Content

Solid state relay

Type selection

1-phase solid-state relays / Zero voltage switching AC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
12 ... 275 VAC	5 mA ... 4 A	4 ... 30 VDC	M	HM D2704	8.6
24 ... 600 VAC	5 mA ... 5 A (25 A)*	4 ... 14 VDC	T	HT D6005L	8.8
48 ... 530 VAC	5 mA ... 5 A (25 A)*	8 ... 32 VDC	T	HT D6005H	8.8
48 ... 530 VAC	5 mA... 10 A	4 ... 14 VDC	Q	HQ D6010L	8.10
48 ... 530 VAC	5 mA ... 10 A	8 ... 32 VDC	Q	HQ D6010H	8.10

* Up to 25 A can be switched with corresponding cooling. See thermal diagram on page 8

Construction M

Construction T

Construction Q

1-phase solid-state relays / Instantaneous switches DC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
2... 60 VDC	5 mA ... 3 A	3 ... 30 VDC	M	HM D0603D	8.6

Construction M

Type selection

1-phase solid-state relays / Zero voltage switching AC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
12 ... 280 VAC	5 mA ... 25 A	3 ... 32 VDC	S	HS D2825	8.12
12 ... 280 VAC	5 mA ... 25 A	185... 265 VAC/DC	S	HS A2825	8.12
24 ... 600 VAC	5 mA ... 35 A	3,5 ... 32 VDC	S	HS D6035	8.12
12 ... 280 VAC	5 mA ... 50 A	3 ... 32 VDC	S	HS D2850	8.14
24 ... 600 VAC	5 mA ... 50 A	3,5 ... 32 VDC	S	HS D6050	8.14
24 ... 510 VAC	5 mA ... 50 A	20 ... 265 VAC/DC	S	HS A5150	8.14
24 ... 600 VAC	5 mA ... 75 A	3,5 ... 32 VDC	S	HS D6075	8.15
24 ... 510 VAC	5 mA ... 75 A	20 ... 265 VAC/DC	S	HS A5175	8.15
24 ... 600 VAC	5 mA ... 125 A	3,5 ... 32 VDC	S	HS D51125	8.15
12 ... 280 VAC	5 mA ... 25 A	3,5 ... 32 VDC	D	HD D2825	8.18
24 ... 600 VAC	5 mA ... 35 A	3,5 ... 32 VDC	D	HD D6035	8.18
24 ... 600 VAC	5 mA ... 50 A	3,5 ... 32 VDC	D	HD D6050	8.18
24 ... 600 VAC	5 mA ... 75 A	3,5 ... 32 VDC	D	HD D6075	8.20

Construction S

Construction D

1-phase solid-state relays / Instantaneous switches AC /DC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
24 ... 510 VAC	5 mA ... 35A	3,5 ... 32 VDC	D	HS D5135M	8.16
5 ... 110 VDC	5 mA ... 20 A	3,5 ... 32 VDC	S	HS D1120D	8.16
5 ... 110 VDC	5 mA ... 40 A	3,5 ... 32 VDC	S	HS D1140D	8.16

Construction S

Type selection

1-phase solid-state relays / Zero voltage switching AC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
12 ... 280 VAC	5 mA ... 25 A	3,5 ... 32 VDC	D	HD D2825K	8.22
24 ... 600 VAC	5 mA ... 35 A	3,5 ... 32 VDC	D	HD D6035K	8.22
24 ... 600 VAC	5 mA ... 50 A	3,5 ... 32 VDC	D	HD D6050K	8.22
24 ... 600 VAC	5 mA ... 75 A	3,5 ... 32 VDC	D	HD D6075K	8.24

Construction D with heat sink

Type selection

3-phase solide-state relays / Zero voltage switching AC

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
24 ... 520 VAC	3 x 5 mA ... 50 A	8,5 ... 30 VDC	L	HL D5250	8.26
24 ... 520 VAC	3 x 5 mA ... 50 A	90 ... 240 VAC/DC	L	HL A5250	8.26

Construction L

3-phase solide-state relays / Zero voltage switching AC with heat sink

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
24 ... 520 VAC	3 x 5 mA ... 22 A	10 ... 30 VDC	L*	HL D5222K	8.28

