 Hz, 15 kV 16.7 Hz, 600 V DC, 750 VDC, 1.5 kV DC, 3 kV DC
- Measurement of consumed and regenerated active and reactive energy
- For DC optionally with up to 3 DC current channels
- Input for GPS receiver
- Load profile recording including location data
- RS-type interface for data communication
- Ethernet-interface (Available in the next version)



Picture 2: EM4T II



Siemens Train

Version	Channel 1	Channel 2	Channel 3	Channel 4
AC	AC-voltage	AC-current		
ACDC	AC-voltage	AC-current	DC-voltage	DC-current
DC	DC-voltage	DC-current		
DCDC	DC-voltage	DC-current	DC-current	
DCDCDC	DC-voltage	DC-current	DC-current	DC-current

Chart 1: EM4T II possible configurations for inputs

For the DC networks, the transducer's inherent isolation properties are adequate.

Analog to Digital Sigma-Delta conversion processors suppress high frequency disturbances in all channels, enhancing even further the capacity to handle the often rapid supply transitions within traction supplies.

The microprocessor reads the sampled values and calculates the real energy in adjustable intervals (standard value = 5 min). The results are then saved in flash memory (a special variant of an EEPROM).

The signals from 2 AC and 2 DC input channels (each for U- and I- input) are used to calculate the energy values. The high-accuracy measurement of the energy value is guaranteed by the digitally sampled signal converter implemented, providing the highest level of temperature and long-term stability.

Optionally, the EM4T II for DC measurement is available in a version with a single voltage input and up to three current inputs to

measure the energy consumption for vehicles with multiple power supply points.

The EM4T II has a dedicated RS232 interface input for receiving serial GPS-data messages according to NMEA 0183, including the location data of the energy consumption point. It synchronizes also the internal clock of the meter using the obtained time information.

A log book in full conformity with EN 50463-3 is stored in the EM4T II. This log book information contains e.g. loss and gain of the operating voltage, power up/power down events of the supply voltage, clock synchronization, and the modification of parameters influencing the energy calculating.

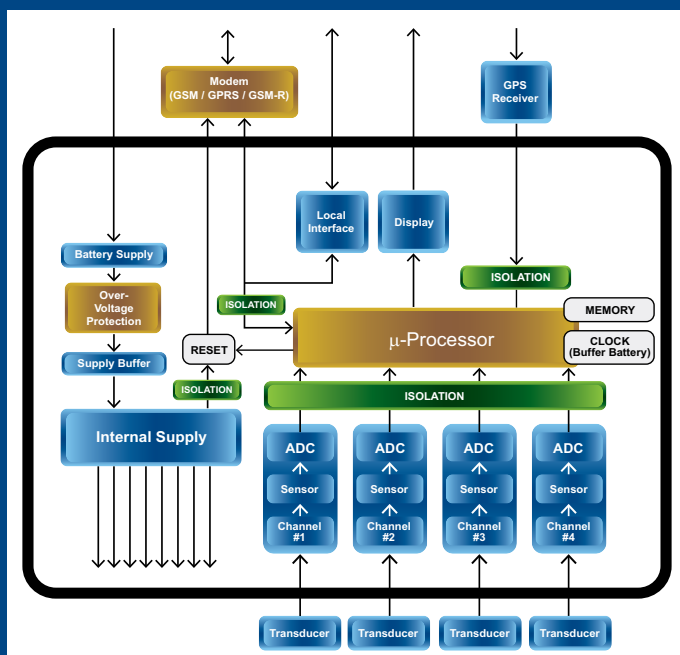
Identification data of the vehicle or train are also stored and can be retrieved separately. The self-luminous display of the EM4T II shows cyclically all relevant energy and status information without required operations of a mechanical or optical button.

All measured and stored data can be read out via the RS-type interface (via modem or local).

The interface versions RS232, RS422 or RS485 are available. The applied data communications protocol is IEC 62056-21 and is therefore easily adaptable by all common remote reading systems. In the next version, the EM4T II will also provide an Ethernet-interface.

The supply voltage is selectable between 24 V and 110 V. Optionally, the EM4T II offers a power supply of 12 V for a communication unit (modem).

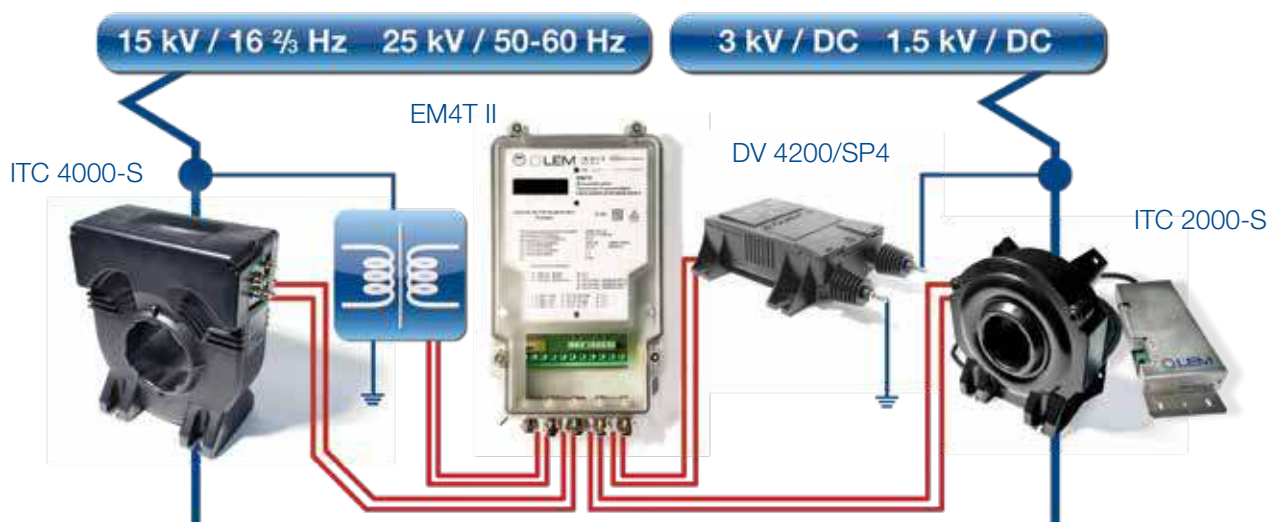
The operating conditions (considering EMC, temperature, vibration, etc.) meet the special requirements for traction use, including EN 50155, EN 50121-3-2, EN 50124-1, and EN 61373. The compact and fire-retardant enclosure provides protection against the ingress of moisture or foreign objects according IP 65.



Picture 3: Block diagram of the LEM energy meter

## Standards & Regulations

- EN 50463-x (2012): Railway application  
Energy measurement on board trains  
DC measurement Class 2  
AC measurement Class 1.5
- EN 50155 (2007): Railway applications  
Electronic equipment used on rolling stock
- EN 50121-3-2 (2006): Railway applications  
Electromagnetic compatibility  
Part 3-2: Rolling stock - Apparatus
- EN 61373 (2010): Railway applications  
Rolling stock equipment  
Shock and vibration tests
- EN 50124-1 (2001): Railway applications  
Insulation coordination  
Part 1: Basic requirements
- IEC 62056-21 (2002): Electricity metering  
Data exchange for meter reading, tariff and load control  
Part 21: Direct local data exchange



Part of a high voltage frame of a multi-system locomotive with the positions needed for current & voltage measurement



## DV-VOLTAGE FAMILY

1200 to 6400 V<sub>RMS</sub>

One unique compact package

Class 0.5R accuracy

Low thermal drift

## ITC 2000...4000-S FAMILY

Better than Class 0.5R

High temperature stability



## Specific Railway Applications

### 1. Interference Frequencies Detection

Most of the trolleybuses, trams, subways and suburban networks work with DC voltage (600 to 3000 V DC).

These networks are divided into different isolated sections, each powered by different substations as seen previously.

In addition to their normal DC voltages provided, these substations are supplying also a small AC signal (of 42 and 50 Hz or 60 or 100 Hz).

When a train enters a given section of the track system, the wheels short the AC signals (through the axle) and the “Track-Free-Signaling-System” protects this area with a red stop signal for the other trains.

By using PWM (Pulse Width Modulation) converters, the drive system of the trains also generate low frequency signals which are fed back into the network.

Due to these generated interference currents, the frequency spectrum must be controlled and limited to 10 A maximum through internal filters, because when a frequency of 42 Hz and/or 50-60-100 Hz is fed into the network, the “Track-Free-Signaling-System” will measure the signal and will open this section of the track for the other trains.

For example, in an application, the 25 Hz current generated and sent back to the DC supply can be 50 times greater than the maximum limit tolerated at 42 or 50 Hz (0.5 A).

LEM **RA** family current transducers have been designed to detect AC currents up to 20 A peak, in a dedicated bandwidth, superimposed on a DC current of 1000 up to 4000 A DC with a given accuracy.

A control system is then used to monitor the output signal of the LEM transducer. If frequencies of 42 Hz and/or 50 - 60 - 100 Hz are present, the system detects them and automated equipment stops the train.

Normally, the PWM converters are designed so that the drive system cannot generate these frequencies, but these may appear because of defects in the internal filter, malfunctioning of the pulse modulation system of the drive, etc. The **RA** products are considered as important products in this application as ensuring a safety function.

That is why the **RA** transducer can be used in a redundant way, with 2 pieces per measurement. Some additional functions are often required in this kind of application and then added, like an built-in test winding, part of the simulation system to check the overall safety chain before every start of the train.

application, a 1 A accuracy for the DC component measurement is sufficient and is performed by a Closed Loop Hall effect transducer. However, to achieve this level of accuracy, and withstand a high parasitic magnetic field environment, a special design is necessary (LEM current transducer **LB 2000-S/SP4** for example). Recall that the standard 2000 A transducers have a DC offset error of at least 2.5 to 3 A (Figure 8).

If the DC component control is made on the primary of the transformer where the supply voltage can be of 25 kV<sub>RMS</sub> AC, the AC current level will be much lower and the low DC component allowed will then require a more precise current measurement technology. Typically, Fluxgate technology can be used for that requirement but that means also a transducer with a large aperture as the primary conductor will have to be isolated

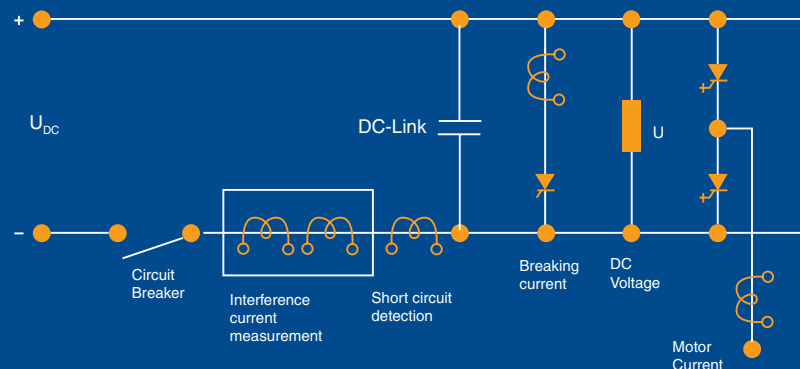


Figure 7: Interference current measurement on the DC link.

### 2. Main Transformer Saturation Detection

The measurement of a low DC component in high AC currents can be requested to control the current supplied by the main transformer previously to the driving converter. This DC component can saturate the transformer and, as a result, has to be limited or the faulty converter disconnected.

A 2000 A<sub>RMS</sub> transducer is required to measure both the AC current and the DC component. For that

for the network voltage (25 kV for example) or the transducer proposed will have to support this voltage level constraint.

