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 40 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 powers 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.

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 0.1 A to 20000 A and voltages from 10 V to 6 400 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 (Geneva and Beijing LEM production and design centers) 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 and contact our sales network for further assistance. Detailed datasheets and application notes are available.

Sincerely,

Hans-Dieter Huber
Vice President Industry

François Gabella
CEO LEM

LEM - At the heart of power electronics.

About Products:

- LTC Series
- LF Series
- LAC Series
- LT 4000 Series
- DVL Voltage Series
- LV 100-Voltage Series
- DV Voltage Series

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Closed Loop Fluxgate Current transducers (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

Operation principle

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.

The secondary compensating current is an exact representation of the primary current. This results in a very good accuracy and a very low temperature drift. The secondary 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 compensating current that compensates the primary ampere turns (I_P x N).

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.

DV & DVL Type Voltage transducers

Features
- Insulating digital technology
- Measurement of all types of signals: DC, AC, pulsed and complex
- Compact size, reduced volume
- High galvanic isolation
- Low consumption and losses
- Very high accuracy, Class 0.5R according to EN 50463
- 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-Analogue (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.

DI Current transducers (Shunt isolator) must be used combined with an external Shunt.

DI current transducers are working as DV voltage transducers except that the input resistor network used inside the DV is replaced by an external Shunt providing then the voltage input to feed the Sigma–Delta modulator that allows to transmit data via one single isolated channel.

* For further information, refer the brochure “Characteristics - Applications - Calculations” or 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 (high 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):

- 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 compromise for the voltage/current transformation. The control of the input voltage (main transformer output) is ensured by LV 100-Voltage or DV Voltage transducers (N°:1 in the figure 2).

This step is necessary for the 15 kV/AC/50 Hz, 25 kV/AC/50Hz, 3 kV/AC/50Hz and 1.5 kV DC systems. 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 transformation, supplied to today’s semiconductors.

1000 V is a typical value at this stage.

No contact and galvanically isolated differential measurement with a large aperture for multiple primary conductors result in safety-friendly transducers and accurate 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 "EMAT II", adapted to various European networks (please see section dedicated to EMAT 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 the over a large range of speed and traction effort.

In simple terms, this is an active rectifier.

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 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 LV 100-Voltage 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 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.

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

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 LV 100-Voltage 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). Series models are also a solution if frequency to follow is higher. 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).

In the case of a direct DC voltage supplied by the catenaries (no maintenance, and increased reliability), the LV 25-Voltage models (N°:3c in the figure 2) such as models derived from LTC 1000 or LT 1005 Series.

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

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 motor speed. Depending on the required torque, voltage and current amplitudes fluctuate with the frequency.
- To control these motor current amplitudes, the switching frequency must be accurately followed. 
- The switching frequency of LTC 350-S is ±0.7 kHz, LTC 500-S is ±0.7 kHz, and LTC 1000-S is ±0.5 kHz.

LTC series : Modular Current transducers
- Measures DC, AC, pulsed... currents with galvanic isolation
- Mountable in 4 positions : 0º, 90º, 180º, 270º
- Different accessories : mounting, clamps, bus bars

Technical data
- Without accessories
- With clamp
- With feed
- With bus bar and feeds
- Without bus bar and feeds
- Other types: contact sales
- Special features: contact sales
- Different bus bars are available

Parameter Description Condition unit
X20 Primary nominal current A max 350 500 500 1000 2400
I0 Measuring range, primary µA peak ±1200 1200 ±1500 ±2400 1
I0 Max. not measurable overload mA ±10 10 ±10 ±10 ±10
I0 Measuring resistance @ ±24V kΩ 60 110 50 15 10
R0 Max. Measuring resistance @ ±15V Ω 30 50 70 15 10
R0 Min. Measuring resistance @ ±15V Ω 10 0 0 0 0
I00 Secondary nominal current mA 175 125 100 200
V0 Supply voltage ±5V V ±15...24 ±15...24 ±15...24
I0 Current consumption @ ±24V mA 35 + I0 35 + I0 35 + I0 35 + I0
Vd Dielectric strength 50Hz 1mA kVrms 13.4 13.4 13.4 13.4 13.4

1) order separately
2) more details: see data sheet

On-Board Applications
On-Board Applications

parameters, LTC current transducers located on each phase of the asynchronous motor, fulfill all the railway requirements for 350 to 1000 kph. A nominal current measurements (N²:4 in the figure 2): The LTC is modular, compact, designed for traction, many possibilities of secondary connections, and fully approved for traction.

