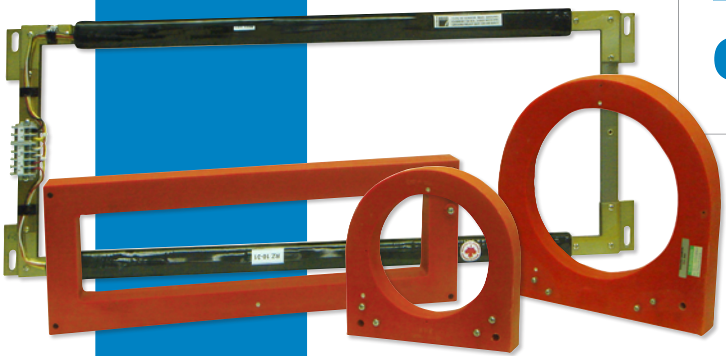
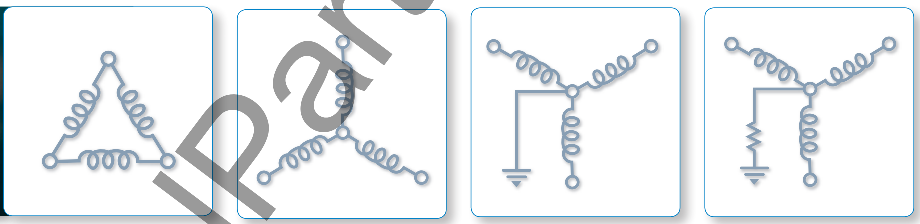
iGARD

ZERO SEQUENCE CURRENT SENSORS



I-SENSORS



the power to protect

Instruction Manual

IPC

T-SENSORS

I-Gard Corporation's zero sequence current sensors are used to detect ground leakage currents on medium or low voltage, grounded or ungrounded AC electrical systems. The output from the Sensors is used to operate I-Gard Corporation's ground fault relays to provide equipment or life protection depending on the relay selected.

The sensor should encircle the phase conductors and the neutral, if it exists and is used, but not the grounding conductor or the shield of the cable.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLES

Theory of Zero Sequence Current Sensors

Every conductor carrying electrical current is surrounded by a concentric, coaxial magnetic field proportional to the current. The direction of the magnetic field is related to the direction and strength of the current flow. If an iron ring is placed around a conductor, the greater permeability of the iron (than the air) causes the magnetic field to concentrate in the iron and so if the current is alternating, an alternating magnetic field is set up in the iron. If a coil of wire is wound onto the iron, a voltage will be generated in it proportional to the strength of the field.

In an ideal electrical system the vector sum of outgoing and returning current must be zero at all times, so in the same iron ring, they will produce equal and opposite magnetic fields and the instantaneous values will be zero. In case of a ground fault, when part of the outgoing current does not flow back to the source through the return conductor, but leaks through the insulation to ground, the vector sum of the currents is no longer zero, hence the magnetic field in the iron ring is not zero. This magnetic field will generate a voltage output in the winding on the iron ring, proportional to the current unbalance, i.e. to the ground current.

The Zero Sequence Current Sensors are rated for 600 volts. They can be used on higher voltage circuits with insulated, or shielded conductors as follows:

- Insulated but not shielded 2.5 kV
- On higher than 2.5 kV with insulated and shielded (with shield grounded in one place only on the load side of the sensor).

Typical sensitivity range of the high impedance toroidal current sensors.

Rating and Performance Data

Voltage Class	600V
Frequency	50-60 HZ
Temperature	0ºC to +65ºC

Construction and Design Features of Type T and R-Sensors

The core of high quality silicon steel and coils are completely moulded in polestiglas compound, with excellent electrical and mechanical properties. The homogeneous, tough polestiglas insulation resists oxidation, arc tracking and moisture penetration.

The secondary and test terminals are no. 6-32 screws complete with lock washers. Complete identification and terminal markings are permanently moulded into the body of the sensors.