### 3. Fault Detection

In underground DC traction power supplies using a positive and a negative running rail, differential current detectors (**CD differential current transducers**) are needed to detect faults from either supply pole to earth (Figure 9).



Such faults would perturbing currents for the signaling system. In this application, primary currents reaching up to 1500 A are controlled with a detection of an imbalance level of 1 A at a precision of 0.1 A.

In the same kind of underground vehicle, the heating circuits must also be controlled with differential current transducers. Currents of approximately 100 A are monitored for imbalance down to 100 mA with a maximum offset error of 15 mA.

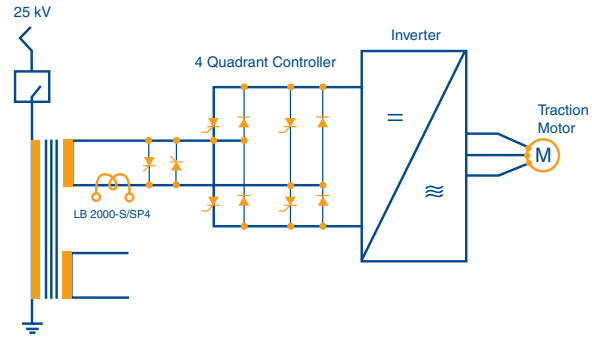


Figure 8: AC+DC measurement in transformer output of driving converter

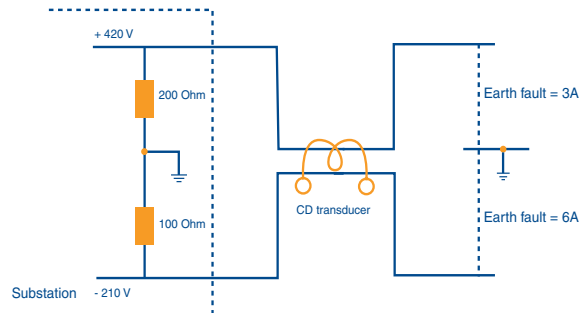


Figure 9: Current balance detector for underground

## CD FAMILY



Copyright ALSTOM

## RA FAMILY



## LB 2000 FAMILY



## Mining Trucks Applications

### Mining Trucks Traction

Off-highway vehicles (trucks) operating in mining use high horsepower diesel engines combined with an electrical drive system to propel them efficiently with electrical motors in harsh environments such as large surface mining.

AC or DC drive systems can be used according to the motors used. The global systems for propulsion of these trucks are quite similar to the ones used for the Diesel-Electric railway locomotives.

LEM, based on its experience in traction applications, supplies current and voltage transducers for control in inverters, one of the major sub-systems in truck drive systems.

In open cast mining (surface mining), the conditions are extreme leading to high constraints.

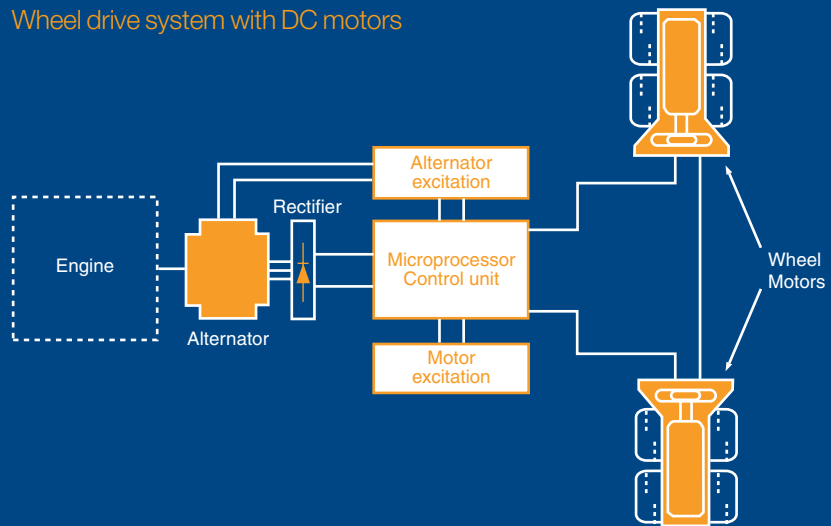
The truck wheels are electrically motorized, either DC or AC motors, driven by a specific drive (or inverter), as the ones used in traction applications to ensure the propulsion locomotives.

Electronic drives systems, compared to mechanical drives, provide lower operating costs and higher haul productivity.

The elimination of torque converters, drive shafts, transmissions, and differentials (all exhibiting high wearing coefficients), reduces the maintenance, improves the trucks life time, reliability and finally overall cost.

The motor torque and speed applied to the wheels is controlled by the DC or AC drives by closely monitoring the voltage and current supplied, avoiding then a gear box. This provides smooth application of the power to the wheels (this also reduces tire wear during wheel spinning and safe operation).

### Wheel drive system with DC motors



To simplify, the system is made up of:

- An alternator,
- a rectifier,
- a microprocessor control unit,
- and motorized wheels (DC motors).

The microprocessor control unit monitors the alternator and rectifier, and DC motorized wheels to deliver optimal performance.

The use of a microprocessor control unit allows quick diagnostics when defects occur.

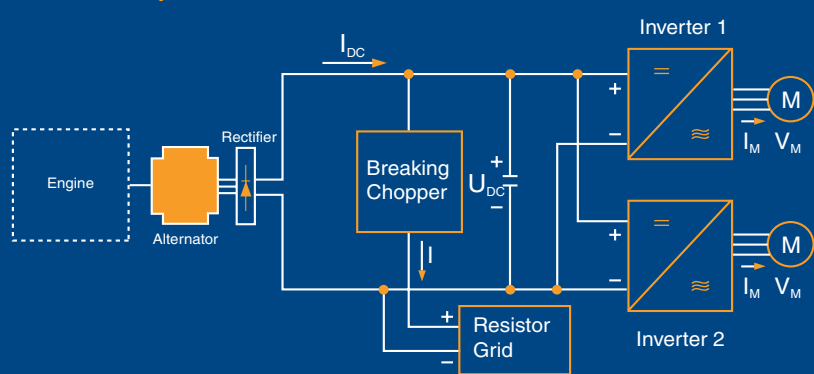
mining) and provide the whole system enhanced productivity by reducing maintenance services (Brushes elimination, contactors decreasing...).

The use of power electronics makes the system simpler and more reliable with increased efficiency. And the improved efficiency leads to less fuel consumption.

To simplify, the AC system is made up of:

- An alternator,
- a rectifier,

### Wheel drive system with AC motors



As for the traction propulsion in railway industry, the trend today is to use IGBT (GTO are also still used) based AC drive systems to control AC motors (generally asynchronous motors driving the wheels) for new levels of performance. AC motors are indeed less restricting (smaller, more robust, and, better suited for harsh environments such as surface

- a DC link,
- one or several DC/AC drive inverters,
- a microprocessor control unit,
- and motorized wheels (asynchronous motors).

The drive inverters are controlled by the microprocessor control unit to convert DC to AC power and

with the desired power (PWM voltage inverter with variable frequency, AC current). This is the same concept used for the drive propulsion inverters for locomotives in railway industry. All of the inverter output parameters (current, voltage, frequency) are controlled by the microprocessor control unit, adjusting if necessary, certain parameters at the inverter leading to attain the required power for the commanded torque and speed of the wheels.

Current and voltage transducers are essential to monitor these parameters. Nevertheless, due to the harsh conditions of the application, the models used have to be well adapted. Mining trucks are exposed to extreme dust, humidity, and temperature conditions all around the world; therefore, the transducer must be designed to perform optimally in this environment.

The result can be models issued from the **HTC** series (500 to 3000 A nominal), **LT 505 - 1005 - 2005** series for current measurement and from **DVM Voltage & DVL Voltage** families for voltage measurement. All transducers are potted or varnished to guarantee exceptional protection against humidity and dust. Also, vibration immunity is important in such applications. This explains the choice of transducers adapted for traction applications, as they have already complied with high level vibration constraints originating from railway applications. Hence, all are qualified against the EN 50155 standard for the environmental tests.



Copyright ALSTOM

## HTA FAMILY

250 A  
1000 A



## HTC FAMILY

500 A  
1000 A  
2000 A  
3000 A



One unique design  
to cover their ranges



## Trackside Applications

The rail industry operates in a physically unique context. If there is a points failure, signal problem or a fault with the rails, you can't just drive around the obstacle. More and more, people and goods are to be moved. Existing infrastructure must be exploited more efficiently.

The increasing separation of infrastructure and railway undertakings responsibilities within the rail system, particularly in Europe, underlines the importance of trackside and on-board monitoring. They serve to optimize the capital and maintenance cost of track equipment and rolling stock while ensuring satisfactory levels of safety and operational performance.

A study about the reliability and maintainability of the rail infrastructure revealed the following needs :

- Introduction of condition monitoring methods,
- Optimization of the maintenance plans,
- Guarantee of the safety level.

Monitoring systems arose from these needs expressed by the various maintenance contractors.

One of the goals was to decrease train service interruptions due to failures to improve the punctuality and to reduce potentially strong penalties.

Also, the availability of the railway network is becoming more and more crucial.

Existing infrastructure must be exploited more efficiently, that's why monitoring crucial track objects (points, crossing gates, signaling...) is an indispensable tool in this context. Online monitoring makes it possible to take preventive action. Replacements take place before abnormalities lead to failures.

Main functions of condition monitoring :

- Preventive maintenance, replacement to prevent failures,
- Maintenance process improvement.

About 25 % of disturbances causing trains delays are due to the point machines.

### 1. Points Machines (Picture 4) and Condition Monitoring

To measure the movement and the position of the switch machines, you can use a:

- Position transducer,
- Power transducer,
- Pressure transducer,
- Current and voltage transducers.

The curve of the motor current is shown every time the switch runs. This curve is compared with an ideal situation (reference curve) of the motor current.

A significant difference between the last curve and the reference curve will result in an alarm signal. Maintenance engineers can adjust the alarm level (Figure 10) and it is also possible to measure the voltage to adjust the trigger if there is a change in the voltage level.

As time elapses, changes in the machine footprint can indicate mechanical wear, lack of lubrication, points misalignment, and jamming within the points mechanism caused by ballast, electrical motor and winding failure. All indications result in an increase in total current absorbed.

Any variation from the normal profile also indicates the likelihood of other developing problems – wear, rust, debris, vandalism, etc.

An early warning of machine failure, using current profile monitoring before problems or critical breakdown occur, is provided to signal preventive maintenance.

When necessary, the replacement of material (points motor for example) is performed, with supporting evidence, i.e. current profile records.

The information is collected and analyzed to predict a more preventive maintenance time for similar equipment.

Generally speaking, this optimizes the efficiency of the railway maintenance staff, minimizes the traffic disruption and keeps costs to an acceptable level.

LEM has designed a dedicated clip-on current transducer family called **PCM** (Points Condition Monitoring), covering DC or AC current measurements of 5, 10, 20 and 30 A nominal. To be mounted directly in the switch and without disruption to existing cabling or connections, the **PCM** current transducer is to be secured around the conductor without any contact. This is one of the main requirements for retrofit applications.

Its mechanical design is also adapted to the harsh environment along the tracks and waterproof versions are available.

Most of the motors used for the points machines have been DC motors but today, the trend is to use AC motors as they are more robust, compact and less expensive on maintenance.

The **PCM-PR** versions are dedicated for these AC motors to control the high speed train switches. They measure the AC low frequency currents (from 0.040 to 1 kHz) exactly for the same reasons as for the DC motors previously and provide a 4-20 mA DC output representing the true RMS value of the measured signal. This kind of output signal is compatible with PLCs that analyze the data.