Construction L*

3-phase solide-state relays / Zero voltage switching AC reversing contactor

Load voltage range	Load current range	Control voltage range	Construc-tion	Type	Page
24 ... 520 VAC	3 x 100 mA ... 8,5 A	12 ... 30 VDC	L	HL D5208R	8.30

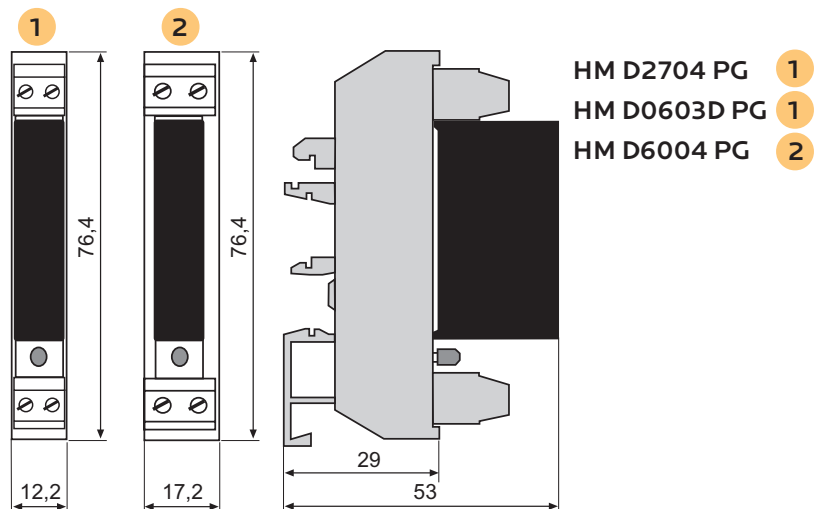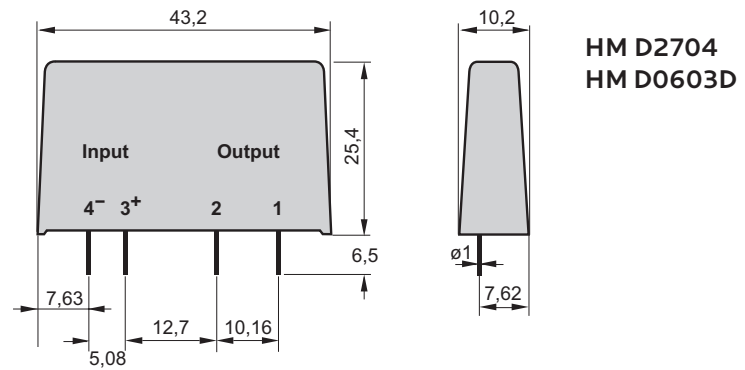Construction L

Printed circuit board mount
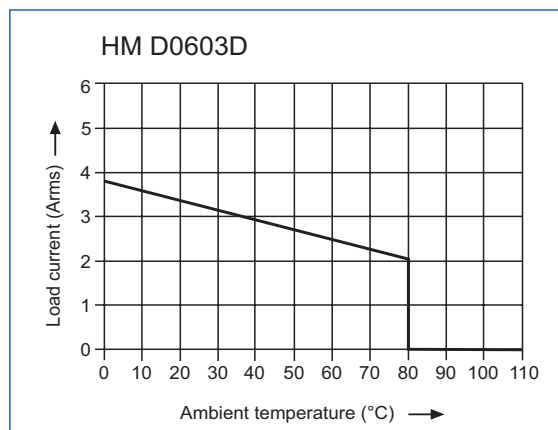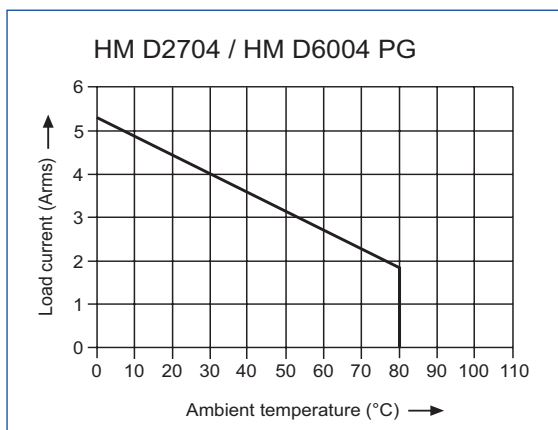
Solid-state relay HM