The ground fault current sensors are manufactured in four basic types.

a) Toroidal ZSCS's for cable conductors

b) Split core toroidal sensors. In retrofit installation of zero sequence sensors where existing load cables cannot be disturbed or disconnected, split core sensors type T3A-S and T6A-S can be applied. The core and winding come apart to go around the existing load cables without disturbing them

c) Rectangular encapsulated ZSCS's for bus bar and large groups of cable conductors

d) Rectangular (open core) RZ only for use with Type MGFR-1200 and MGFR-SE relays

Table 1

CAT. NO.	WINDOW SIZE (2)		APPLICATION	SENSITIVITY
T2B	1.875” dia.	48mm dia.	Type CDD-1 A and CDD-1AT	10-200mA (0.01-0.2A)
T3B	2.75” dia.	70mm dia.	MGFR-1, DGF-CT-A	10-200mA (0.01-0.2A)
T5B	4.625” dia.	117mm dia.		10-200mA (0.01-0.2A)
T2A	1.875” dia.	48mm dia.	Type GM Meter,	0.2-1200A
T3A	2.75” dia.	70mm dia.	DSP-MKii®, DSA, DSP-OHMNI,	0.2-1200A
T3A-S (1)	2.625” dia.	67mm dia.	DGF-CT-A,	0.2-1200A
T6A	5.75” dia.	146mm dia.	MGFR -2, -20, -200, -1200	0.2-1200A
T6A-S (1)	5.75” dia.	196mm dia.		0.2-1200A
T9A	8.75” dia.	222mm dia.		0.2-1200A
R4-17A	4.25 x 17.625”	108 x 448mm		0.2-3000A
R7-13A	7.5 x 13.5”	191 x 343mm		0.2-3000A
R8-26A	8 x 26.5”	203 x 674mm		0.2-3000A
RZ5-11	4.5 x 11”	114 x 280mm	Type MGFR-1200 and	100-1200A
RZ5-21	4.5 x 21”	114 x 534mm	MGFR-SE-Z relays only	100-1200A
RZ5-31	4.5 x 31”	114 x 788mm		100-1200A
RZ5-35	4.5 x 35”	114 x 890mm		100-1200A
RZ10-11	10.5 x 11”	267 x 280mm		100-1200A
RZ10-21	10.5 x 21”	267 x 533mm		100-1200A
RZ10-31	10.5 x 31”	267 x 788mm		100-1200A

Notes: (1) Split core toroidal sensors.

(2) See Table 2, page 9 for selection criteria

Application

High sensitivity (10-200mA) Type T Series B ground current sensors are used for life protection on grounded systems with Type CDD-1 A, type MGFR-1 and Type DGF-CT ground relays.

Medium sensitivity (200mA-1200A) Type T Toroidal Series A and Type R Rectangular Series A ground current sensors can be used for equipment protection.

a) On ungrounded or high resistance grounded systems (up to maximum 25 amps ground fault current) with Type DSP OHMNI ground alarm/trip unit, DSA ground alarm, GFR-RM, SIGMA and MGFR-2, -20 relays

b) On low resistance grounding systems (up to 400 Amps of ground fault current) with the SIGMA relay

c) On solidly grounded systems with all Type MGFR -2, -20, -200 and -1200 ground fault relays

Low Sensitivity Type RZ sensors are used on electrical systems with high ground fault currents (above 100A) with equipment protection provided with Type MGFR-1200 and MGFR-SE relays.

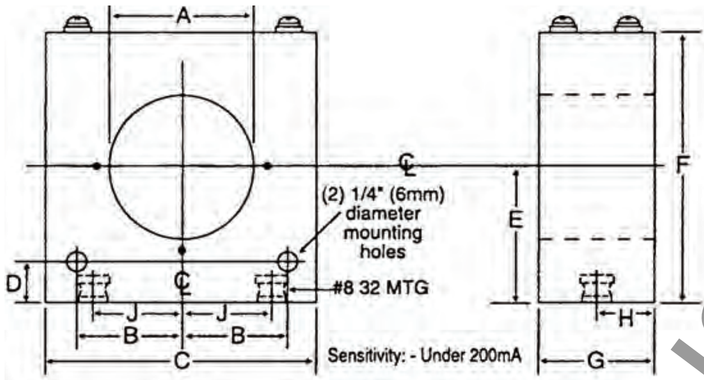


Figure 1 - Type T2B

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	J in/mm
T2B	1.75/45	1.375/35	3.5/89	0.5/13	1.75/45	3.5/89	1.5/38	0.75/19	1.25/32

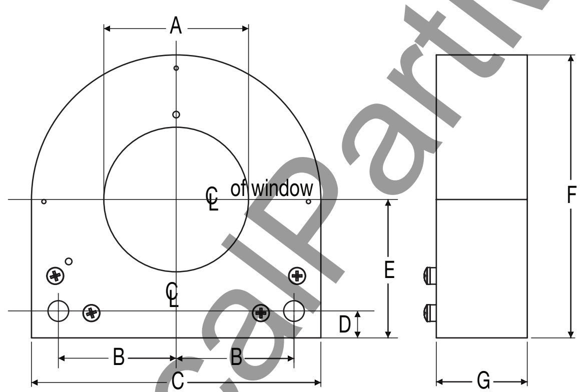


Figure 2 - Type T3B, T5B

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm
T3B	2.75/70	2.25/57	5.5/40	.5/13	2.5625/65	5.3125/135	1.5/38
T5B	4.625/117	3.15/80	3.65/93	0.62/16	3.90/99	7.60/193	1.50/38

