SIL Calculation Report
(Machinery Directive 2006/42/EC)

Client:	**LS Industrial Systems Co., Ltd.**
Adress:	**56, Samsung 4-gil, Mokcheon-eup, Cheonan-si. Chungcheongnam-do 330-845, Korea**
Product Name:	**LS VARIABLE FREQUENCY DRIVE**
Model Name:	**SV0008iS7, SV0015iS7, SV0022iS7, SV0037iS7, SV0055iS7, SV0075iS7, SV0110iS7, SV0150iS7, SV0185iS7, SV0220iS7, SV0300iS7, SV0370iS7, SV0450iS7, SV0550iS7, SV0750iS7, SV0900iS7, SV1100iS7, SV1320iS7, SV1600iS7, SV1850iS7, SV2200iS7, SV2800iS7, SV3150iS7, SV3750iS7**
Test Engineer:	**Edward Cho (010.5096.3839)**
SGS File No.	**G-44-2017-03891**
Technical File No.	**ls_ec_20180316111837**
Harmonized Standards	**EN 61800-5-2:2007 (STO, SIL 2); EN 62061:2005/A1:2013 (SILCL 2); EN ISO 13849-1:2015 (PL d, Category 3); EN 61508-1 (SIL 2); EN 61508-2 (SIL 2); EN 60204-1:2006/AC:2010**

SGS

Safety Division

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1. PURPOSE, SCOPE AND CONDITIONS

1.1. Purpose

SGS KOREA (SGS) have contracted with LS Industrial System Co., Ltd. (LSIS) to certify the iS7 Series. The report summarizes calculation result of SIL, Safety Integrity Level (SIL) and Performance Level (PL) with Category
according to EN 61800-5-2, EN 61508-1, EN 61508-2, EN ISO 13849-1 and EN 62061.

1.2. Scope and Conditions

1) The Report is prepared only for LS VARIABLE FREQUENCY DRIVE SV-iS7 Series
2) Unless otherwise stated in the report, the evaluation applies to electrical circuits and components of STO (Stop Torque Off) and PS/VM (Power Supply/Voltage Monitoring) circuit only
3) If the equipment is modified such that the configuration, components, materials, devices, manufacturing methods,
or system loading is changed, this evaluation will be considered invalid
4) The test report shall not be reproduced without prior written consent of SGS KOREA

1.3. Referenced Standard

EN 61800-5-2:2007
Adjustable Speed Electrical Power Drive Systems, Part 5-2: Safety Requirements - Functional

EN 61508-1:2010
Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems,
Part 1: General Requirements

EN 61508-2:2010
Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
Part 2: Requirements for Electrical/Electronic/Programmable Electronic Safety related Systems

EN 61508-6:2010
Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3

EN ISO 13849-1:2015
Safety of Machinery - Safety-related Parts of Control Systems, Part 1: General Principles for Design

EN ISO 13849-2:2012
Safety of Machinery - Safety-related Parts of Control Systems, Part 1: General Principles for Design

EN 62061:2005/A1:2013
Safety of Machinery - Functional Safety of Safety-related Elctrical, Electronic and Programmable Electronic Control Systems

EN 60204-1:2006/AC:2010
Safety of Machinery - Electrical Equipment of Machines, Part 1: General Requirements

2. Definitions and Abbreviations

2.1 Abbreviations

1oo1	1 out of 1 Channel
2oo2	2 out of 2 Channel
CPLD	Complex Programmable Logic Device
CCF	Common Cause Failure
DC	Diagnostic Coverage
E/E/PE	Electrical/Electronic/Programmable Electronic
FIT	Failure In Time (10^{-9})
FMEA	Failure Modes Effects Analysis
FMEDA	Failure Modes Effects and Diagnostic Analysis
HFT	Hardware Fault Tolerance
IGBT	Insulated Gate Bipolar Transistor
MooN	M out of N Channel Architecture
MooND	M out of N Channel Architecture with Diagnostics
MTBF	Mean Time Between Failures
MTTF	Mean Time To Failure
MRT	Mean Repair Time
MTTR	Mean Time to Restoration
HTF	Hardware Fault Tolerance
PDS (SR)	Safety Related Adjustable Speed Electrical Power Drive System
PFD	Probability of Dangerous on Demand
PFD_{avg}	Average Probability of Dangerous on Demand
PFH	Probability of Dangerous Failure per Hour
PL	Performance Level
PLr	Required Performance Level
SFF	Safe Failure Fraction
SIL	Safety Integrity Level
STO	Stop Torque Off
SRS	Safety Requirements Specification
T1	Proof Test Interval
β	CCF Factor

2.2 Mode of Operation (refered from EN 61800-5-2)

Low Demand Mode:
Where the frequency of demands for operation made on a safety-related system is no greater than one per year and no grater than twice the proof-test frequency

High Demand Mode (Continuous Mode):
Where the frequency of demands for operation made on a safety-related system is greater than one per year or greater than twice the proof-test frequency.