**PCM** products are designed for use by the railway maintenance contractors as a retrofit tool for the actual infrastructure. Typically, the contractors provide current measurement without disruption to the operating points machines. It is important not to interrupt the current carrying conductors to the points motors as this would disrupt the safety chain mechanism. Hence, the **PCM** transducers are designed to allow uninterrupted



connection and measurement by way of the clip-on package. This type of retrofit is a requirement by the integrators and infrastructure owners.

Of course, condition monitoring using transducers may be integrated into the initial design of the points machine system. If this is the case, electrical current interruption is not a concern and therefore other, more cost effective, current measurements are available. Being part of the original electronic assembly, PCB mounted current transducers might be viable solutions. LEM can offer the **LXSR 6-15-25-NPS** or the **LA 25-NP** or **CAS/CASR/CKSR 6-15-25-50-NP** series transducers for this particular application.

## 2. Track Circuits (Picture 5) and Condition Monitoring

About 5 % of disturbances causing trains delays are due to track circuit failures. The track circuit is a method of indicating the presence of a train on a given section of line. With relay-operated signals, the extend of the circuit typically corresponds to a signaling block section.

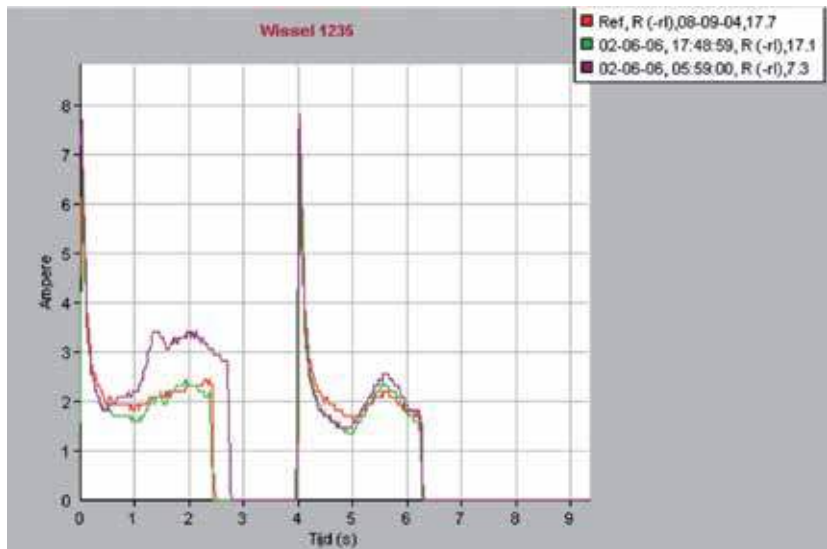


Figure 10: Typical current profile of a points DC Motor over the time  
Picture provided by courtesy of STRUKTON

## PCM FAMILY

5 to 30 A



Clip-on design - Ideal for retrofit applications



Picture 4: Points Machine along the tracks.



## CASR FAMILY

6 - 15 - 25 - 50 A



## LXSR FAMILY

6 - 15 - 25 A



## LA 25-NP FAMILY

0.25 to 25 A

PCB mounted current transducers

The source of current begins at one end of the isolated rail section, the driving current travels down the rail to the end of the section where it then energizes a relay, is redirected to the other rail section and finally, returns to the power supply to complete the circuit. The energized relay prevents the signaling lights to operate indicating that the rail section is free. (Figure 11).

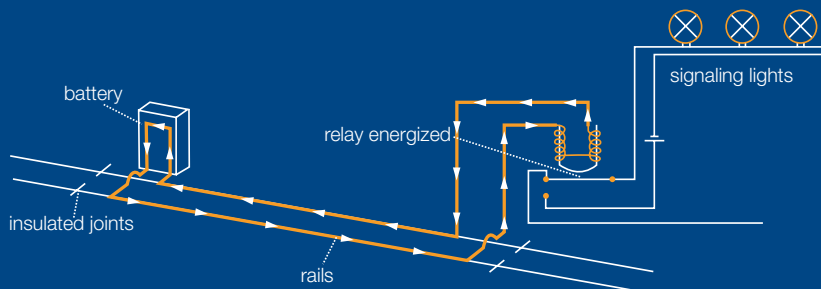


Figure 11: Track circuit situation with no train on the track.

However, if there is a train on the section, the current path is shorted through the wheels and axles, bypassing the relay, back to the other rail and returning to the power supply. The relay is now de-energized and the signaling lights are in operation indicating the presence of a train (Figure 12).

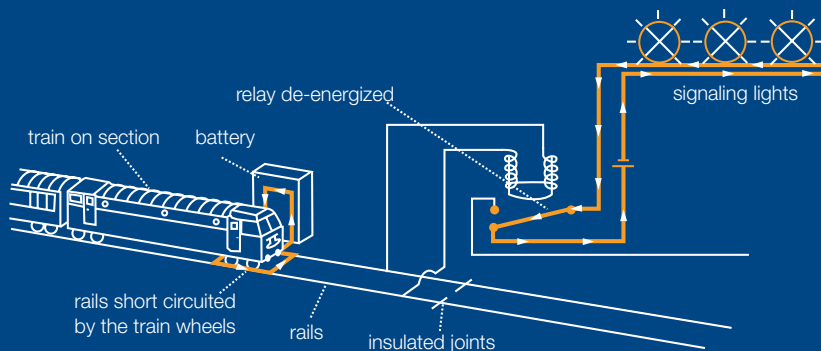


Figure 12: Track circuit situation with a train on the track

For the system to work reliably, rail joints have to be electrically bonded with a wire connecting the two rail ends. At each end of the section, the circuit has to be kept in isolation. Foreign objects (ice, leaves, etc.) on the line can cause failure of this circuit resulting in an avoidance or creation of an untimely short circuit.

This kind of circuit is typical for older and existing installations, however today, with modern continuous welded rails, it is more and more difficult and less desirable to fit insulated joints. Today, coded electrical impulse track circuits are installed.

Monitoring the actual track circuit current flow, in lieu of the relay,

would allow interpretation of the current levels as an indication of potential problems as well as knowing when a train is passing or not. Typical current monitoring levels are between 20 and 90 mA depending of the resistance of the short circuit. A current threshold detector can be used to report relay failure when the

circuit current changes but the relay does not operate.

By sensing the current in the lamps, the system can not only determine if the lamp filaments are intact and wired properly but, can also record the aspect (color) of the signal when a train passes a section of track. Consequently, an alarm can be issued if the driver passes a red signal.

Monitoring of the supply voltages for both the track circuit and signal lamps will also highlight failures. LEM transducers can work with AC or DC track circuits and are extensively used in the railway industry.

The measurement of the currents in the vast number of relays used within the rail network is required. For non-contact measurement (which is clearly a requirement for avoiding interference of relay operation), the CTSR series is an option with nominal measurements of 300, 600 mA<sub>RMS</sub> or 1 A<sub>RMS</sub> and a large aperture of 20.1 mm diameter.

Other current transducers are also available for this function, such as the CKSR 6-NP or LXSr 6-NPS or LV 25-P (1.5A<sub>RMS</sub> and 6 A<sub>RMS</sub> and 10 mA<sub>RMS</sub> nominal, respectively) capable of measuring AC or DC waveforms with an integrated primary conductor.

### 3. Crossing gates (Picture 6) and Condition Monitoring

About +/-15 % of disturbances causing trains delays are due to crossing gate failures.

In the USA, priority is on the level crossings (railroad crossings). Each new level crossing uses current measurement for the motor, the incandescent lamps and bells. The current measured may be DC as well as AC.

Although the future is LED lamp technology and thereby smaller currents, current measurement is still necessary for condition monitoring.

It is easily understood that the monitoring system must detect if the gate motor and signals are working properly when there is an approaching train. This is a question of safety and current measurement provides this knowledge. The motor current waveform can be analyzed and compared with the typical current profile during gate activation.

the motor could signify a potential failure or problem such as the end of life of the motor or an obstacle in front of the gate.

Signal monitoring is a method to identify if the lamps are working fine. The current provided to the LED lamp cluster is monitored by a highly accurate current transducer. A reduced LED current level would indicate that one or several individual LEDs have ruptured. There is a defined number of allowable defective LEDs in a lamp and this can be determined from the current level and then the defective LEDs can be replaced to ensure the minimum safety. Current transducers provide this information.

This early warning detection is useful when scheduling routine maintenance thereby reducing the costs to schedule an unplanned repair run.

Typical current consumption for a lamp produced with several LEDs is 500 mA and 10 A for the gate motor when lifting or lowering.

An inexpensive transducer solution for motor current monitoring is the **LXSR** series with nominal current measurements from 6 to 25 A<sub>RMS</sub>. For signal monitoring, the **CTSR** series meets the requirement with 3 models covering accurate measurements from 300 mA<sub>RMS</sub> up to 1 A<sub>RMS</sub>.

These transducers provide measurement with no contact with the conductor. In this type of application, it is important not to add any new items in the existing signaling circuit, that is to say, not to introduce a new potential disruption in the circuit. The non-contact measurement is a must as they are considered safety items.



Picture 5: Tracks network



Picture 6: Signaling at a crossing gate

## CTSR -P & -TP FAMILY

### PCB mounting



0.3 / 0.6 / 1 A

## Non-contact small current measurement

### LV 25-P FAMILY



Current measurement of 10 mA<sub>RMS</sub>



## LEM's Quality & Standards

Quality is demanded by everyone and it is quite justified.

The levels of quality required by customers are different depending on the application as well as the standards to comply with.

This quality has to be reached but also maintained and constantly improved for both products and services. The different LEM design and production centers around the world are either ISO TS 16949, ISO 9001 and/or ISO 14001 certified. Our main production centers for traction transducers are IRIS certified, a must for companies supplying the railway market.

Several quality tools have been implemented at LEM to assess and analyze its performances. LEM utilizes this information to take the necessary corrective actions to remain a responsive player in the market.

Among which the most representatives are:

**DPT FMEA** (Design, Process & Tool Failure Mode Effect Analysis) tool used preventively to:

- identify the risks and the root causes related to the product, the process or the machinery and,
- set up the corrective actions,

**Control Plan:** Description of checks and monitoring actions executed along the production process,

**Cpk – R&R** (Capability for Processes & Measurement Systems):

- **Cpk:** Statistical tool used to evaluate the ability of a production procedure to remain stable and accurate within a specified allowance range,
- **R&R:** Repeatability and Reproducibility: Tool to monitor the accuracy of a measurement

device within a pre-determined allowance range,

**QOS – 8D** (Quality Operating System – Eight Disciplines):

- **8D:** Problem solving process used to identify and eliminate the recurrence of quality problems,
- **QOS:** System used to solve problems,

**IPQ** (Interactive Purchase Questionnaire): Tool aimed at involving the supplier in the quality of the purchased parts and spare parts.

In addition to these quality programs, and since 2002, LEM embraces **Six Sigma** as its methodology in pursuit of business excellence. The main goal is to create an environment in which anything less than **Six Sigma** quality is unacceptable.

### LEM's Standards

LEM traction transducers are designed and tested according to recognized worldwide standards.

The EN 50155 standard dedicated to "Electronic Equipment used on Rolling stock" in railway applications is our standard of reference for electrical, environmental and mechanical parameters. It guarantees the overall performances of our products in railway environments. All of the LEM traction products are designed according to the EN 50155 standard.

CE marking is a guarantee that the product complies with the European EMC directive 2004/108/EEC and low voltage directive and therefore warrants the electro-magnetic compatibility of the transducers. Transducers comply to the EN 50121-3-2 standard (Railway EMC standard).

UL is used as a reference to define the flammability of the materials (UL94V0) as well as the NFF 16101 and 16102 standards for the fire/smoke materials classification.