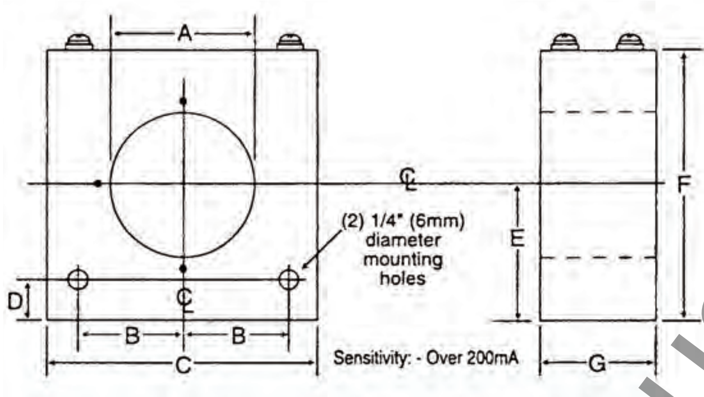


Figure 3 - Type T2A

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm
T2A	1.875/48	1.625/41	4.125/105	0.5/13	2.0625/52	4.125/105	1.75/45

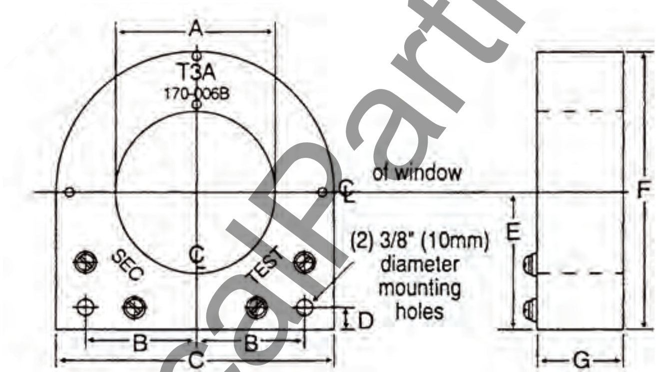


Figure 4 - Type T3A, T6A, T9A

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm
T3A	2.75/70	2.25/57	5.5/140	.5/13	2.625/67	5.375/137	1.75/44
T6A	5.75/146	3.375/86	8.25/210	.75/19	4.25/108	8.375/213	1.5/28
T9A	8.75/222	5/127	12/305	1/25	6/152	12/305	2/51

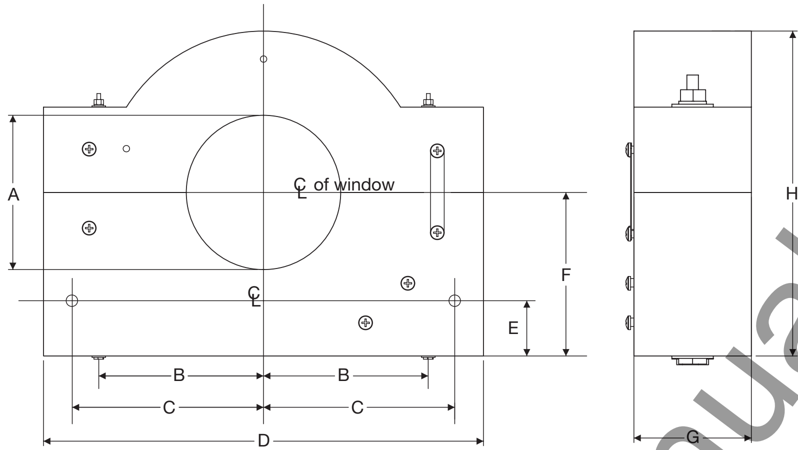


Figure 5 - Type T3A-S, T6A-S

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm
T3A-S	2.625/67	2.75/70	3.25/83	7.5/191	.937/24	2.812/71	2/51	5.625/143
T6A-S	5.75/146	6.75/172	Not given	9.812/249	.812/21	4.5/114	2/51	8.625/219