* The low demand mode of operation is not generally considered to be relevant for PDS (SR) application. Therefore, PDS (SR) is only considered to operate in the high demand or continuous mode.

Table - Safety Integrity Levels - Target Failure Measures for a Safety Function Operating in High Demand Mode of Operation of Continuous Mode of Operation

SIL	Average Frequency of a Dangerous Failure of the Safety Function $[h^{-1}]$
4	≥ 10–9 to < 10–8
3	≥ 10–8 to < 10–7
2	≥ 10–7 to < 10–6
1	≥ 10–6 to < 10–5

2.3 Type A and Type B Subsystems (refered from EN 61800-5-2)

Type A:
subsystem can be regarded as type A if, for the components required to achieve the safety function:

a) The failure modes of all constituent components are well defined; and
b) The behaviour of the subsystem under fault conditions can be completely determined; and
c) There is sufficient dependable failure data from field experience to show that the claimed failure rates for detected and undetected dangerous failures are met.

Type B:
A Subsystem shall be regarded as type B if, for the components required to achieve the safety function, one or more of the criteria of type A is not satisfied.

2.4 Maximum Allowable Safety Integrity Level for a Safety Function Carried out by a Type A Safety Related Element of Subsysten (refered from EN 61508-2)

SFF	HTF N		
	0	1	2
< 60 %	SIL 1	SIL 2	SIL 3
60 % to < 90 %	SIL 2	SIL 3	SIL 4
90 % to < 99%	SIL 3	SIL 3	SIL 4
≥ 99 %	SIL 3	SIL 4	SIL 4

2.5 Maximum Allowable Safety Integrity Level for a Safety Function Carried out by a Type B Safety Related Element of Subsysten (refered from EN 61508-2)

SFF	HTF N		
	0	1	2
< 60 %	N/A	SIL 1	SIL 2
60 % to < 90 %	SIL 1	SIL 2	SIL 3
90 % to < 99%	SIL 2	SIL 3	SIL 4
≥ 99 %	SIL 3	SIL 4	SIL 4

3. Failure Modes

Component	Failure Mode	Typical Failure Mode Ratios %
Switch with positive opening on demand, for example push button, emergency stop device, position switches, cam operated, selector switches	Contacts will not open	20
	Contacts will not close	80
Electromechanical position switch, limit switch, manually operated switch, etc. (not positively opening on demand)	Contacts will not open	50
	Contacts will not close	50
Relay	All contacts remain in the energized position when the coil is de-energized	25
	All contacts remain in the deenergized position when the coil is energized	25
	Contacts will not open	10
	Contacts will not close	10
	Simultaneous short circuit between three contacts of a change-over contact	10
	Simultaneous closing of normally open and normally closed contacts	10
	Short circuit between two pairs of contacts and/or between contacts and coil terminal	10
Circuit Breaker, Differential Circuit Breaker, Residual Current Device	All contacts remain in the energized position when the coil is de-energized	25
	All contacts remain in the deenergized position when the coil is energized	25
	Contacts will not open	10
	Contacts will not close	10
	Simultaneous short circuit between three contacts of a change-over contact	10
	Simultaneous closing of normally open and normally closed contacts	10
	Short circuit between two pairs of contacts and/or between contacts and coil terminal	10
Contactor	All contacts remain in the energized position when the coil is de-energized	25
	All contacts remain in the deenergized position when the coil is energized	25
	Contacts will not open	10
	Contacts will not close	10
	Simultaneous short circuit between three contacts of a change-over contact	10
	Simultaneous closing of normally open and normally closed contacts	10
	Short Circuit Between Two Pairs of Contacts and/or Between Contacts and Coil Terminal	10
Diode, General	Short Circuit	50
	Open Circuit	30
	Parameter Change	20
Fuse	Fails to Blow (Short Circuit)	20
	Open circuit	80