LEM is currently UL recognized for main models.

You can consult the UL website to get the updated list of recognized models at [www.UL.com](http://www.UL.com).

The individual datasheets precisely specify the applicable standards, approvals and recognitions for individual products.

The EN 50124-1 ("Basic requirements – Clearances and creepage distances for all electrical and electronic equipment") standard is used as reference to design the creepage and clearance distances for the transducers versus the needed insulation levels (rated insulation voltage) and the conditions of use.

The rated insulation voltage level allowed by a transducer intended to be used in an application classified as being "Railway", is defined according to several criteria listed under the EN 50124-1 standard. Some criteria are dependent on the transducer itself when the others are linked to the application.

These criteria are the following:

- Clearance distance (the shortest distance in air between two conductive parts),
- Creepage distance (the shortest distance along the surface of the insulating material between two conductive parts),
- Pollution degree (application specific - this is a way to classify the micro-environmental conditions having effect on the insulation),
- Overvoltage category (application specific - characterizes the exposure of the equipment to overvoltages),
- Comparative Tracking Index (CTI linked to the kind of material used for the insulated material) leading to a classification over different Insulating Material groups,
- Simple (Basic) or Reinforced isolation need.



LEM follows this thought process for the transducer designs:  
Example: LTC 600-S, current transducer in an propulsion inverter

Conditions of use:

Creepage distance: 66.70 mm,  
Clearance distance: 45.90 mm,  
CTI: 600 V (group I),  
Overvoltage category: II,  
Pollution Degree: 3.

#### Basic or Single insulation:

According to EN 50124-1 standard:  
With clearance distance of 45.90 mm and PD3,  $U_{Ni}$  (Rated impulse voltage) = 30 kV.  
With  $U_{Ni}$  = 30 kV & OV II, the rated insulation voltage (AC or DC) called " $U_{Nm}$ " can be from  $\geq 6.5$  up to  $< 8.3$  kV.

With a creepage distance of 66.70 mm and PD3 and CTI of 600 V (group I), it is allowed to have 12.5 mm/kV, leading to a possible rated insulation voltage  $U_{Nm}$  of 5.336 kV. In conclusion, the possible rated insulation voltage,  $U_{Nm}$ , in these conditions of use, is of 5.336 kV (the lowest value given by the both results from the creepage and clearance distances).

#### Reinforced insulation:

Let's look for the reinforced insulation for the same creepage and clearance distances as previously defined:

When dimensioning reinforced insulation, from the clearance distance point of view, the rated impulse voltage,  $U_{Ni}$ , shall be 160% of the rated impulse voltage required for basic insulation.

The clearance distance of 45.90 mm is already designed and then, we look for the reinforced insulation with this distance.

Reinforced  $U_{Ni}$  = 30 kV obtained with the clearance distance of 45.90 mm.

Basic  $U_{Ni}$  = Reinforced  $U_{Ni}$  / 1.6 = 18.75 kV.

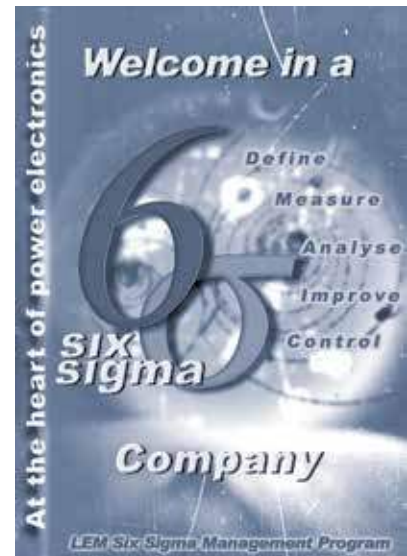
Reinforced  $U_{Nm}$ : From  $\geq 3.7$  up to

$< 4.8$  kV, according to the clearance distance.

From the creepage distance point of view, when dimensioning reinforced insulation, the rated insulation voltage  $U_{Nm}$  shall be two times the rated insulation voltage required for the basic insulation.

With a creepage distance of 66.70 mm and PD3 and CTI of 600 V (group I), it is then allowed to have 25 mm/kV ( $2 \times 12.5$ ) vs. 12.5 mm/kV previously (for basic insulation), leading to a possible reinforced rated insulation voltage  $U_{Nm}$  of 2.668 kV.

In conclusion, the possible reinforced rated insulation voltage  $U_{Nm}$ , in these conditions of use, is of 2.668 kV (the lowest value given by the both results from the creepage and clearance distances).



#### Key Six Sigma Statistics

Company Status	Sigma Level	Defect Free	Defects Per Million
Non Competitive	2	65%	308,537
	3	93%	66,807
Industry Average	4	99.4%	6,210
	5	99.976%	233
World Class	6	99.9997%	3.4

Source: Six Sigma Academy, Cambridge Management Consulting

**IRIS**   
**Certification**

**RoHS** 

According to RoHS 2 directive 2011/65/EU

## Solutions for Voltage Measurement



LV 25-P Family

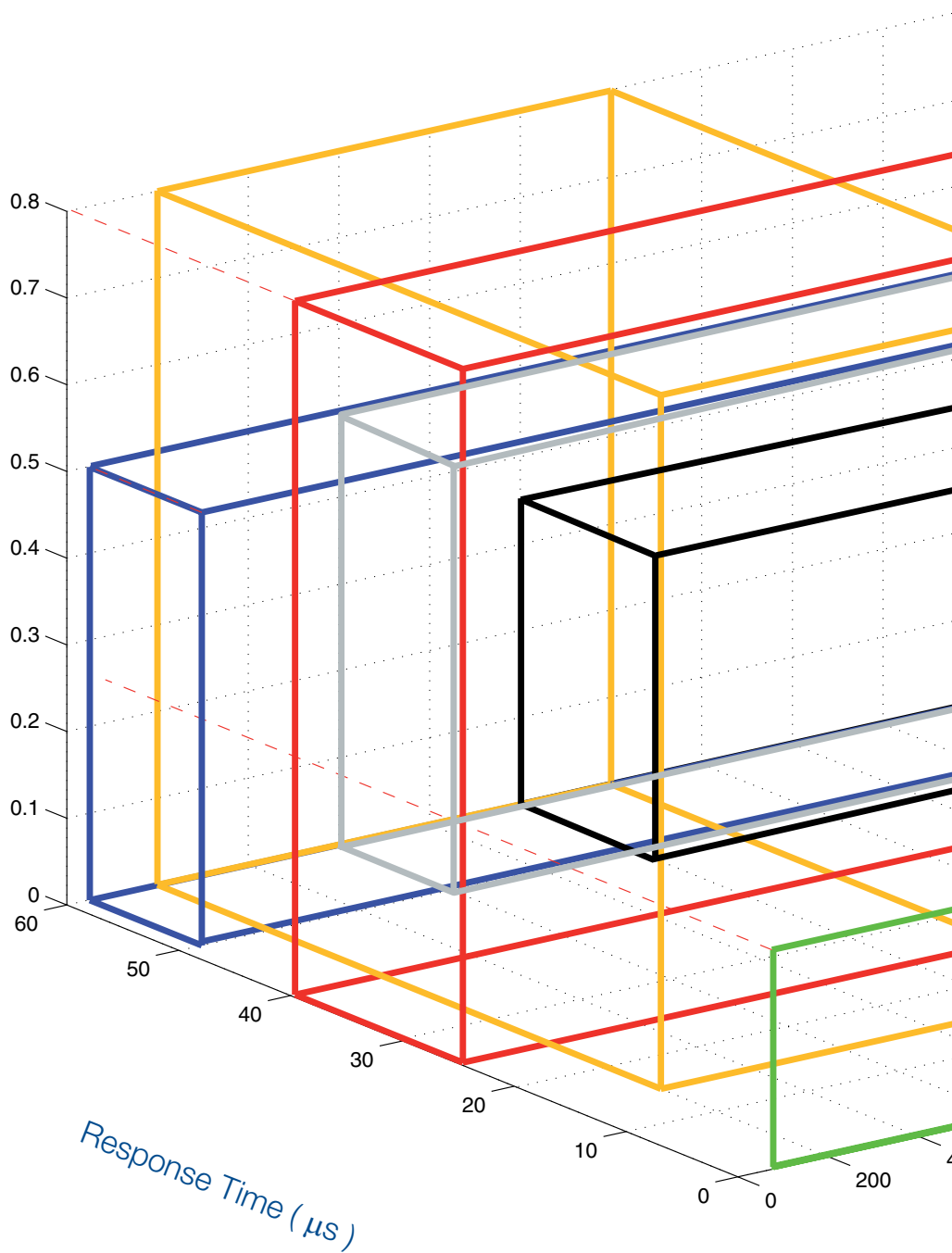


LV 25-Voltage



DVL Voltage

Overall Accuracy @ +25 °C ( % of  $V_{PN}$  )





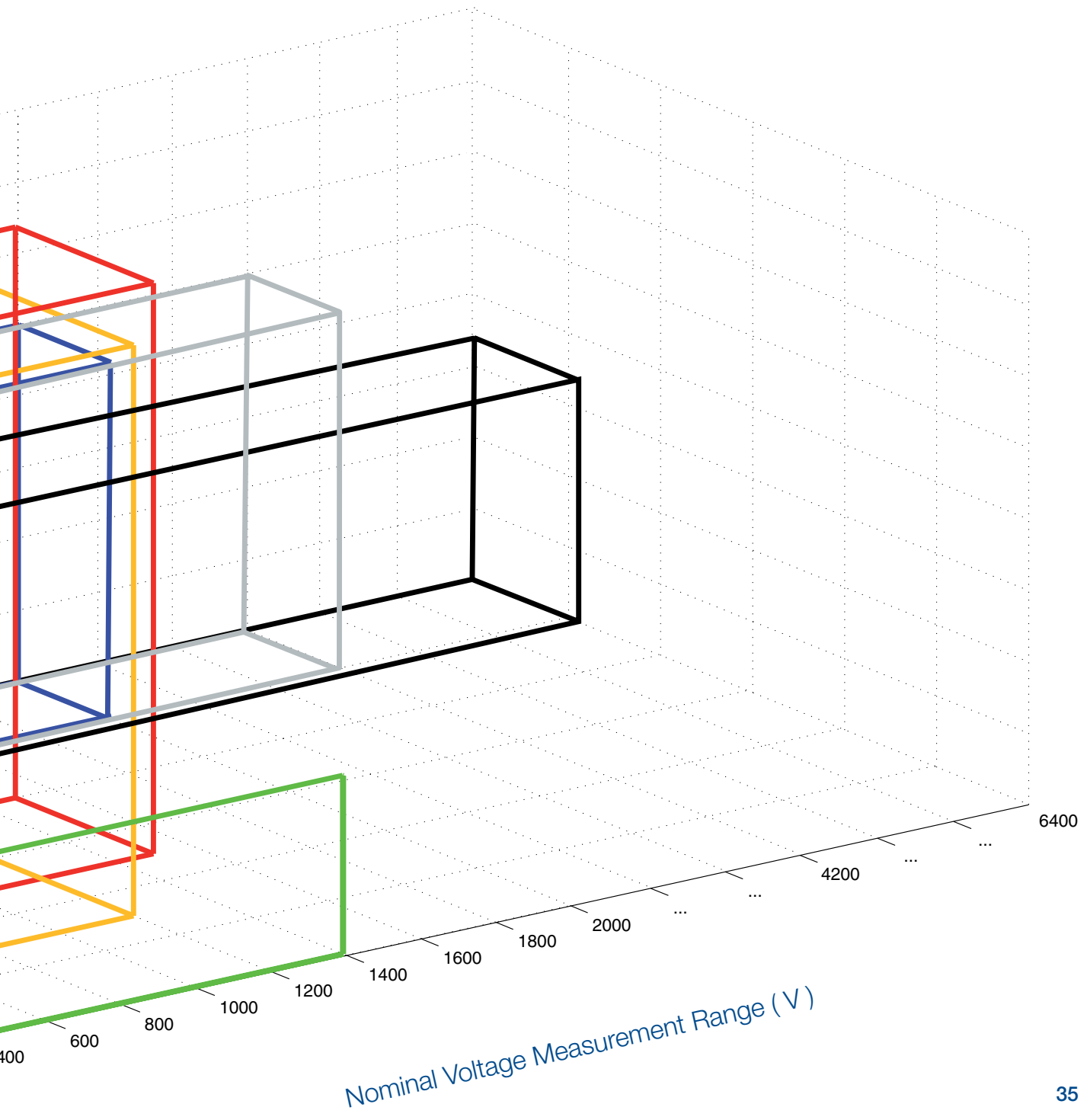
CV 3-Voltage



DVM-Voltage



DV Voltage



	On-Board										
	Main circuit breaker	Main rectifier	DC Link	Auxiliary inverter	Propulsion inverter	Energy measurement	SECONDARY SYSTEM				
							Lighting / plugs	HVAC	Doors Control	Battery Charger	
CURRENT MEASUREMENT											
VOLTAGE											
ENERGY											