The LF 205, 605, and 2005 series are also recognized for this function, and have been used for several years in these applications. The highest 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 chopping 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 be also controlled with help from two voltage transducers derived from the LV 100-Voltage, extending the LV Voltage families for speed control (N²:6 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 comfort of the passengers. Depending on the catenary voltages on the applied loads at the output, on the constraints dictated by the car itself, whether 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 LV, Voltage, DSL Voltage and LV 100-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 plugins, lighting, etc. These voltages have to be filtered and stabilized, and 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, consequently, it 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 Voltage family (200 V to 1200 Volt) and for current measurements, models derived from the LTC and LV families are typically the best solutions.

All use the Closed Loop Hall effect technology providing solutions high bandwidth, overall accuracy at ±0.2 between 0.4 and 0.8 % of nominal current (or voltage).
and fast response time for current transducers (less than 1 μs @ 90 % of Ipn).

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 LT 305 / 1005 / 2005-S families for example. However, if the price is the main issue and if overall accuracy of 1 % of Ipn at +25°C, a slightly longer response time (between 3 and 10μs @ 90 % of Ipn) 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, HAP 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 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 trams are becoming more and more important in cities to reduce the local air pollution. Trolleybuses are however more abundant than trams, 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-modal), the rail network can be extended outside cities by using the diesel mode. Also, the trolleybuses and trams, with their batteries charged via the auxiliary inverter or through wired 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. 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 trams.

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 motorstat 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.
### LF 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

### Technical Data

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Condition</th>
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**Standards**

- EN50155
- IEC 61800-3

1) more details: see data sheet
2) for LV100-2000/SP15
3) for DV & DVL models
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, Italy, 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 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...
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 800 to 3000 VDC.

Current transducers DI (Shunt), 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.

DI current transducers associated to appropriated shunts allow also these kinds of current measurements providing high insulation as required by the 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 LV 100-4000/SP2 and EV 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. The 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 insulation for transducers is required (12 kV 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.

Measurement from 4000 A to 20000 ARMS
with the same compact size
Energy Measurement

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, this energy meter 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

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 measuring circuits of the EM4T II via differential inputs (Picture 2 and 3), designed for connection of all actual available 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 unit railways.

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 used), the primary energy (delta) values are recorded together with data such as:

- Data 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 energy meter 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.

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- 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 ENS0163: 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)

<table>
<thead>
<tr>
<th>Version</th>
<th>AC Channel 1</th>
<th>AC Channel 2</th>
<th>AC Channel 3</th>
<th>AC Channel 4</th>
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<td>AC-current</td>
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<td>DC-current</td>
<td>DC-current</td>
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</table>

Shunts can also be used at this level associated to LEM EM models providing the required insulation and the class 1R accuracy (when used with a class 0.2R shunt).
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 EMAT 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 EMAT 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 EMAT II. This log book information contains e.g. loss and gain of the operating 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 EMAT 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 EMAT II will also provide an Ethernet-interface.

The supply voltage is selectable between 24 V and 110 V. Optionally, the EMAT 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.

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Standards & Regulations
- EN 50463-x (2012): Draft: Railway application Energy measurement on board trains DC measurement Class 2 AC measurement Class 1.5
- EN 50155 (2007): Railway applications
- EN 61373 (2010): Railway applications Rolling stock equipment Shock and vibration tests
- IEC 62056-21 (2002): Electricity metering Data exchange for meter reading, tariff and load control Part 21: Direct local data exchange

ITC 2000...4000-S FAMILY
Better than Class 0.5R
High temperature stability
Specific Railway Applications

1. Interference Frequencies Detection

Most of the trolleybuses, trains, 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 protect the track area with a red stop signal 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.

2. Main Transformer Saturation Detection

The measurement of a low DC component in high AC currents is required 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 Amax transducer is required to measure both the AC current and the DC component. For that 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 kVmax 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.

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.

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).