Proximity Switch	Permanently low resistance at output	25
	Permanently high resistance at output	25
	Interruption in power supply	30
	No operation of switch due to mechanical failure	10
	Simultaneous short circuit between three contacts of a change-over contact	10
Temperature Switch	Contacts will not close	30
	Contacts will not open	10
	Short circuits between adjacent contacts	10
	Simultaneous short circuit between three terminals of change-over contacts	10
	Faulty sensor	20
	Change of the detection or output characteristic	20
Pressure Switch	Contacts will not close	30
	Contacts will not open	10
	Short circuits between adjacent contacts	10
	Simultaneous short circuit between three terminals of change-over contacts	10
	Faulty sensor	20
	Change of the detection or output characteristic	20
Solenoid Valve	Does not energize	5
	Does not de-energize	15
	Change of switching times	5
	Leakage	65
	Other failure modes	10
Transformer	Open circuit of individual winding	5
	Short circuit between different windings	15
	Short circuit in one winding	5
	Change in effective turns ratio	65
Inductances	Open circuit	80
	Short circuit	10
	Random change of value	10
Resistors	Open circuit	80
	Short circuit	10
	Random change of value	10
Resistor networks	Open circuit	70
	Short circuit	10
	Short circuit between all connections	10
	Random change of value	10
Potentiometers	Open circuit of individual connection	70
	Short circuit between all connections	10
	Short circuit between any two connections	10
	Random change of value	10

Connector / Connection	Open	61
	Poor Contact / Intermittent	23
	Short	16
Capacitors	Open Circuit	40
	Short Circuit	40
	Random Change of Value	10
	Changing value tan α	10
Electronic components — Discrete semiconductors (e.g. Diodes, Zener diodes, Transistors, Triacs, Thyristors, Voltage regulators, Quartz Crystal, Phototransistors, Light-Emitting Diodes [LEDs])	Open Circuit of Any Connection	25
	Short Circuit between Any Two Connections	25
	Short Circuit between All Connections	25
	Change in Characteristics	25
Non-programmable integrated circuits (noncomplex, i.e. less than 1 000 gates and/or less than 24 pins, operational amplifiers, shift registers, and hybrid modules)	Open Circuit of Any Connection	20
	Short Circuit between Any Two Connections	20
	“Stuck at” Faults	20
	Parasitic Oscillation of Outputs	20
	Changing Values (e.g. Input/Output Voltage of Analogue Device)	20
Microcircuit, Memory, MOS	Data Bit Loss	34
	Short Circuit between Any Two Adjacent Pins	26
	Open Circuit of Individual Connector Pins	23
	Slow Transfer of Data	17
Opto-Couplers	Open Circuit of Individual Connection	30
	Short Circuit between Any Two Input Connections	30
	Short Circuit between Any Two Output Connections	30
	Short Circuit between Any Two Connections of Input and Output	10
Plug and Socket, Multi-Pin Connector	Short Circuit between Any Two Adjacent Pins	10
	Short Circuit of Any Conductor to An Exposed Conductive Part	10
	Open Circuit of Individual Connector Pins	80
Transistor, Bipolar	Short Circuit	73
	Open Circuit	27
Terminal block	Short Circuit between Adjacent Terminals	10
	Open Circuit of Individual Terminals	90

NOTE 1 This data has been derived from a number of industry sources including:
MIL-HDBK 217F(Notice 2) Reliability Prediction of Electronic Equipment (28-02-95), Parts Stress Analysis
MIL-HDBK 217F(Notice 2) Reliability Prediction of Electronic Equipment (28-02-95), Appendix A, Parts Count Reliability Prediction
SN 29500 Part 7, Failure Rates of Components, Expected Values for Relays, April 1992
SN 29500 Part 11, Failure Rates of Components, Expected Values for Contactors, August 1990
The documents in the SN 29500 series are publicly available and can be obtained from:
Siemens AG, CT SR SI
Otto-Hahn-Ring 6
D-81739 München
NOTE 2 Electrical failure modes taken from Tables D.5 of ISO 13849-2. Mechanical failure modes (where applicable) are taken from Annexes A, B and C of ISO 13849-2.
NOTE 3 For a number of electrical/electronic components, for example resistors and capacitors, different designs may have a different distribution of failure modes from those given in the table.
Failure Mode/Mechanism Distribution FMD-91, RAC 1991