		Trackside			Substation		Product Solution	Nominal Range
	Interference measurement	Points	Relays	Signaling	Switch-gear	Package represented on page n°		
						13	LT 505-S family	250-720 A
						13	LT 1005-S family	1000 A
						13	LT 2005-S family	1100-2000 A
					●	13 & 14	LT 4000-S family	4000-4400 A
						7 & 9	LTC family	200-1000 A
						11	LAC 300-S	300 A
						13	LA 205/305-S family	200-500 A
						11	LF 210-S family	100-200 A
						11	LF 310-S family	300 A
						14	LF 510-S family	500 A
						14	LF 1010-S family	1000 A
						14	LF 2010-S family	2000 A
						27	HTA family	250-1000 A
						17	HAR family	1000 A
						27	HTC family	500-3000 A
					●	23	ITC family	2000-4000 A
					●	19	HAZ family	4000-20000 A
						25	LB family	2000 A
	●					25	CD family	2 x 1000 A, 1200 A, 1500 A, 2 to 10 A differential
						25	RA family	10-20 A AC Peak superposed on 1000 to 4000 A DC
			●	●		31	CTSR-P & -TP family	0.3-0.6-1 A
		●		●		29	LA 25-NP family	0.25-25 A
		●				29	PCM family	5-10-20-30 A
		●		●		29	LXSR & CAS/CASR/CKSR families	1.5-50 A
				●		31	LV 25-P family	0.01 A
		●		●		34	LV 25-P family	10-1500 V
		●				34	LV 25-Voltage family	200-1200 V
					●	15, 17 & 35	DVM-Voltage family	600-4200 V
						34	CV 3-Voltage family	85-1400 V
						15, 17, 34	DVL Voltage family	50-2000 V
					●	22 & 35	DV-Voltage family	1200-6400 V
						21	EM4T II	

Various options for secondary connections



Molex 5045/A  
Series connector



JST VH Series  
Connector



Molex Mini-Fit, Jr 5566  
Series Connector



Molex 70543  
Series Connector



Threaded Studs, M4, M5, UNC...



...or Faston 6.30 x 0.80 or  
screws...



...or the both, in the same time



M4, M5 inserts



LEMO Connectors



AMP Connectors



Burndy Connectors



Sub-D Connectors



Cables, Shielded Cables...



But also Wago, Phoenix, Souriau ... connectors



<b>LEM Subsidiary :</b> _____		<b>Contact :</b> _____		<b>Date :</b> _____	
<b>Customer information</b>				<b>e-mail :</b> _____	
Company : _____		City : _____		Country : _____	
Contact person : _____		Phone : _____		Fax : _____	
Project name : _____					
<b>Application</b>					
<b>Type</b>	<input type="checkbox"/> industrial	<input type="checkbox"/> traction	<input type="checkbox"/> automotive	<input type="checkbox"/> process autom.	<input type="checkbox"/> other: _____
<b>Utilisation</b>	<input type="checkbox"/> voltage	<input type="checkbox"/> current	<input type="checkbox"/> power	<input type="checkbox"/> other: _____	
<b>Function</b>	<input type="checkbox"/> control	<input type="checkbox"/> display	<input type="checkbox"/> ground fault detection		
	<input type="checkbox"/> detection	<input type="checkbox"/> differential measurement	<input type="checkbox"/> other (provide a separate descr.)		
<b>Electrical &amp; Environmental characteristics</b> <i>Transducer reference (if relevant):</i> _____					
<b>Signal to measure</b>			<b>Static and intrinsic values</b>		
Type of signal : <input type="checkbox"/> AC sin. <input type="checkbox"/> DC			Global accuracy (% of nominal value, @ 25 °C) _____ %		
<input type="checkbox"/> square <input type="checkbox"/> pulse					
<input type="checkbox"/> other			Overall accuracy over operating temperature range _____ %		
<input type="checkbox"/> bidirectional <input type="checkbox"/> unidirectional					
Nominal value: _____ rms			Maximum offset @ 25 °C: _____ mA/mV		
Measuring range: _____ pk			Dielectric strength:		
(please provide a graph)			Primary/secondary (50 Hz/ 1 mn): _____ kV rms		
Overload value to be measured _____ rms			Screen/secondary: _____ kV rms		
Peak: _____ pk			Impulse withstand voltage _____ kV rms		
Duration: _____ s			PD Level @ 10 pC: _____ kV		
Non measured overload: _____ pk			OV category: _____ Pollution degree: _____		
(to withstand) Frequency: _____ Hz			Rated Isolation Voltage:		
duration: _____ ms			Single isolation: _____ V		
di/dt to be followed: _____ A/μs			Reinforced isolation: _____ V		
Bandwidth: _____ kHz			Preferred output: _____ <input type="checkbox"/> mA/A <input type="checkbox"/> mV/A		
Operating frequency: _____ Hz			_____ <input type="checkbox"/> mA/V <input type="checkbox"/> mV/V		
Ripple: _____ pk-pk			Turn ratio: _____		
Ripple frequency: _____ Hz			Temperature range		
dv/dt applied on primary circuit: _____ kV/μs			Operating: _____ °C to _____ °C		
Power supply: _____ V ± _____ %			Storage: _____ °C to _____ °C		
<input type="checkbox"/> bipolar <input type="checkbox"/> unipolar					
<b>Mechanical requirements</b>					
Maximum dimensions required: L _____ mm x W _____ mm x H _____ mm					
Mounting on: <input type="checkbox"/> PCB <input type="checkbox"/> Panel					
Output terminals: <input type="checkbox"/> PCB <input type="checkbox"/> Faston <input type="checkbox"/> Threaded studs M_ <input type="checkbox"/> Molex <input type="checkbox"/> Cable					
<input type="checkbox"/> other: _____					
Primary connection: <input type="checkbox"/> through hole: L _____ mm x W _____ mm; or Ø _____ mm					
<input type="checkbox"/> busbar L _____ mm x W _____ mm x H _____ mm					
<input type="checkbox"/> other: _____ For the bus bar, please provide layout					
<b>Applicable standards:</b> industrial <input type="checkbox"/> EN 50178 traction <input type="checkbox"/> EN 50155 other <input type="checkbox"/>					
If other, please specify: _____					
<b>Project management (amounts given in EUR)</b>					
Financials Target price _____ and Target cost _____ or Gross margin _____ %					
Total quantity for the project: _____ and product life time _____ or quantity per year _____					
Delivery: <input type="checkbox"/> Engineering samples Quantity: _____ Date: _____					
<input type="checkbox"/> Prototype Quantity: _____ Date: _____					
<input type="checkbox"/> Initial samples Quantity: _____ Date: _____					
<input type="checkbox"/> Series 1 Quantity: _____ Date: _____					
Required response time _____					



## DESIGN SPECIFICATION

**Comments:**

\_\_\_\_\_

Railway Current & Voltage Transducers, Edition 2013, Published by LEM  
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Terms of delivery and rights to change design or specifications are reserved.



# PRODUCT CODING / Industrial & Traction Transducers

## Family

A	: transducers using the principle of isolation amplifier
C	: transducers using the principle of fluxgate compensation
D	: digital transducers
F	: transducers using the detector of fields
H	: transducers using the Hall effect without magnetic compensation
I	: compensation current transducers with high accuracy
L	: transducers using the Hall effect with magnetic compensation
R	: transducers using the principle of the Rogowski loop
T	: transducers using the simple transformer effect

## Group:

A or AK or AL or AS 1) or AT or AX or AZ	: with rectangular laminated magnetic circuit
AR or AW or AC or X or XN	: with rectangular laminated magnetic circuit
AF	: with rectangular laminated magnetic circuit and flat housing
AH	: vertical mounting
AIS, XS, ASS, AFS	: rectangular laminated magnetic circuit + unidirectional power supply + reference access
ES	: rectangular magnetic circuit + unipolar power supply
ESR, PSR, XSR, ASR, KSR	: rectangular magnetic circuit + unipolar power supply + reference access
AY	: rectangular magnetic circuit + hybrid
B	: double toroidal core
C	: apparent printed circuit
D	: differential measurement
HS	: Hall effect without magnetic compensation; magnetic concentrators + unidirectional power supply + reference access. When used with F (FHS): Minisens, SO8 transducer
F	: flat design
I	: shunt isolator
MS	: surface mounted device + unidirectional power supply + reference access
OP	: opening laminated magnetic circuit
TC	: transducer reserved for the traction
TD	: double measurement
TKS, TFS	: core, flat case + unidirectional power supply + reference access
TP, TO, TN, TZ, TL, T, TA, TB, TY	: toroidal core
TR	: opening core
TS	: core + unipolar power supply
TSR, TSP	: core + unipolar power supply + reference access
TT	: triple measurement
VM, V, VL	: voltage measurement
Y	: compact hybrid for PCB mounting

## Nominal Amperage

- current transducer : rms amperes
- voltage transducer : rms amperes-turns
  - 0000 : Nominal Voltage (-1000 meaning 1000 V, with built in primary resistor R1)
  - AW/2 : particular type of voltage transducer
  - AW/2/200: Nominal voltage for AW/2 design (200 meaning 200V with built in primary resistor R1)

## Execution

N	: multiple range
P	: assembly on printed circuit
S(l)	: with through-hole for primary conductor
T(l)	: with incorporated primary busbar

## Particularities (1 or 2 optional characters or figures)

B	: bipolar output voltage
BI	: bipolar current output
C	: fastening kit without bus bar
F	: with mounting feet
FC	: with mounting feet + fastening kit
P	: assembly on printed circuit
PR	: programmable
R	: rms output
RI	: rms current output
RU	: rms voltage output

1) When used with L (LAS): current transducer with secondary winding and unipolar power supply using Eta technology

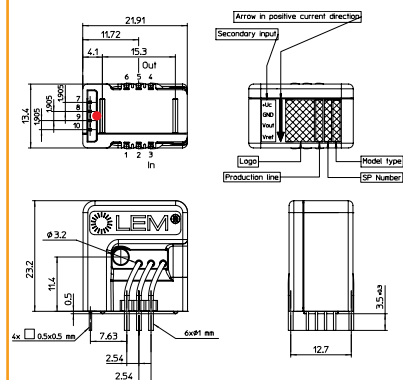
## Variants

Differing from the standard product... /SPXX

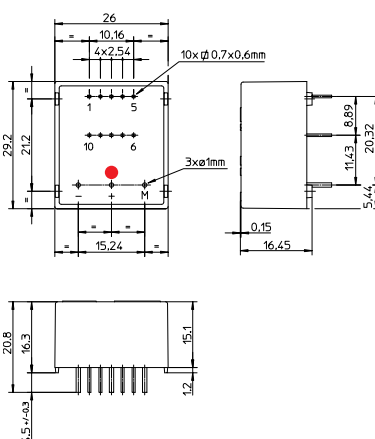
When used with C (CAS): current transducer with rectangular magnetic circuit + unipolar power supply

LTC 600-SF/...