![Interference current measurement on the DC link](Figure 7)

![AC+DC measurement in transformer output of driving converter](Figure 8)

![Current balance detector for underground](Figure 9)
Mining Trucks Applications

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 speed and torque 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

Wheel drive system with AC motors

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).

To simplify, the system is made up of:
- An alternator,
- a rectifier,
- a microprocessor control unit, and
- motorized wheels (DC motors).

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

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.

As for the traction propulsion in railway industry, the trend today is to use IGBT (IGBT 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 mining) and provide the whole system enhanced productivity by reducing maintenance services (Brushes elimination, contacts decreasing...).

The use of power electronics makes the system simpler and more reliable with increased efficiency. 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

To cover their ranges

250 A
1000 A
2000 A
3000 A

HTA FAMILY

HTC FAMILY

Copyright ALSTOM
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 abnormal behavior 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:

- 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, minimizing the traffic disruption and keeping 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 50 Amperes. 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 0.010 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 LTS 6-15-25-NP or the LA25-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

**CASR FAMILY**

- 6 - 15 - 25 - 50 A

**LTS FAMILY**

- 6 - 15 - 25 A

**LA 25-NP FAMILY**

- 0.25 to 25 A

Clip-on design - Ideal for retrofit applications

**Picture 4:** Points Machine along the tracks.

**PCB mounted current transducers**
An excess of supplied current to 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 LTS series with nominal current measurements from 6 to 25 Amps. For signal monitoring, the CTSR series meets the requirement with 3 models covering accurate measurements from 300 mA RMS up to 1 Amps. 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.
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. LEfB 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:

- **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.

**Cpk – R&R (Capability Operating System – Eight Disciplines):**

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

**PIQ (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 its 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.

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

**The EN 50124-1 (‘Basic requirements – Creepage and clearance 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 800-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 Single insulation:**

According to EN 50124-1 standard:

**With clearance distance of 45.90 mm and PD3.**

**U_{n m} = 30 kV & OV II**, the rated insulation voltage (AC or DC) called “U_{n m} can be from >= 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_{n m} of 5.336 kV.

In conclusion, the possible reinforced rated insulation voltage U_{n m} in these conditions of use, is of 2.568 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, when dimensioning reinforced insulation, the rated insulation voltage U_{n m} shall be 150% of the rated insulation 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_{n m} = 30 kV / 1.6 = 18.75 kV.**

**Reinforced U_{n m}: From >= 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_{n m} 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 x 12.5) vs. 12.5 mm/kV previously (for basic insulation), leading to a possible reinforced rated insulation voltage U_{n m} of 2.568 kV.

In conclusion, the possible reinforced rated insulation voltage U_{n m} in these conditions of use, is of 2.568 kV (the lowest value given by the both results from the creepage and clearance distances).

**Key Six Sigma Statistics**

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<th>Sigma Level</th>
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<tr>
<td></td>
<td>6</td>
<td>99.9997%</td>
<td>3.4</td>
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</table>

Source: Six Sigma Academy, Cambridge Management Consulting.
Solutions for Voltage Measurement

Overall Accuracy @ +25 °C (% of VPN)

Response Time (µs)

Nominal Voltage Measurement Range (V)

LV 25-P Family

LV 25-Voltage

DVL Voltage

CV 3-Voltage

LV 100 Family

LV 100-Voltage

CV 4-Voltage

LV 200-AW/2/Voltage

DV Voltage
<table>
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<th>Main circuit breaker</th>
<th>Main rectifier</th>
<th>DC Link</th>
<th>Auxiliary inverter</th>
<th>Propulsion inverters</th>
<th>Energy measurement</th>
<th>Lighting /RGB</th>
<th>HVAC</th>
<th>Doors control</th>
<th>Battery charge</th>
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<th>Switchgear</th>
<th>Package representation</th>
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</table>

**Trackside**

- Points
- Relays
- Signaling

**Substation**

- Product Solution
- Nominal Range

**Product Solution**

- LT 655-S family
- LT 1205-S family
- LT 2205-S family
- LT 4200-S family
- LTC family
- LA 300-S family
- LA 205/305-S family
- LF 505-S family
- LF 2005-S family
- HTA family
- HAR family
- HTC family
- ITC family
- HAZ family
- LB family
- CD family
- RA family
- CTSR -P & -TP family
- LA 25-NP family
- PCM family
- U3 and U3x/CAR/RCSR family
- LV 25-P family
- LV 25-F family
- LV 25-Voltage family
- LV 150-Voltage family
- LV 200-Voltage family
- LV 200-AW/Voltage family
- CV 9-Voltage family
- CV 4-Voltage family
- DVL Voltage family
- DV Voltage family