4. Failure Rate of Components

Part Name	λ ref (FIT)
Resistor (Carbon Film - ≤ 100 kOhm)	0.3
Resistor (Carbon Film - > 100 kOhm)	1
Resistor (Metal film)	0.2
Resistor (Networks (film circuits) per resistor element - Standard)	0.1
Resistor (Networks (film circuits) per resistor element - Custom Design)	0.5
Resistor (Metal-Oxide)	5
Resistor (Wire-Wound)	5
Resistor (Variable)	30
Capacitor (Metal foil - Polystyrol)	1
Capacitor (Metal foil - Polypropylene)	1
Catacitor (Metal foil - Polycarbonate)	2
Catacitor (Metal foil - Polyethylene terephtalate)	1
Capacitor (Metallized film - Polyethylene terephtalate)	0.7
Capacitor (Metallized film - Polycarbonate)	0.7
Capacitor (Metallized film - Polypropylene)	0.7
Capacitor (Metallized film - Acetyl cellulose)	0.7
Capacitor (Metallized paper (film))	2
Capacitor (Mica)	1
Capacitor (Glass)	2
Capacitor (Ceramic - COG, NPO)	1
Capacitor (Ceramic - X7R, X5R)	2
Capacitor (Ceramic - Z5U, Y5V, Y4T)	5
Capacitor (Aluminium electrolytic - non solid electrolyte)	5
Capacitor (Aluminium electrolytic - solid electrolyte)	3
Capacitor (Tantalum electrolytic - non solid electrolyte)	10
Capacitor (Tantalum electrolytic- solid electrolyte)	1
Connector (Clamp)	0.5
Connector (Press in)	0.25
Connector (Screw)	0.5
Connector (Terminal Point)	0.25
Connector (Wire-Warp)	0.25
Diode (Universal)	1
Diode (Schottky)	1
Diode (Suppressor)	1
Diode (Reference)	7
Diode (Zenor, Ptot < 1kW)	1
Diode (Zenor, Power)	25
Inductor (Inductor for EMC Applications - ≤ 3A)	1.5
Inductor (Inductor for EMC Applications - > 3A)	3
Inductor (Low frequencey inductors and transformers - ≤ 25 kHz)	3
Inductor (High frequencey inductors and transformers - > 25 kHz)	5
Inductor (Main transformers and transformers for switched-mode power supplies)	10
LED Visible Light (Radial and SMT)	1.5
LED Visible Light (Large Power Packages >100 mA DC)	4
LED IRED (GaAs)	2
LED IRED (InP)	20
Microproessors (Bipolar, Number of Gate : below 1k, Number of Transistors: Below 5k)	50
Microproessors (NMOS, Number of Gate : below 1k, Number of Transistors: Below 5k)	50
Microproessors (NMOS, Number of Gate : 1k ~ 10 k, Number of Transistors: 5k ~ 50k)	60
Microproessors (NMOS, Number of Gate : 10k ~ 100 k, Number of Transistors: 50k ~ 500k)	100
Microproessors (CMOS, Number of Gate : below 1k, Number of Transistors: Below 5k)	25
Microproessors (CMOS, Number of Gate : 1k ~ 10 k, Number of Transistors: 5k ~ 50k)	30
Microproessors (CMOS, Number of Gate : 10k ~ 100 k, Number of Transistors: 50k ~ 500k)	50
Microproessors (CMOS, Number of Gate : 100k ~ 1000 k, Number of Transistors: 500k ~ 5M)	80
Microproessors (CMOS, Number of Gate : 1M ~ 10M, Number of Transistors: 5M ~ 50M)	120
Microproessors (CMOS, Number of Gate : 10M ~ 100M, Number of Transistors: 50M ~ 500M)	150
Microproessors (BICMOS, Number of Gate : 100k ~ 1M, Number of Transistors: 500k ~ 5M)	50

Varistors	1
PTC Thermistors (Measuring Applications)	5
PTC Thermistors (Heating and Starting Applications)	5
NTC Thermistors	3
Surge Arresters	1
Ceramic Resonators	5
Filters	10
Filters (Surface Wave Filters - SAW)	20
Filters (Surface Wave Oscillators - SAW-Oscillators)	30
Filters (Voltage Controlled Oscillators - VCO)	40
Piezoelectric Components (transducers and sensors)	30
Crystals	15
Crystal Oscillators (Clock)	30
Crystal Oscillators (Voltage controlled)	60
Crystal Oscillators (Temperature compensated)	100
Crystal Oscillators (Oven controlled)	200
Feed-through Capacitors	5
Feed-through Filters	5
Fuses	25
Optocouplers (with Bipolar Output)	15
Optocouplers (with FET Output)	40
Optocouplers (with Subsequent Electronics)	20
Optocouplers (with Subsequent Power Electronics)	40
Light Barrier (with Diode Output/Transistor Output)	50
Light Barrier (with Subsequent Electronics)	65
RAM (Bipolor)	50
PROM (Bipolar)	60
RAM (MOS ,CMOS and BICMOS)	50
ROM Mask (MOS ,CMOS and BICMOS)	50
EPROM, OTPROM (MOS ,CMOS and BICMOS)	30
FLASH (MOS ,CMOS and BICMOS)	30
EEPROM, EAROM (MOS ,CMOS and BICMOS)	30
Hermetically Sealed Relays with Twin Contacts in Inert Gases or Mercury Wetted Contacts (with Monitoring)	0.5
Hermetically Sealed Relays with Twin Contacts in Inert Gases or Mercury Wetted Contacts (without Monitoring)	1
Plastic Sealed Relays with Low Outgasing, Tempered Plastic and Twin Contacs made of Noble Metals and Their Alloys	2
Open and Dust-Tight Relays with Twin Contacts Made of Noble Metals and Their Alloys	4
Dust-Tight Relays with Single Contacts with Contact Alloys on a Silver Basis, with or without Gold Coating	5
Open and Dust-Tight Relays with Single Contacts on a Silver Basis	1
Transistor (Bipolar, Universal)	3
Transistor (Bipolar, Arrays)	12
Transistor (Bipolar, Low Power)	20
Transistor (Bipolar, Power)	60
Transistor (FET - Sperrschicht / Junction)	5
Transistor (FET - MOS)	5
Transistor (MOS, Leistung / Power, SIPMOS) e.g. TO3, TO220, D(D)-Pack	60
Transistor (IGBT Leistung / Power) e.g. TO3, TO220, D(D)-Pack	60
Intergrated Circuits (For EMC Applicatoins)	3
IGBT-Module	70
ASIC, Full Custom, Gate Arrays, A/D Converters (Bipolar - TTL)	30
ASIC, Full Custom, Gate Arrays, A/D Converters (Bipolar - ECL)	60
ASIC, Full Custom, Gate Arrays, A/D Converters (Bipolar - HV)	40
ASIC, Full Custom, Gate Arrays, A/D Converters (NMOS)	30
Inductor (Low Frequency Inductors and Transformers)	3
Inductor (High Frequency Inductors and Transformers)	5
Inductor (Main Transformers and Transformers for Switched Modes and Power Supplies)	10
Regulators and Power Amplifiers	25