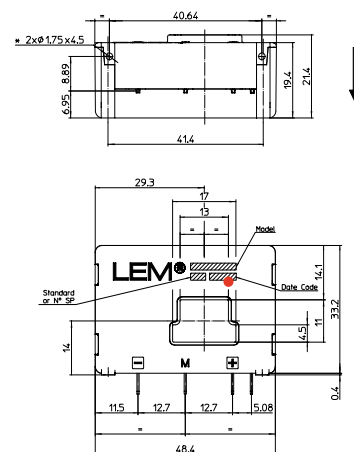
LXSR 6-NPS; LXSR 15-NPS; LXSR 25-NPS



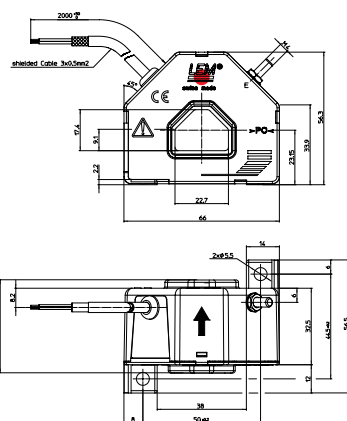
LA 25-NP/SP25



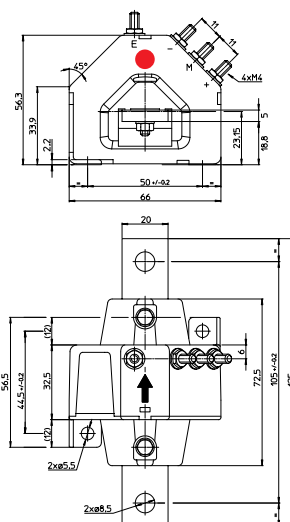
LA 200-P/SP4



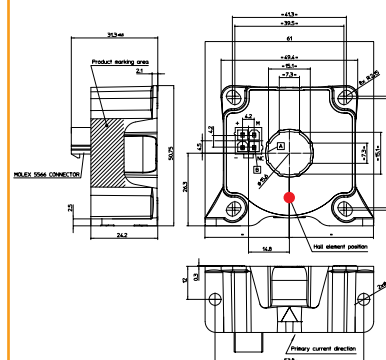
LA 205-S/SP21



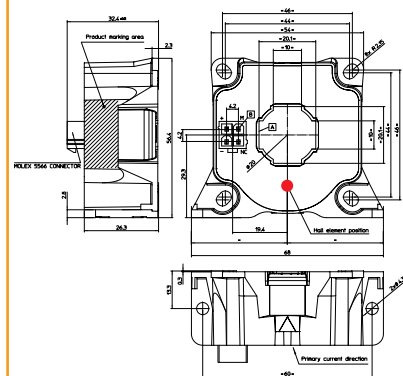
LA 205-T/SP16



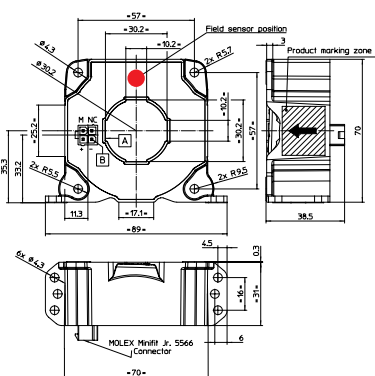
LF 210-S/SP5; LF 210-S/SP11



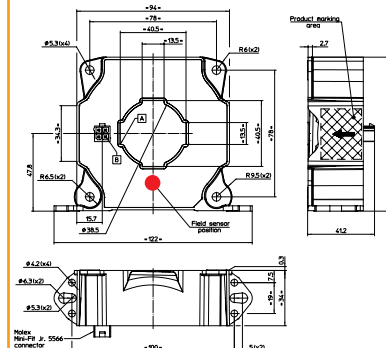
LF 310-S/SP20

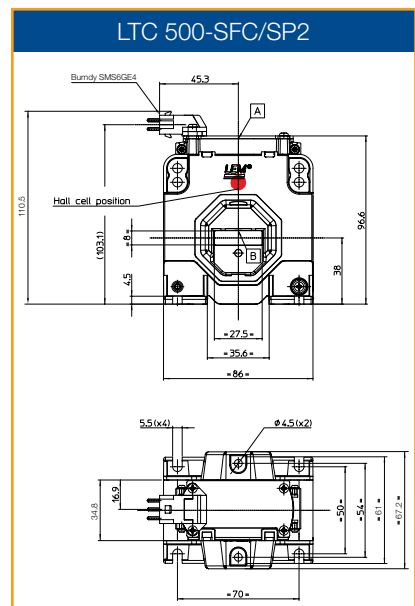
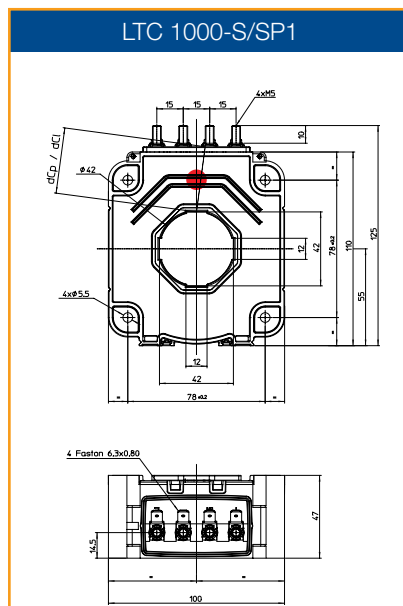
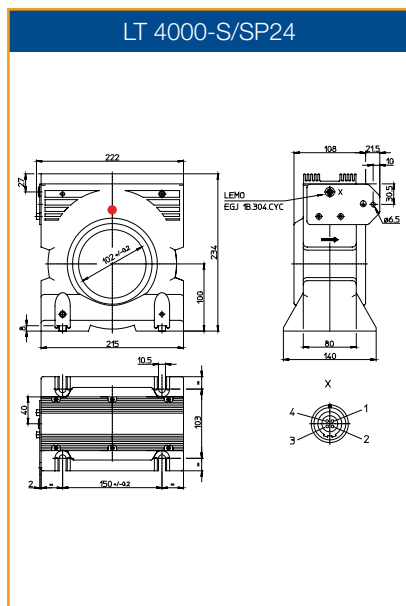
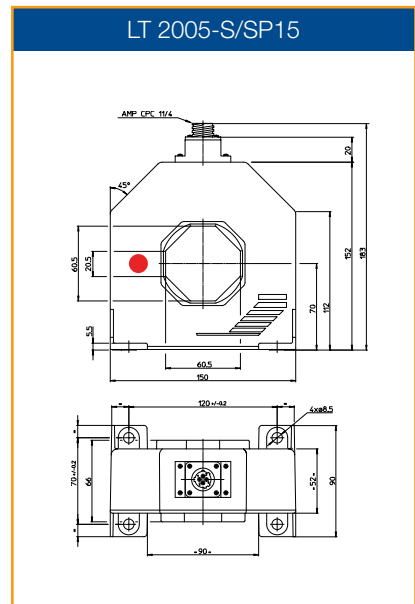
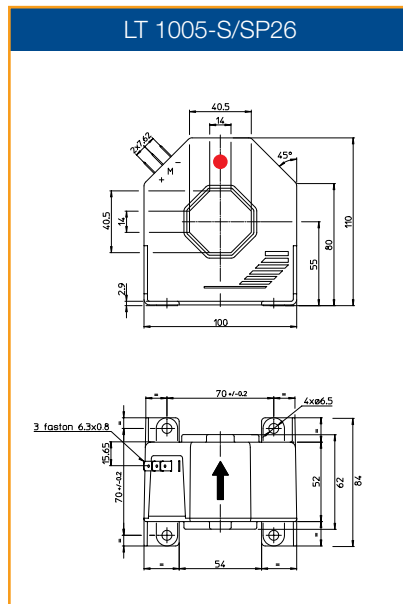
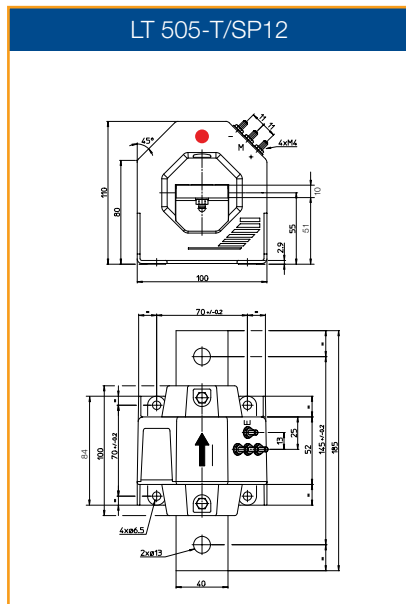
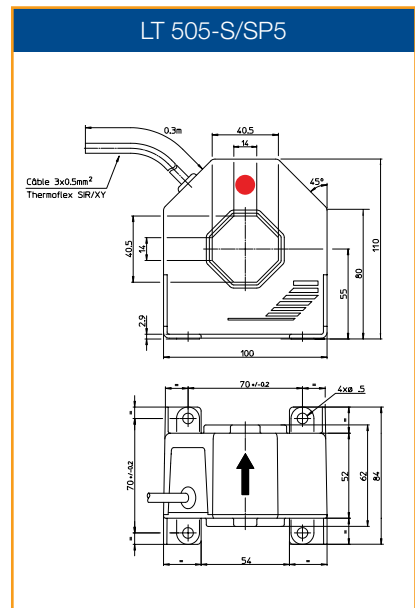
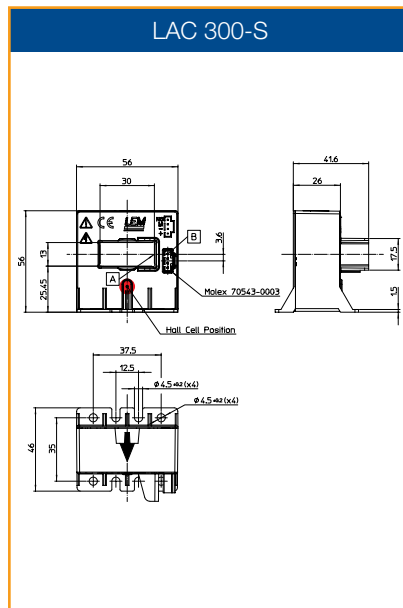
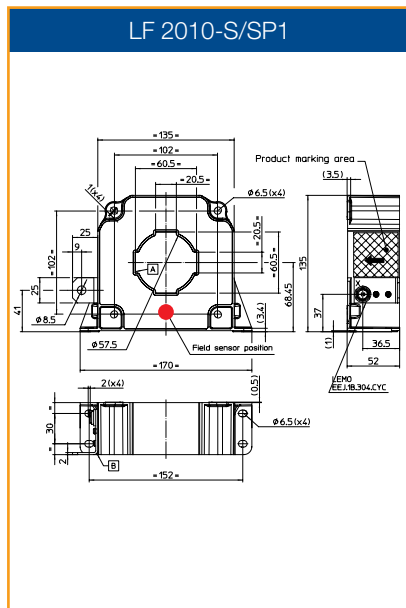