**Nominal Range**

- 250-720 A
- 1000 A
- 1100-2000 A
- 4000-4400 A
- 350-1000 A
- 300 A
- 200-500 A
- 100-200 A
- 250-300 A
- 500 A
- 1000 A
- 2000 A
- 250-1000 A
- 1000 A
- 500-3000 A
- 2000-4000 A
- 4000-20000 A
- 2000 A
- 0.3-0.6-1 A
- 0.25-25 A
- 5-10-20-30 A
- 1.5-50 A
- 0.01 A
- 10-1500 V
- 200-1200 V
- 100-4000 V
- 50-4200 V
- 100-6400 V
- 85-1400 V
- 1767-4200 V
- 50-2000 V
- 1200-4200 V
- 30-200 mV
- 10-200 mV

**From the Application to the Product**

- EMAT II
- DI (Shunt Isolator)
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

---

### DESIGN SPECIFICATION

**LEM Subsidiary:**

**Contact:**

**Date:**

**Customer information**

- **Company:**
- **City:**
- **Country:**
- **Contact person:**
- **Phone:**
- **Fax:**

**Application**

- **Type:**
  - [ ] industrial
  - [ ] traction
  - [ ] automotive
  - [ ] process autom.
  - [ ] other:

- **Utilisation:**
  - [ ] voltage
  - [ ] current
  - [ ] power
  - [ ] other:

- **Function:**
  - [ ] control
  - [ ] display
  - [ ] ground fault detection
  - [ ] other (provide a separate descr.):

**Electrical & Environmental characteristics**

<table>
<thead>
<tr>
<th>Signal to measure</th>
<th>Transducer reference (if relevant):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range:</td>
<td>Spurriesss:</td>
</tr>
<tr>
<td>Nominal value:</td>
<td>rms</td>
</tr>
<tr>
<td>Measuring range:</td>
<td>pk</td>
</tr>
<tr>
<td>Overload value to be measured</td>
<td>pk</td>
</tr>
<tr>
<td>Peak:</td>
<td>pk</td>
</tr>
<tr>
<td>Duration:</td>
<td>s</td>
</tr>
<tr>
<td>Non measured overload:</td>
<td>pk</td>
</tr>
<tr>
<td>(to withstand)</td>
<td>Hz</td>
</tr>
<tr>
<td>Frequency:</td>
<td>Hz</td>
</tr>
<tr>
<td>Duration:</td>
<td>ms</td>
</tr>
<tr>
<td>di/dt to be followed:</td>
<td>A/µs</td>
</tr>
<tr>
<td>Bandwidth:</td>
<td>kHz</td>
</tr>
<tr>
<td>Operating frequency:</td>
<td>Hz</td>
</tr>
<tr>
<td>Ripple:</td>
<td>Hz</td>
</tr>
<tr>
<td>Ripple frequency:</td>
<td>Hz/µs</td>
</tr>
<tr>
<td>dv/dt applied on primary circuit:</td>
<td>kV/µs</td>
</tr>
<tr>
<td>Power supply:</td>
<td>V ± %</td>
</tr>
<tr>
<td>Bipolar</td>
<td>Unipolar</td>
</tr>
</tbody>
</table>

**Mechanical requirements**

- **Maximum dimensions required:** L mm x W mm x H mm
- **Mounting on:**
  - [ ] PCB
  - [ ] Panel
  - [ ] Threaded studs M
  - [ ] Molex
  - [ ] Cable
- **Output terminals:**
  - [ ] PCB
  - [ ] Faston
  - [ ] Through hole:
  - [ ] L mm x W mm; or Ø mm
  - [ ] Busbar:
  - [ ] L mm x W mm x H mm
- **Primary connection:**
  - [ ] Through hole:
  - [ ] Through hole:
  - [ ] Studs:
  - [ ] For the bus bar, please provide layout

**Applicable standards:**

- [ ] industrial
- [ ] EN 50178
- [ ] traction
- [ ] EN 50155
- [ ] other

If other, please specify:

**Project management (amounts given in EUR)**

<table>
<thead>
<tr>
<th>Financials</th>
<th>Total quantity for the project:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target price</td>
<td>and product life time or quantity per year</td>
</tr>
<tr>
<td>Target cost</td>
<td>or Gross margin %</td>
</tr>
<tr>
<td>Required response time</td>
<td></td>
</tr>
<tr>
<td>Engineering samples</td>
<td>Quantity: Date:</td>
</tr>
<tr>
<td>Prototype</td>
<td>Quantity: Date:</td>
</tr>
<tr>
<td>Initial samples</td>
<td>Quantity: Date:</td>
</tr>
<tr>
<td>Series 1</td>
<td>Quantity: Date:</td>
</tr>
</tbody>
</table>
### 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

**Grids**
- A or AK or AL or AS 1): with rectangular laminated magnetic circuit
- or AT or AX or AZ: with rectangular laminated magnetic circuit and flat housing
- AR or AW or AC or X or XN: with rectangular laminated magnetic circuit + unidirectional power supply + reference access
- AIS, XS, ASS, AFS: with rectangular laminated magnetic circuit + unidirectional power supply + reference access. When used with F (FHS): Minisens, SO8 transducer
- AH: with rectangular magnetic circuit + unipolar power supply + reference access
- AY: with rectangular magnetic circuit + hybrid
- B: double toroidal core
- C: apparent printed circuit
- D: differential measurement
- H5: Hall effect without magnetic compensation; magnetic concentrators
- R: rms output
- RI: rms current output
- RU: rms voltage output

**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 200 V with built-in primary resistor R1)

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

**Particularities**
- 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

**Variants**
- When used with L (LAS): current transducer with secondary winding and unipolar power supply using Eta technology
- When used with C (CAS): current transducer with rectangular magnetic circuit + unipolar power supply

**Comments:**

Railway Current & Voltage Transducers, Edition 2013, Published by LEM

gLEM International SA, Geneva, Switzerland 2013, e-mail: sro@lem.com

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The paper of this publication is produced with pulp bleached without chlorine, neutral sized and non-aging.

As far as patents or other rights of third parties are concerned, liability is only assumed for components per se, not for applications, processes and circuits implemented with components or assemblies. For more details see the available data sheets.

Terms of delivery and rights to change design or specifications are reserved.
All dimensions are in mm

Hall effect chip location

LTS 6-NP, LTS 15-NP, LTS 25-NP
LA 25-NP/SP25
LA 250-P/SP4
LA 205-S/SP21
LA 205-T/SP16
LF 205-S/SP5
LF 305-S/SP7
LF 505-S/SP22
LF 1005-S/SP26
LT 505-T/SP12
LT 1005-S/SP26
LT 2005-S/SP15
LT 4000-S/SP24
LT 1000-S/SP1
LTC 500-SFC/SP2
LTC 1000-S/SP1
LTC 500-SFC/SP2
Dimension Drawings

All dimensions are in mm

- Hall effect chip location

LTC 1000-S/SP4

LB 2000-S/SP4

HTA 1000-S/SP9

HAR 1000-S

HTC 5000-S/SP4

HAZ 4000-S/SP9

CD 1000-T/SP7

RA 1000-S, Rogowski Principle

CTSR 0,3/0,6/1-P Fluxgate Principle

PCM 10-P

LV 25-P/SP5

LV 100-2000/SP15

LV 25-1000/SP3

LV 100-1000/SP13

LV 200-AW/2/640D

CV 3-100/SP3

CV 4-4000/SP1

For the HAZ 4000 models

For the other models

LTC 1000-SF/SP4

LB 2000-S/SP4

HTA 1000-S/SP9

HAR 1000-S

HTC 5000-S/SP4

HAZ 4000-S/SP9

CD 1000-T/SP7

RA 1000-S, Rogowski Principle

CTSR 0,3/0,6/1-P Fluxgate Principle

PCM 10-P

LV 25-P/SP5

LV 100-2000/SP15

LV 25-1000/SP3

LV 100-1000/SP13

LV 200-AW/2/640D

CV 3-100/SP3

CV 4-4000/SP1
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

Francois Gabella
CEO LEM

June 2011/Version 1