5. SYSTEM DESIGN

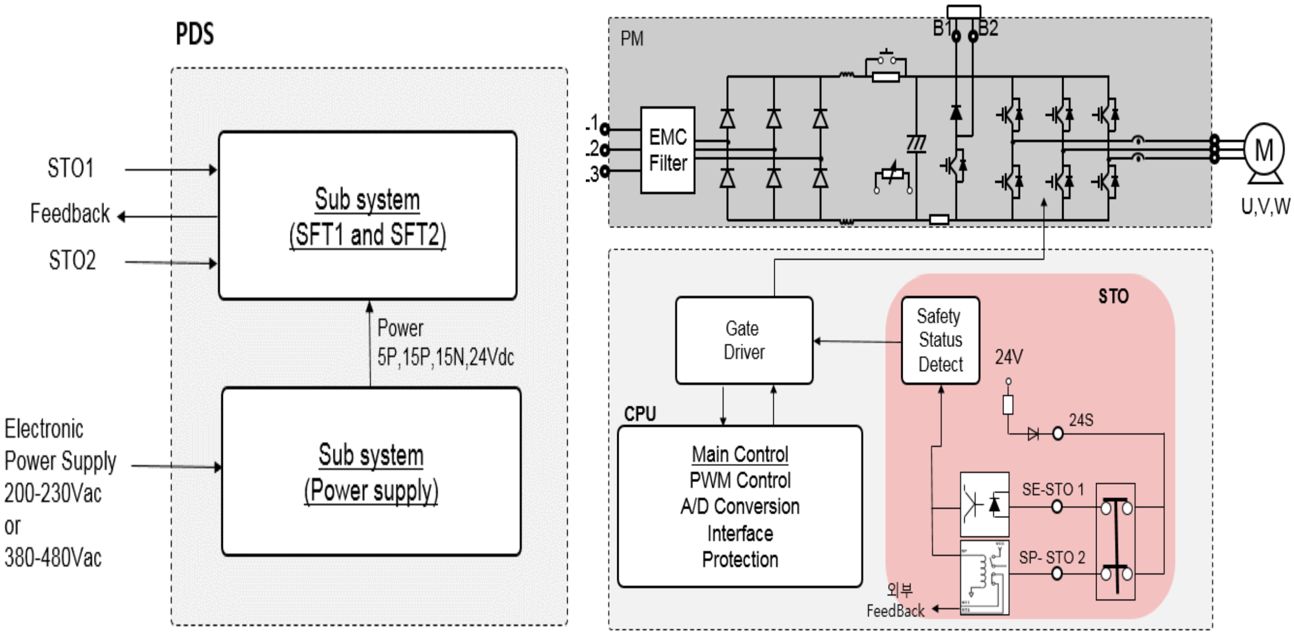
5.1 System Feature

The safety function is a safety torque off (STO) function used to prevent a torque and to block the power supply to the motor by interrupting the gate using hard wires.