T3A-S: Mounting Holes dia.: 3/8"/10mm
T6A-S: Mounting Holes dia.: 3/8"/10mm

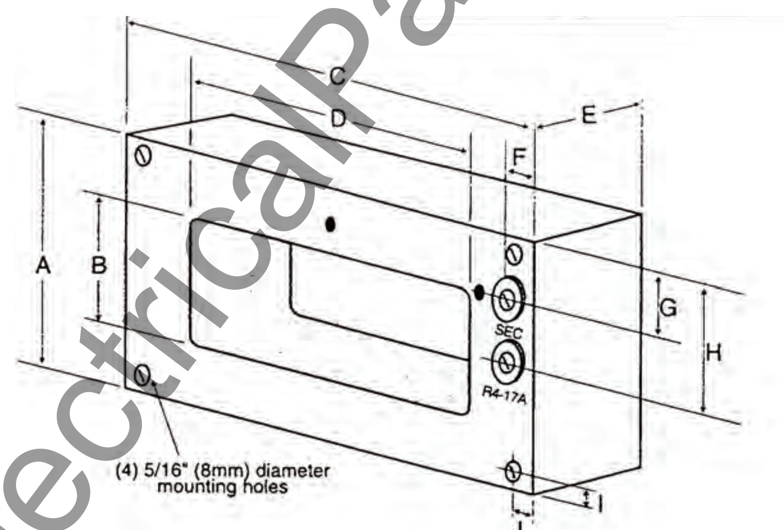


Figure 6 - Type R4-17A

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	I in/mm	J in/mm
R4-17A	7.5/191	4.25/108	20.75/527	17.625/448	2.0/51	0.5/13	1.5/38	2.5/63	0.5/13	0.375/10

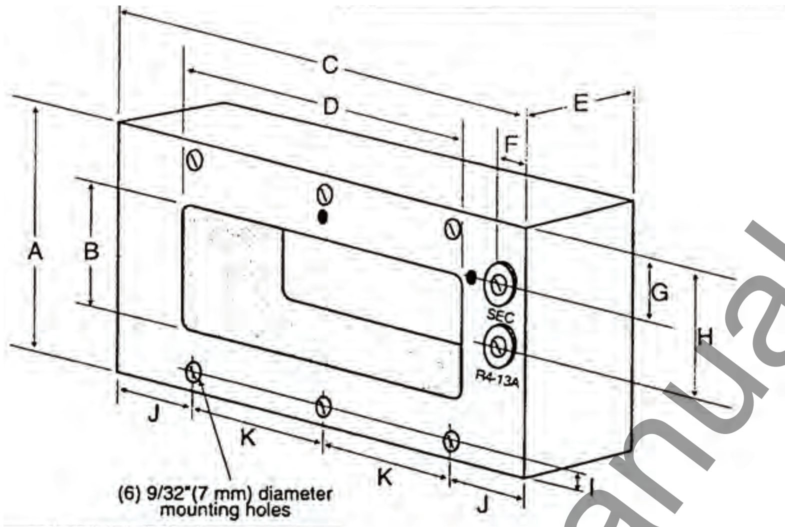


Figure 7 - Type R7-13A

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	I in/mm	J in/mm	K in/mm
R7-13A	12.0/305	7.5/191	17.0/432	13.5/343	2.0/51	0.625/16	2.6875/68	3.6875/94	0.375/10	2.5/64	6.0/152

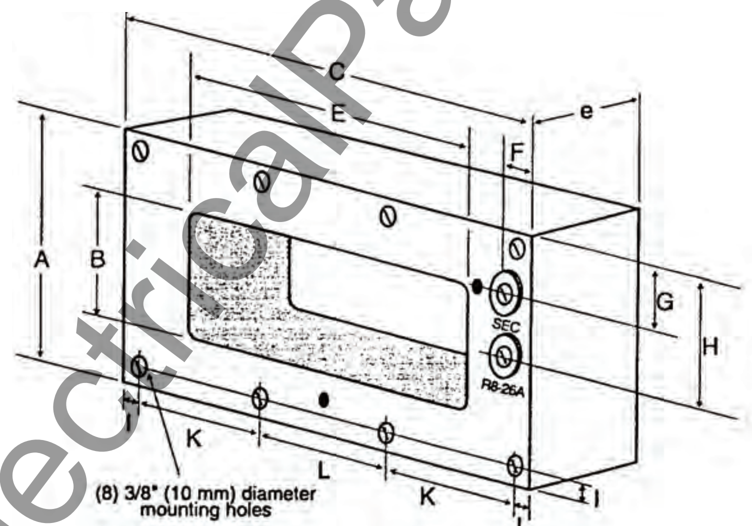


Figure 8 - Type R8-26A

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	I in/mm	J in/mm	K in/mm	L in/mm
R8-26A	13.125/333	8.0/203	30.25/768	26.5/674	2.25/57	1.0/25	3.1875/81	4.4375/113	0.5/13	0.3/13	10.0/254	9.25/235