LF 510-S/SPA2



LF 1010-S/SPA2

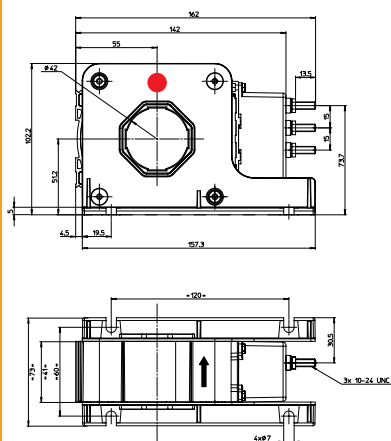




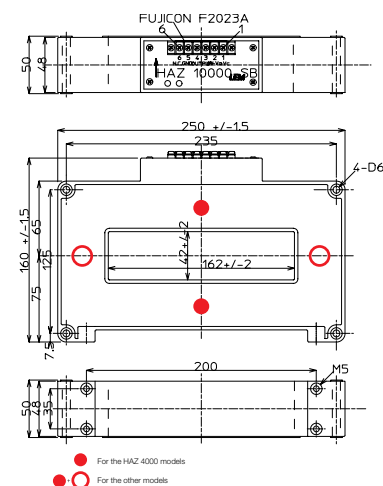
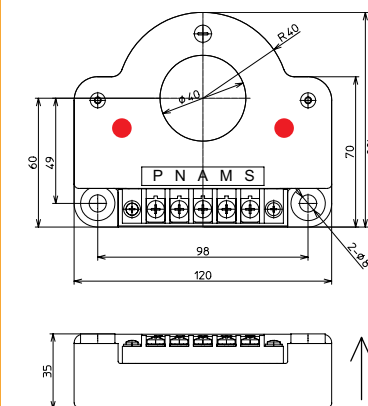
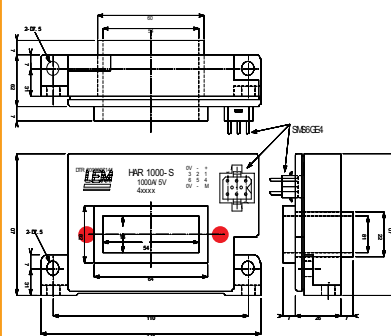
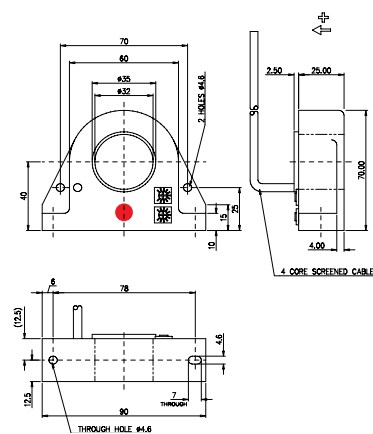
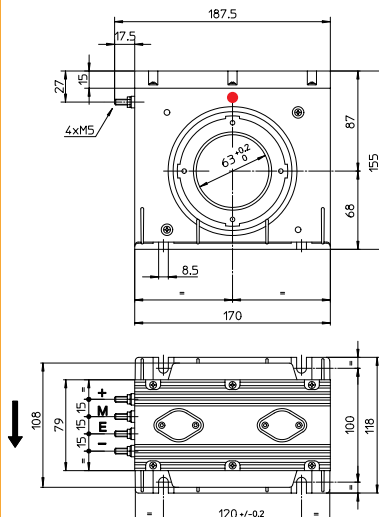
All dimensions are in mm