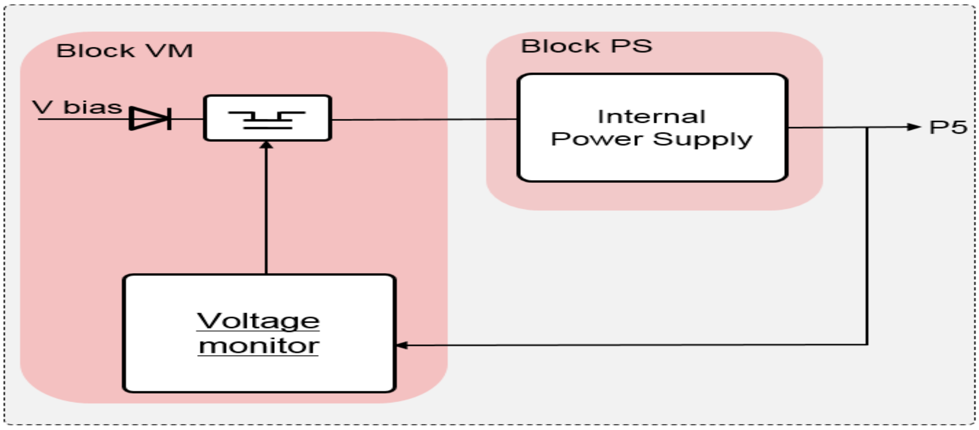
The STO function is independently connected to each input signal for 2 channels (SE(SFT11) and SP(SFT2)). The connected circuit cuts off the operation signal for the inverter output and turns off the power modules.
If the safety function is activated during operation, the inverter blocks the output and the motor enters Free Run mode. Also, the “Safety Opt Err” message is displayed on the keypad.
To release the fault trip, short-circuit terminal block to return to the normal operation status and press the [STOP/RESET] key.

5.2 Block Diagram

5.2.1 STO Part



5.2.2 PS/VM Part



6. Part List

No	Part Name	Specification	Manufacturer	Number
1	Connector	B7B-XH-A	YEONHO	CN1
2	Capacitor	50V 104	SAMSUNG	C1,C2,C3
3	Capacitor	104 50V C2125	SAMSUNG	C4,C5
4	Capacitor	102 50V C2125	SAMSUNG	C6,C7,C8,C9,C10,C11
5	Capacitor	103 50V C2125	SAMSUNG	C12,C13
6	Capacitor	105 50V C3216	SAMSUNG	C14,C15
7	Diode	ES2D	Richwood International	D1,D2
8	Diode	KDR721S	KEC	D3,D4,D5
9	Connector	CONN PCB 13x2-P	SOLTEK	J1
10	Optocouple	TLP781(D4-GB-TP6,F)	TOSHIBA	PC1
11	Transistor	KRA101S	KEC	Q1
12	Relay	SR4D4024	TYCO	RLY1
13	Resistor	1/2W 3.3KJ	WALSIN	R1,R2
14	Resistor	1/16W 4.7KJ	WALSIN	R3
15	Resistor	1KF 1/10W R2012	WALSIN	R4,R5,R6,R7,R8
16	Resistor	1.21KF 1/10W R2012	WALSIN	R9
17	Resistor	4.7KF 1/10W R2012	WALSIN	R10,R11
18	Resistor	4.99KF 1/10W R2012	WALSIN	R12
19	Resistor	470F 1/10W R2012	WALSIN	R13
20	Resistor	10KF 1/4W R3225	KOA	R14, R15
21	Single Voltage Comparator	TA75S393F	TOSHIBA	U1
22	Dual 2-Input NAND Gate	TC7W00FU	TOSHIBA	U2
23	Light Emitting Diode	Green LED	KEC	LED1, LED2
24	Terminal Block	OS-13-2P	OSADA	TB1,TB2,TB3
25	Capacitor	DC2KV103Z,F	SAMWHA	C2,C14
26	Capacitor	50V 102	SAMSUNG	C4,C12
27	Capacitor	50V 224	SAMSUNG	C5
28	Capacitor	50V 222	SAMSUNG	C6
29	Capacitor	LXV 25V 100uF	SAMYOUNG	C8,C31
30	Capacitor	16V 105	SAMYOUNG	C9,C81
31	Capacitor	25V 105	SAMSUNG	C10
32	Capacitor	50V 104	SAMSUNG	C11,C13,C80,C94
33	Capacitor	LXV 50V 68uF	SAMYOUNG	C28
34	Capacitor	LXV 35V 470uF	SAMYOUNG	C17
35	Capacitor	LXV 10V 1000uF	SAMYOUNG	C20,C21
36	Capacitor	LXV 25V 220uF	SAMYOUNG	C22,C26
37	Capacitor	50V 473	SAMSUNG	C30
38	Capacitor	50V 105	SAMSUNG	C32,C33
39	Diode	ES1D	Richwood International	D1,D7,D11,D12,D13
40	Diode	RH2F	SANKEN	D3
41	Diode	ES2D	Richwood International	D5
42	Diode	SS34	Richwood International	D6,D9
43	Inductor	SP5845-330, 33uH	GETPLUS	L1
44	IC	TLP181-GB	TOSHIBA	PC3,PC4
45	FET	2SK2225	HITACHI	Q1
46	Diode	CR05AS-4	MITSUBISHI	Q2
47	Transformer	KTN2222AS	KEC	Q3
48	Diode	KIA431U	KEC	Q7,Q8
49	Resistor	1/4W 2.2J	Walsin	R1,R2
50	Resistor	1W 2.7J	Walsin	R10
51	Resistor	1/16W 1KF	Walsin	R12,R14,R50,R53,R55,R56
52	Resistor	1/8W 10J	Walsin	R13
53	Resistor	1/16W 47KJ	Walsin	R15,R17
54	Resistor	1/16W 100KJ	Walsin	R16
55	Resistor	1/10W 1.5KF	Walsin	R18
56	Resistor	1/16W 5.1KF	Walsin	R22
57	Resistor	1/16W 9.31KF	Walsin	R23
58	Resistor	1/10W 10KJ	Walsin	R24
59	Resistor	1/8W 100J	Walsin	R25
60	Resistor	1/2W 22KJ	Walsin	R26,R31,R32,R36
61	Resistor	1/16W 200F	Walsin	R29,R112
62	Resistor	1W 1KJ	Walsin	R30,R35
63	Resistor	1/10W 200J	Walsin	R51
64	Resistor	1/16W 1.05KF	Walsin	R52
65	Resistor	1/16W 1.6KF	Walsin	R54
66	Resistor	1/16W 1.21KF	Walsin	R57
67	Resistor	1/4W 2KJ	Walsin	R58
68	Resistor	2W 150KJ	RARA	R110,R116
69	Resistor	1/16W 20KF	Walsin	R111
70	Transformer	TRANS2/TRANS4	중원	T1
71	Intergrated Circuit	TL2844	TEXAS INSTRUMENT	U1
72	Zener Diode	PTZ18B	ROHM	ZD1
73	Zener Diode	BZX84-C18	SERIAL MICROELECTRONICS PTE.,LTD(OVS_0000347)	ZD2
74	Zener Diode	PTZ5B6	ROHM	ZD3