Construction M

- **Control voltage range: 4 ... 30 VDC, 3 ... 30 VDC**
- **Load voltage range: 12 ... 275 VAC, 2 ... 60 VDC**
- **Load current range: 5 mA ... 4 A, 5 mA ... 3 A**

Dimensions

43,2

10,2

Input   Output

4⁻ 3⁺   2   1

25,4

6,5

7,63

12,7   10,16

5,08

ø1

7,62

HM D2704
HM D0603D

76,4

76,4

29

53

12,2

17,2

HM D2704 PG ①
HM D0603D PG ①
HM D6004 PG ②

Thermal diagrams

HM D2704 / HM D6004 PG

Load current (Arms)

Ambient temperature (°C)

HM D0603D

Load current (Arms)

Ambient temperature (°C)

Printed circuit board mount

Solid-state relay HM

Technical data	HM D2704	HM D0603D	HM D6004 PG
Zero switching	Yes	–	Yes
Instantaneous switching-on	–	Yes	–
Control circuit	DC	DC	DC
Load circuit	AC	DC	AC
Load circuit			
Voltage range	12 ... 275 VAC	2 ... 60 VDC	24 ... 600 VAC
Operating frequency range	10 ... 440 Hz	–	10 ... 440 Hz
Transient overvoltage	600 V	60 V	1200 V
Load current range	5 mA ... 4 A	5 mA ... 3 A	5 mA ... 4 A
Max. surge current (10 ms/AC; 1s/DC)	100 A	10 A	120 A
Max. off-state leakage current (rated voltage)	0,3 mA	1 mA	0,3 mA
Min. off-state du/dt	500 V/µs	200 V/µs	500 V/µs
Max. on-state voltage drop	1,6 V	1,6 V	1,6 V
Max. turn-on time	10 ms	200 µs	10 ms
Max. turn-off time	10 ms	800 µs	10 ms
Max. I^2t for fusing (< 10 ms)	50 A^2s	3 A	72 A^2s
Control circuit			
Control voltage range	4 ... 30 VDC	3 ... 30 VDC	5 ... 30 VDC
Must release voltage	0,8 VDC	1 VDC	0,8 VDC
Nominal input impedance	1000 Ω	1000 Ω	1000 Ω
Typical input current at nominal voltage	3 mA	1 mA	3 mA
Generalities			
Insulation input/output	4000 Vrms	2500 Vrms	4000 Vrms
Galvanic insulation input ↔ output	No	No	No
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	
Ambient storage temperature range	-40 ... +150 °C	-40 ... +105 °C	
Weight (typical)	20 g	20 g	
Approvals	UL	–	
Article number	42310081	42310080	
(Order data see chapter 1)			

Mounted on profile housing	HM D2704 PG	HM D0603D PG	HM D6004 PG
Generalities			
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	-40 ... +80 °C
Ambient storage temperature range	-40 ... +150 °C	-40 ... +105 °C	-40 ... +105 °C
Weight (typical)	30 g	30 g	30 g
Approvals	UL	–	–
Article number	42310086	42310087	42310088
(Order data see chapter 1)			