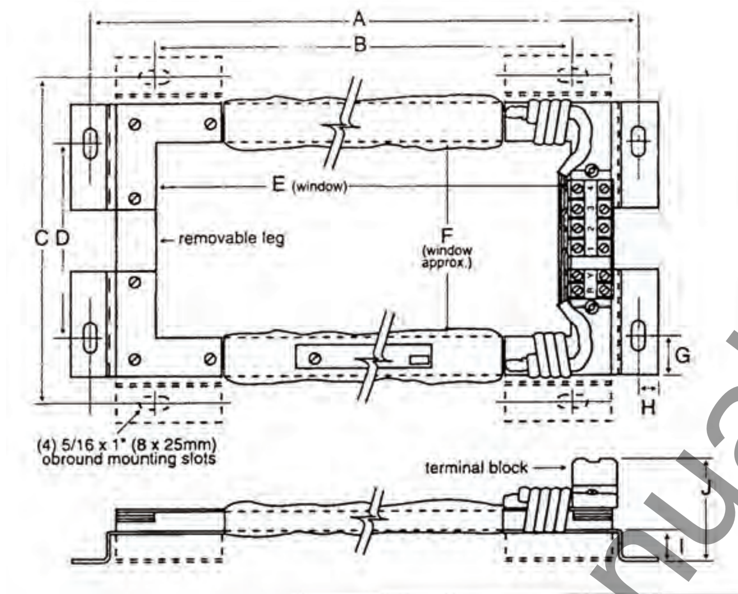


Figure 9 - Type RZ5-11,21,31, Type RZ10-11,21,31

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	I in/mm	J in/mm
RZ5-11	14.375/365	11.5/292	8.5/216	5.5/140	11/279	4.5/114	.75/19	.5/13	.75/19	2.875/53
RZ5-21	24.375/619	21.5/546	8.5/216	5.5/140	21/533	4.5/114	.75/19	.5/13	.75/19	2.875/53
RZ5-31	34.375/8973	31.5/800	8.5/216	5.5/140	31/787	4.5/114	.75/19	.5/13	.75/19	2.875/53
RZ10-11	14.375/365	11.5/292	14.5/368	11.5/292	11/279	10.5/267	.75/19	.5/13	.75/19	2.875/53
RZ10-21	24.375/619	21.5/546	14.5/368	11.5/292	21/533	10.5/267	.75/19	.5/13	.75/19	2.875/53
RZ10-31	34.375/873	31.5/800	14.5/368	11.5/292	31/787	10.5/267	.75/19	.5/13	.75/19	2.875/53

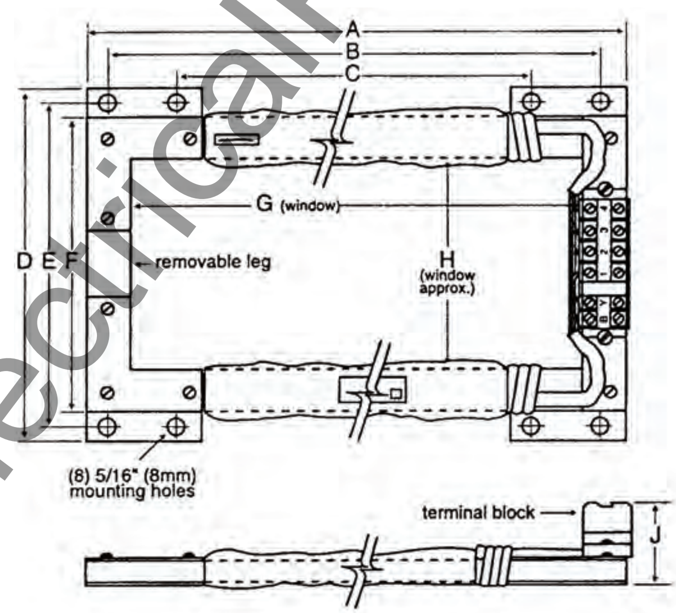


Figure 10 - Type RZ5-35

CATALOGUE NUMBER	A in/mm	B in/mm	C in/mm	D in/mm	E in/mm	F in/mm	G in/mm	H in/mm	J in/mm
RZ5-35	37.0/940	36.0/914	33.0/838	8.875/225	8.0/203	7.0/176	35.0/890	4.5/114	1.875/48

Selection of Zero Sequence Current Sensors (ZSCS)

The size and type of ZSCS's used with any ground relay depends on the size of feeder to which it is to be applied. If the feeder is a bus duct, a rectangular ZSCS should be used. The recommended size of toroidal ZSCS's for different feeder sizes are listed below.