7. COMMON CAUSE FAILURES (CCF) AND β VALUE

Below Table is derived from EN 62061:2005/AC:2010, Table F.1 - Criteria for Estimation of CCF

Table F.1 - Criteria for Estimation of CCF

No.	Item	Y/N	Score
Separation / Segregation			
1a	Are SRECS signal cables for the individual channels routed separately from other channels at all positions or sufficiently shielded?	Y	5
1b	Where information encoding/decoding is used, is it sufficient for the detection of signal transmission errors?	N	10
2	Are SRECS signal and electrical energy power cables separate at all positions or sufficiently shielded?	Y	5
3	If subsystem elements can contribute to a CCF, are they provided as physically separate devices in their local enclosures?	N	5
Diversity/Redundancy			
4	Does the subsystem employ different electrical technologies for example, one electronic or programmable electronic and the other an electromechanical relay?	N	8
5	Does the subsystem employ elements that use different physical principles (e.g. sensing elements at a guard door that use mechanical and magnetic sensing techniques) ?	N	10
6	Does the subsystem employ elements with temporal differences in functional operation and/or failure modes?	N	10
7	Do the subsystem elements have a diagnostic test interval of ≤ 1 min?	Y	10
Complexity/Design/Application			
8	Is cross-connection between channels of the subsystem prevented with the exception of that used for diagnostic testing purposes?	N	2
Assessment/Analysis			
9	Have the results of the failure modes and effects analysis been examined to establish sources of common cause failure and have predetermined sources of common cuase failure been eliminated by design?	Y	9
10	Are field failures analysed with feedback into the design?	Y	9
Competence/Training			
11	Do subsystem designers understand the causes and consequences of common cause failures?	Y	4
Environmental Control			
12	Are the subsystem elements likely to operate always within the range of temperature, humidity, corrosion, dust, vibration, etc. over which it has been tested, without the use of external environmental control ?	Y	9
13	Is the subsystem immune to adverse influences from electromagnetic interference up to and including the limits specified in Annex E?	Y	9

NOTE *An alternative item (e.g. references 1a and 1b) is given in Table F.1 where it is intended that a claim can be made for a contribution towards avoidance of CCF from only the most relevant item.*

Table F.2 - Estimation of CCF factor (β)

Overall Score	Common Cause Failure Factor (β)	Score and β Value
< 35	10 % (0.1)	N/A
35 - 65	5 % (0.05)	**Score: 60, β: 5 % (0.05)**
65 - 85	2 % (0.02)	N/A
85 - 100	1 % (0.01)	N/A