- Hall effect chip location

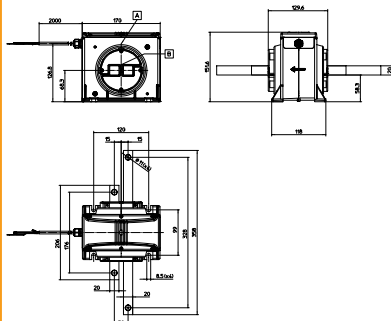
LTC 1000-SF/SP4



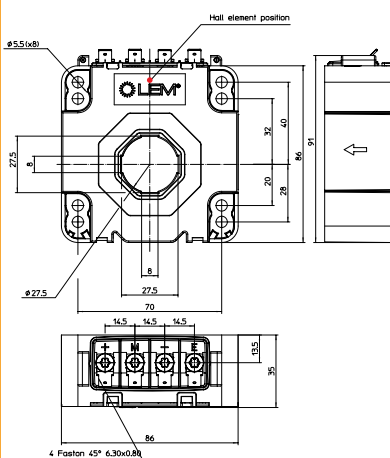
LB 2000-S/SP4



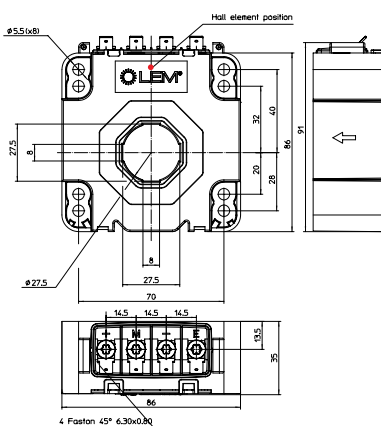
CD 1000-T/SP7



LTC 200-S

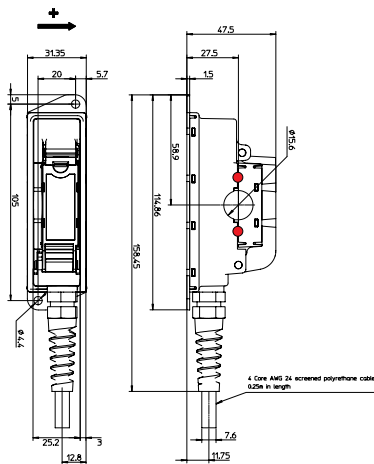


LTC 400-S

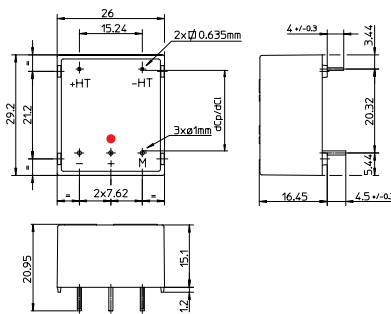




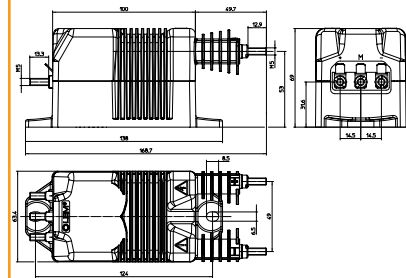
PCM 10-P



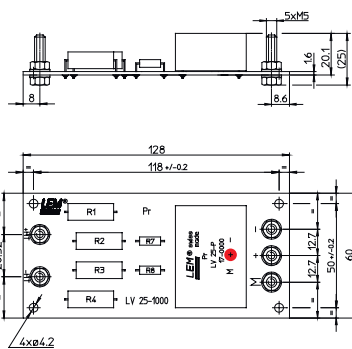
LV 25-P/SP5



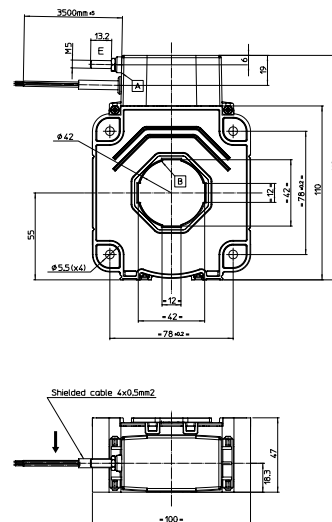
DVM 2000



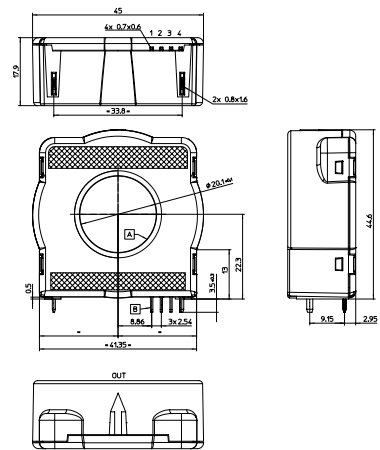
LV 25-1000/SP3



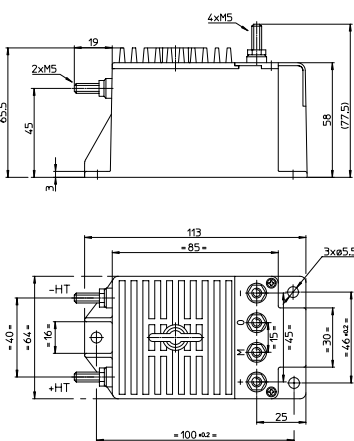
RA 1005-S, Rogowski Principle



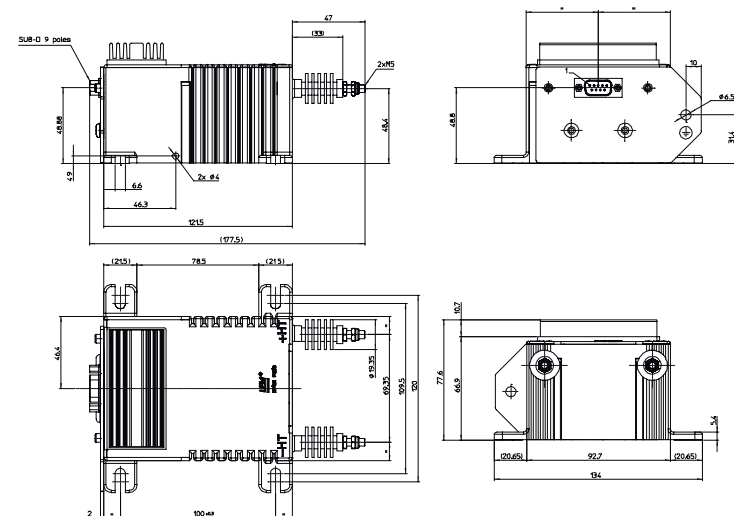
CTSR 0.3/0.6/1-P Fluxgate Principle



CV 3-100/SP3

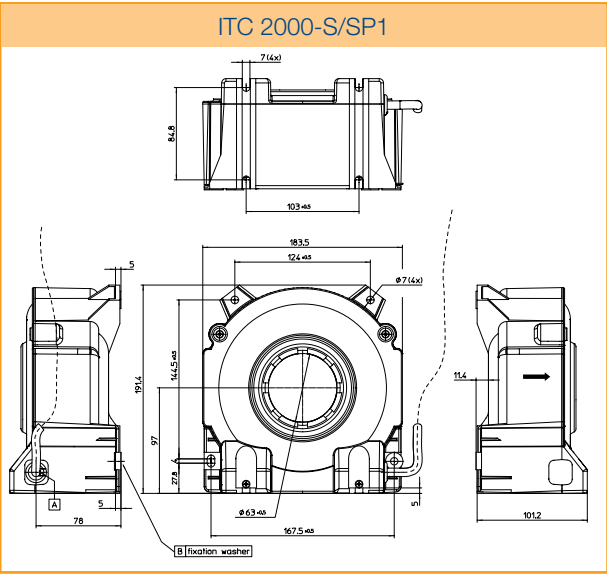
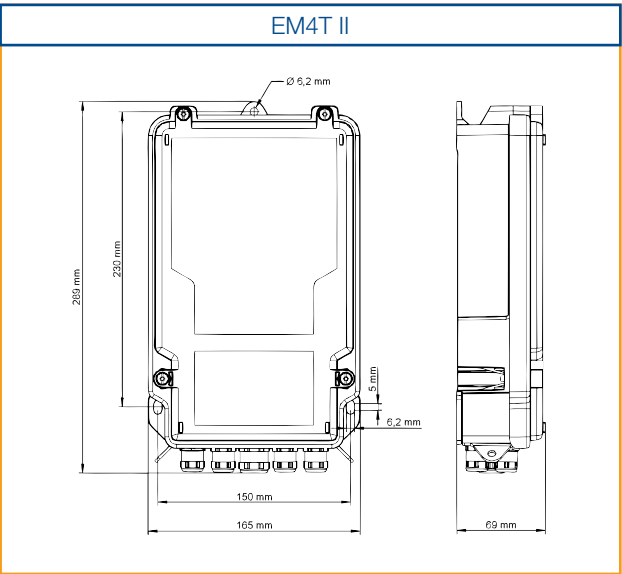
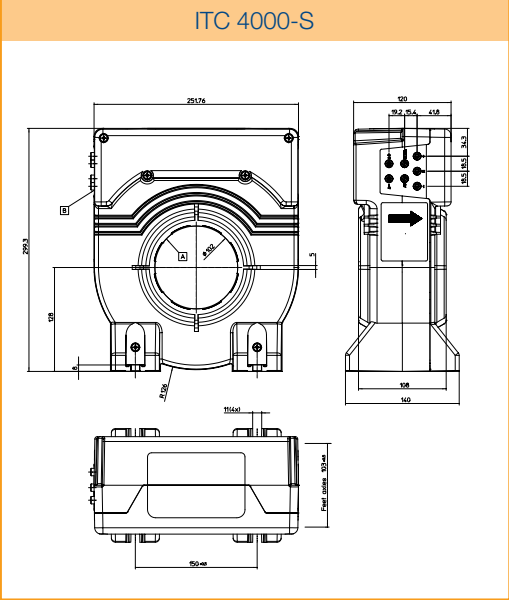
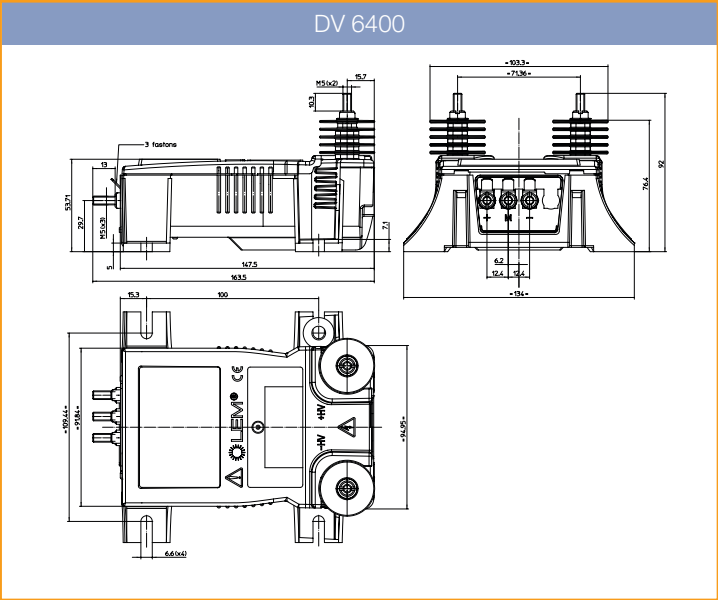
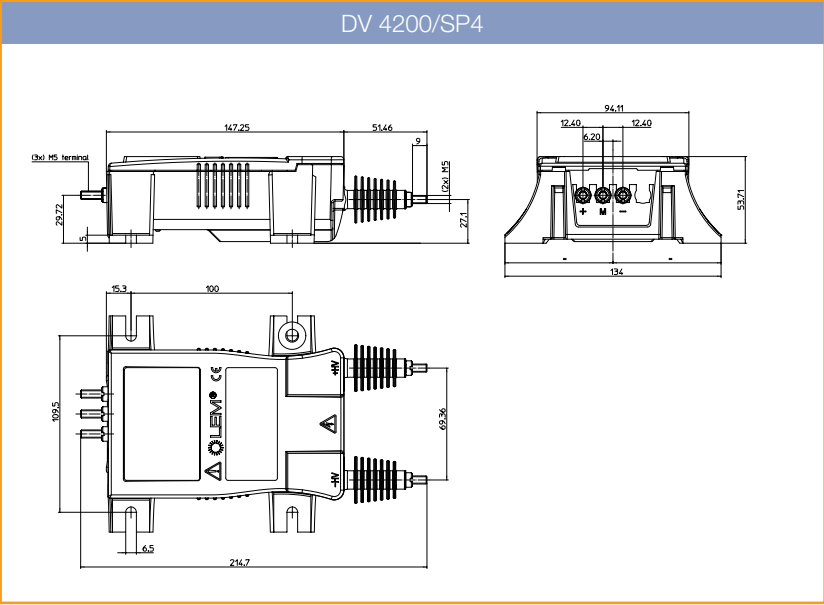
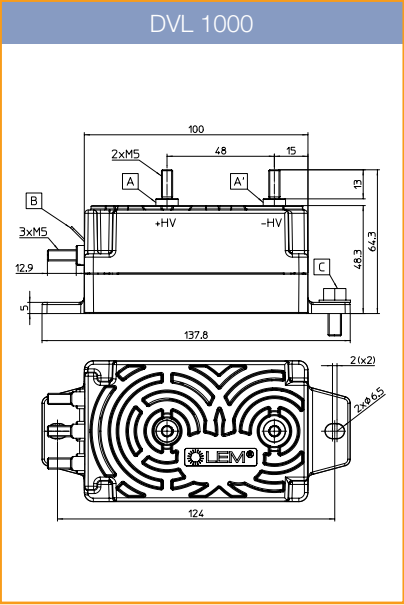


CV 4-4000/SP1



All dimensions are in mm

● Hall effect chip location





### 5 Year Warranty on LEM Transducers

We design and manufacture high quality and highly reliable products for our customers all over the world.

We have delivered several million current and voltage transducers since 1972 and most of them are still being used today for traction vehicles, industrial motor drives, UPS systems and many other applications requiring high quality standards.

The warranty granted on LEM transducers is for a period of 5 years (60 months) from the date of their delivery (not applicable to Energy-meter product family for traction and automotive transducers where the warranty period is 2 years).

During this period LEM shall replace or repair all defective parts at its' cost (provided the defect is due to defective material or workmanship).

Additional claims as well as claims for the compensation of damages, which do not occur on the delivered material itself, are not covered by this warranty.

All defects must be notified to LEM immediately and faulty material must be returned to the factory along with a description of the defect.

Warranty repairs and or replacements are carried out at LEM's discretion.

The customer bears the transport costs. An extension of the warranty period following repairs undertaken under warranty cannot be granted.

The warranty becomes invalid if the buyer has modified or repaired, or has had repaired by a third party the material without LEM's written consent.

The warranty does not cover any damage caused by incorrect conditions of use and cases of force majeure.

No responsibility will apply except legal requirements regarding product liability.  
The warranty explicitly excludes all claims exceeding the above conditions.

Geneva, 21 June 2011

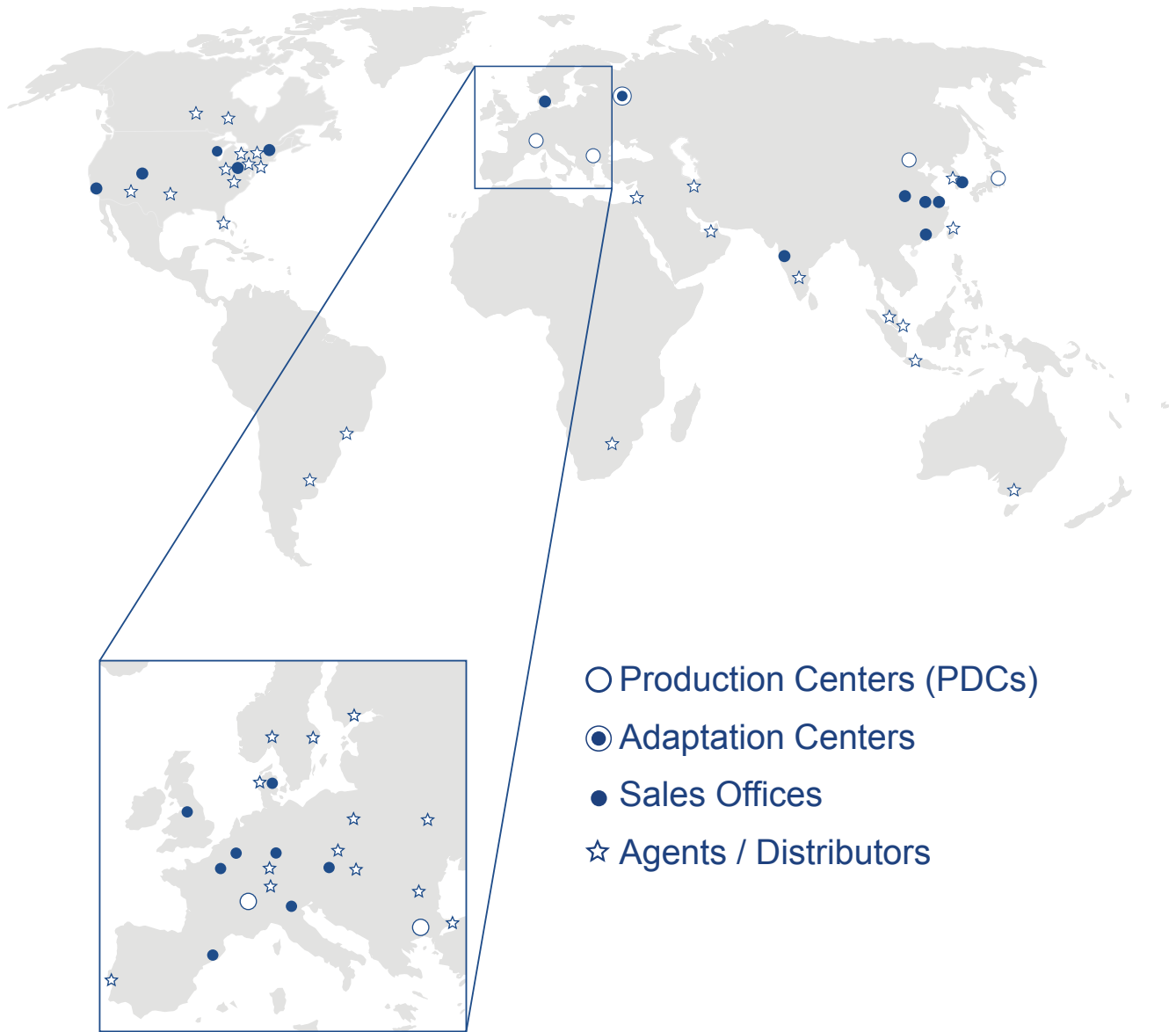
Frank Rehfeld  
CEO LEM

June 2011/Version 1

## Our contacts

Simpex Electronic AG  
Binzackerstrasse 33  
CH-8622 Wetzikon  
Telefon +41-44-931 10 30

[www.simpex.ch](http://www.simpex.ch)  
[contact@simpex.ch](mailto:contact@simpex.ch)  
CHE-108.018.777 MWST



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LEM International SA  
8, Chemin des Aulx, P.O. Box 35  
CH-1228 Plan-les-Ouates  
Tel. +41 22 706 11 11, Fax +41 22 794 94 78  
e-mail: [lsa@lem.com](mailto:lsa@lem.com); [www.lem.com](http://www.lem.com)

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