The table is based on the following:

1) The cables are thermoplastic or rubber covered
2) The cables are tightly bundled
3) The bundled cables are centered in the ZSCS and fill a maximum 50% of the window diameter

The first factor controls the insulation and jacket thickness, which has an effect on the overall diameter of the cable bunch. The second factor enables one to calculate the bundled cable diameter, but the actual diameter will be greater than the calculated value, because the cables may be bent or kinked slightly and close bundling becomes more difficult as the cable diameter increases. The third factor, accurate centering within the ZSCS should always be observed to minimize as much as possible that part of the ZSCS output which is related directly to the load current, and the larger the cables the more important this factor becomes. When in doubt, specify the next larger diameter ZSCS.

Although the rectangular ZSCS's are designed for bus bar application, they can be used, with caution, on cable feeders.

To select the correct size of rectangular sensor for cables, all the properties of the feeder cable - number of conductors, cross section, insulation, diameter, etc. - should be take into consideration, because each rectangular ZSCS has been designed for specific bus bar configuration - bar size, separation, etc. - and its output depends upon the conductor geometry.

For accurate relay operation it is important to have all the cables bundled together in a rectangular shape and centered in the window with equal clearances on each side, not less than one inch (25.4mm).

Zero Sequence Current Sensor Application

Since the rectangular ZSCS's are designed for specific bus bar arrangements through the window - horizontal or vertical - they must be carefully matched with bus geometry. Each bus bar arrangement produces a signal at the ZSCS output depending on the air gaps between the bars and ZSCS core. This signal, the sum of high unbalanced load current, third harmonics, geometry of the bus bars, etc., is called noise voltage and is a fixed level output of a ZSCS when current flows in the conductors but the zero sequence current is zero.

The contribution of the unbalanced load currents and third harmonics cannot be reduced or eliminated, only the accurate positioning of the bus bars can lower the noise level. Locating the bus bars on the centre lines of the window with one inch (25.4mm) clearance on each side will reduce the noise voltage to a minimum. Any off centre deviation from the horizontal or vertical centre lines and uneven clearances will increase the noise level.

For this reason, the application of rectangular ZSCS's with high sensitivity relays, under 5 amp pick up settings, is not recommended. At higher pick up settings, due to the reduced relay impedance, the noise level will influence the operation of the relay to a lesser degree.

When a bus duct is connected to a switchboard, it is recommended that the ZSCS is mounted at the point of entrance, or as close to it as possible; because of the randomness of switchboard configurations, it is impossible to give an exact specification on rectangular ZSCS installations.

As a general rule, the bus arrangement with the flat side of the bars parallel to the short side of the sensor is recommended (Fig. 10). The bus arrangement with the flat side of the bars parallel to the long side of the sensor may be used (Fig. 12) on solidly grounded systems with load current up to 3000 amps at high relay pick up settings (100 amp and higher) when the accuracy, reduced by the noise level, will not jeopardize the co-ordination. This latter type of bus arrangement may be used on high resistance grounded systems up to 600 amps balanced load current, but the application is not recommended, since off centre deviation of the bus bars in the window, third harmonics or occasional unbalanced load currents may increase the noise level beyond the permitted values for an accurate relay operation.

Table 2: Recommended Zero Sequence Current Sensor (Toroidal) Sizes for Various Feeder Sizes