7. Evaluation Result

7.1 Factors Relating SIL Grade

λsd of STO Circuit (Detected Safety Failure)	λsu of STO Circuit (Safety Undetected Failure)	λdd of STO Circuit (Dangerous Detected Failure)	λdu of STO Circuit (Unetected Dangerous Failure)	λs of STO Circuit (Safety Failure = λsd + λsu)	λd of STO Circuit (Dangerous Failure = λdd + λdu)	DC of STO Circuit (Diagnostic Coverage = λdd / λd)	SFF of STO Circuit (Safe Failure Fraction) = (λs + λdd) / (λs + λd))
46.31	79.10	26.95	0.00	125.41	26.95	100.00	83.47%
λsd of PS/VM Circuit (Detected Safety Failure)	**λsu of PS/VM Circuit (Safety Undetected Failure)**	**λdd of PS/VM Circuit (Dangerous Detected Failure)**	**λdu of PS/VM Circuit (Unetected Dangerous Failure)**	**λs of STO Circuit (Safety Failure = λsd + λsu)**	**λd of STO Circuit (Dangerous Failure = λdd + λdu)**	**DC of STO Circuit (Diagnostic Coverage = λdd / λd)**	**SFF of PS/VM Circuit (Safe Failure Fraction) = (λs + λdd) / (λs + λd))**
0.00	155.47	0.00	9.07	95.47	9.07	0.00	91.32%
λsd of Total Circuit (Detected Safety Failure)	**λsu of Total Circuit (Safety Undetected Failure)**	**λdd of Total Circuit (Dangerous Detected Failure)**	**λdu of Total Circuit (Unetected Dangerous Failure)**	**λs of STO Circuit (Safety Failure = λsd + λsu)**	**λd of STO Circuit (Dangerous Failure = λdd + λdu)**	**DC of STO Circuit (Diagnostic Coverage = λdd / λd)**	**SFF of Total Circuit (Safe Failure Fraction) = (λs + λdd) / (λs + λd))**
0.00	234.57	0.00	9.07	220.88	36.02	25.00	N/A

7.2 Maximum Allowable SIL Grade

Table 2 of EN 61508-2- Maximum allowable safety integrity level for a safety function carried out by a type A safety-related element or subsystem

Safe Failure Fraction of an Element (STO)	Hardware Fault Tolerance			Safe Failure Fraction of an Element (PS/VM)	Hardware Fault Tolerance		
	0	1	2		0	1	2
< 60 %	SIL 1	SIL 2	SIL 3	< 60 %	SIL 1	SIL 2	SIL 3
60 % - < 90 %	SIL 2	SIL 3	SIL 4	60 % - < 90 %	SIL 2	SIL 3	SIL 4
90 % - < 99 %	SIL 3	SIL 4	SIL 4	90 % - < 99 %	SIL 3	SIL 4	SIL 4
≥ 99 %	SIL 3	SIL 4	SIL 4	≥ 99 %	SIL 3	SIL 4	SIL 4

Table 3 of EN 61508-2- Maximum allowable safety integrity level for a safety function carried out by a type B safety-related element or subsystem

Safe Failure Fraction of an Element (STO)	Hardware Fault Tolerance			Safe Failure Fraction of an Element (PS/VM)	Hardware Fault Tolerance		
	0	1	2		0	1	2
< 60 %	Not Allowed	SIL 1	SIL 2	< 60 %	Not Allowed	SIL 1	SIL 2
60 % - < 90 %	SIL 1	SIL 2	SIL 3	60 % - < 90 %	SIL 1	SIL 2	SIL 3
90 % - < 99 %	SIL 2	SIL 3	SIL 4	90 % - < 99 %	SIL 2	SIL 3	SIL 4
≥ 99 %	SIL 3	SIL 4	SIL 4	≥ 99 %	SIL 3	SIL 4	SIL 4

7.3 Summary

The system is **type B** and have **1 of Hardware Fault Tolerance**, and designed as **2oo2** of IEC 61508-6.

The FMEDA result shows that **SFF** of STO and PS/VM circuit are **83.47 %** and **91.32 %**, therefore the circuit can reach up to **SIL 2** as according to Table 2 of EN 61508-2.

Total **λd** of STO and PS/VM Circuit is **36.02 FIT** and, **PFHd** is **72.04 FIT (7.2 x 10^{8})** by formula of IEC 61508-6.

This system can be reached to **SIL 2**, according to the table in EN 61508-1 and calculation result of SFF.

Safety Integrity Level	Average Frequency of a Dangerous Failure of the Safety Function [H^{1}]
4	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-5}$