WIRE SIZE		10	8	6	4	2	1	1/0	2/0	3/0	4/0	250 MCM	300 MCM	350 MCM	400 MCM	500 MCM	750 MCM
Diameter of cable	in. mm	.179 4.6	.241 6.1	.310 7.9	.358 9.1	.418 10.6	.481 12.2	.530 13.5	.576 14.6	.628 15.9	.685 17.4	.765 19.4	.820 20.8	.871 22.1	.918 23.3	1.003 25.5	1.22 31.0
NO. OF CABLES (PHASE & NEUTRAL) IN FEEDER		MINIMUM DIAMETER OF BUNDLE AND RECOMMENDED ZSCS DIAMETER															
3 Cables (form factor 2.16)	in. mm	.39 10	.52 13	.67 17	.77 20	.95 23	1.06 26	1.14 29	1.24 32	1.35 34	1.48 38	1.66 42	1.77 45	1.88 48	1.98 50	2.17 55	2.61 67
4 Cables (form factor 2.42)	in. mm	.43 11	.59 15	.75 19	.87 22	1.02 26	1.19 30	1.29 33	1.40 36	1.52 39	1.66 42	1.86 47	1.99 551	2.11 54	2.23 57	2.43 62	2.92 75
6/7 cables (form factor 3.0)	in. mm	.54 14	.73 18	.93 24	1.07 27	1.26 32	1.47 37	1.59 40	1.73 44	1.89 48	2.06 52	2.30 58	2.46 62	2.69 66	2.76 70	3.01 77	3.62 93
9/10 cables (form factor 3.85)	in. mm	.69 18	.93 24	1.19 30	1.38 35	1.62 41	1.88 47	2.04 52	2.22 56	2.42 61	2.85 67	2.95 75	3.16 80	3.36 85	3.54 90	3.86 98	4.65 119
12 cables (form factor 4.15)	in. mm	.75 19	1.00 25	1.29 33	1.47 38	1.74 44	2.03 51	2.20 56	2.39 61	2.61 66	2.85 72	3.18 81	3.41 86	3.36 92	3.82 96	4.16 106	5.01 128
Sensor Type Inside diameter	in. mm	T2A 1.875 48	T3A 2.75 70		T6A 5.75 146						T9A 8.75 222						

Note: Diameter of cable bundle = diameter of single cable X form factor.

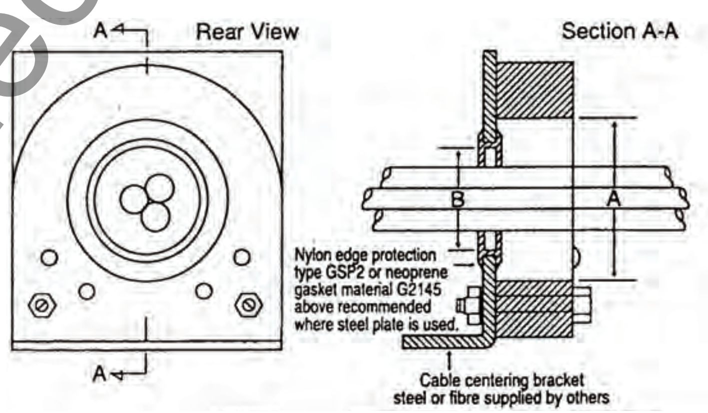


Figure 11 - Example

Example: A T-sensor for 480 Volt feeder having three (3) 500 MCM cables going through (one cable per phase) the diameter of each cable being 1.003 inches each. The T-Sensor should be selected as follows:

The bundle of 3- 500 MCM cables has an approximate diameter of (1.003 x form factor of 2.16) 2.17 inches. Therefore it is recommended to use a T6A ZSCS (window diameter of 5.75 inches).

However if the feeder requires three (3) 500 MCM cables per phase, the resulting bundle would be of 9 cables and the form factor for the diameter of the bundled would now be 3.85 with an approximate diameter of 3.85 x 1.003" = 3.86 inches. Therefore it is recommended to use a T9A ZSCS (window diameter of 8.75 inches).

There is one important general requirement for locating the ZSCS's on bus bar connections, anywhere in the switchboard. Any current carrying bus bars running parallel to either the long or short side of the sensor, must be kept as far from the current sensor as possible, since a current carrying bus bar placed parallel to the sensor will produce noise voltage, which may cause nuisance tripping when no ground current flows.

In all cases the ZSCS mounting should be such that the current carrying bus bars which are not perpendicular to either the long or short side of the sensor should be as far as possible from the sensor. As guideline the following minimum clearances (X) should be applied to (Fig. 3).

Flat side Parallel Bus Arrangement

Recommended on solidly grounded or high resistance grounded systems.

Figure 12

Edge Side Parallel Bus Arrangement

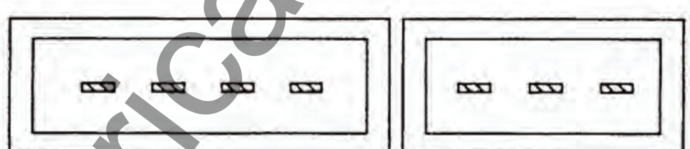


Figure 13

May be used on solidly grounded systems up to 3000A load currents at 100A and higher relay pick-up setting or on low resistance grounded systems up to 600A load current. The use of rectangular zero sequence current sensors on high resistance grounded systems is not recommended.

Edge Side Parallel Bus Arrangement

CIRCUIT RATING	DIM X	
600 amps load current	4"	102mm
1000 amps	6"	153mm
2000 amps	8"	203mm
3000 amps	10"	254mm
4000 amps	12"	305mm

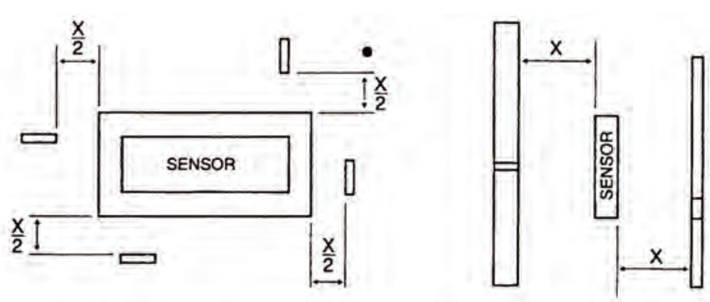


Figure 14

Edge Side Parallel Bus Arrangement

May be used on solidly grounded systems up to 3000A load currents at 100A and higher relay pick-up setting or on low resistance grounded systems up to 600A load current. The use of rectangular zero sequence current sensors on high resistance grounded systems is not recommended.

Recommended Clearances for Sensors

Perpendicular bus bars should have a minimum clearance of half of the suggested distance indicated on the table above, if possible.

These requirements are also applicable to the toroidal ZSCS's. However, one-half the clearances can be used except for lower load currents when the clearances can be reduced to a minimum of 2 inches (51 mm).

For Type RZ sensors up to 3000 amps use the clearances applicable to toroidal sensors, over 3000A use rectangular clearances.

On high resistance grounded systems the minimum clearances for parallel or perpendicular bus bars should be increased to twice the recommended distances.

Mounting

The current sensors should be mounted rigidly in the switchboard. Any sensor movement will increase the noise level. Zero sequence current sensors must encircle all the phase conductors and the neutral (if it exists) but not the grounding wire or the shield of the cable.

Multi-conductor cables with metallic sheath or with ground wire must have grounds made on the load side of the sensors. Where this is not convenient the cable terminator should be insulated and the ground cable returned back through the window and then grounded on the load side of the ZSCS.

Split Core Sensors

On medium voltage cables where the metallic sheath has been stripped back, a stress cone sheath should be placed around the cable jacket to eliminate any stress or corona. This sheath must be grounded to the ground bus.

The following arrangements are recommended to ensure correct cable installation of the toroidal sensor.

1) The sensors when mounted at cable bends should be mounted at 45 degree angle to avoid sharp cable bends of not more than 90 degrees

2) For pick up settings below 100A a fibre or steel mounting plate is recommended on one side of the sensor. This plate should provide a window of a diameter of the bundled cables to ensure the centering of the cables running through as shown below.

All ground fault sensors, except type RZ, are mounted with bolts, through mounting holes provided in the body of the sensors.

The type RZ sensors have mounting brackets external to the body of the sensors.

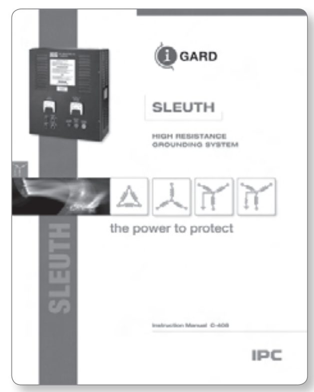
C-101 StopLight
High Resistance Grounding
System Manual

C-102 Gemini
High Resistance Grounding
System Manual

C-105 Fusion
Ground Fault Protection
System Manual

C-322 MGFR
Ground Fault Relay Manual

C-407 GCHK-100 Mining Relay
Ground Fault Protection
System Manual



C-408 Sleuth
High Resistance
Grounding System Manual

C-409 DSP Ohmni
High Resistance
Grounding System Manual

C-403 GFR-RM Sigma
Resistor Monitoring
and Ground Fault Relay

C-107 Sentinel
High Resistance
Grounding System

the power to protect

I-GARD

7615 Kimbel St., Unit 1
Mississauga, Ontario
Canada L5S 1A8

Phone 905-673-1553
Toll Free 1-800-737-4787
Fax 905-673-8472
e-mail: sales@i-gard.com
www.i-gard.com