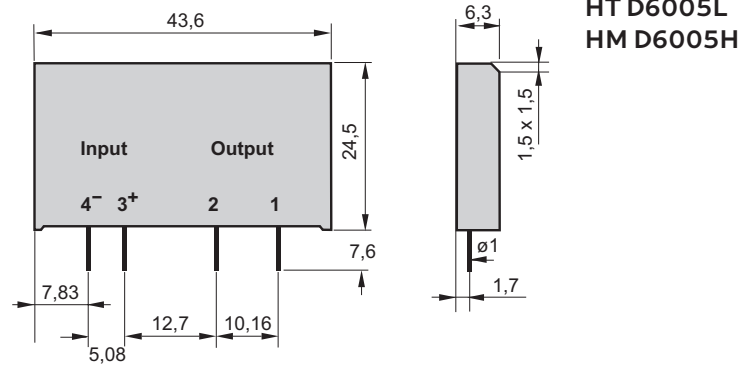# Printed circuit board mount
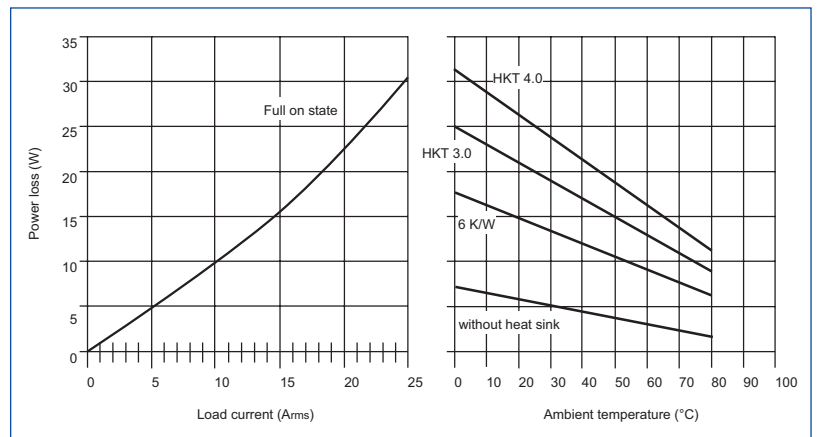
Solid-state relay HT
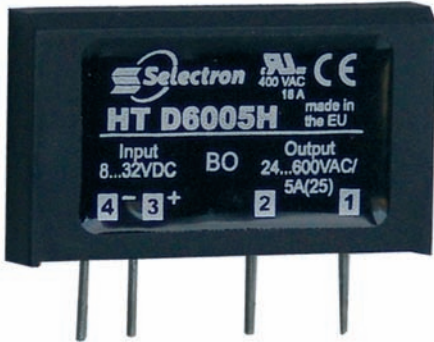
Construction T

- **Control voltage range: 4 ... 14 VDC, 8 ... 32 VDC**
- **Load voltage range: 24 ... 660 VAC**
- **Load current range: 5 mA ... 5 A (25)***

Dimensions

HT D6005L
HM D6005H

43,6

24,5

Input   Output

4⁻ 3⁺   2   1

7,83

12,7   10,16

5,08

7,6

6,3

1,5 x 1,5

ø1

1,7

Thermal diagram

Up to 25 A can be switched with corresponding cooling.

Heat sinks see on pages 32, 33 and 34

Printed circuit board mount

Solid-state relay HT

Technical data	HT D6005L	HT D6005H	ESG 8.9
Zero switching	Yes	Yes	
Instantaneous switching-on	–	–	
Control circuit	DC	DC	
Load circuit	AC	AC	
Load circuit			
Voltage range	24 ... 600 VAC	24 ... 600 VAC	
Operating frequency range	10 ... 800 Hz	10 ... 800 Hz	
Transient overvoltage	1200 V	1200 V	
Load current range	5 mA ... 5 A (25 A)*	5 mA ... 5 A (25 A)*	
Max. surge current (10 ms)	300 A	300 A	
Max. off-state leakage current (rated voltage)	1 mA	1 mA	
Min. off-state du/dt	500 V/µs	500 V/µs	
Max. on-state voltage drop	1,6 V	1,6 V	
Max. turn-on time	10 ms	10 ms	
Max. turn-off time	10 ms	10 ms	
Max. I^2t for fusing (< 10 ms)	450 A^2s	450 A^2s	
Control circuit			
Control voltage range	4 ... 14 VDC	8 ... 32 VDC	
Must release voltage	1 VDC	1 VDC	
Nominal input impedance	440 Ω	1640 Ω	
Typical input current at nominal voltage	25 mA	13,5 mA	
Generalities			
Insulation input/output	4000 Vrms	4000 Vrms	
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	
Ambient storage temperature range	-40 ... +120 °C	-40 ... +120 °C	
Weight (typical)	15 g	15 g	
Approvals	UL	UL	
Article number	42310082	42310083	
(Order data see chapter 1)			

*   Up to 25 A can be switched with corresponding cooling. See thermal diagram
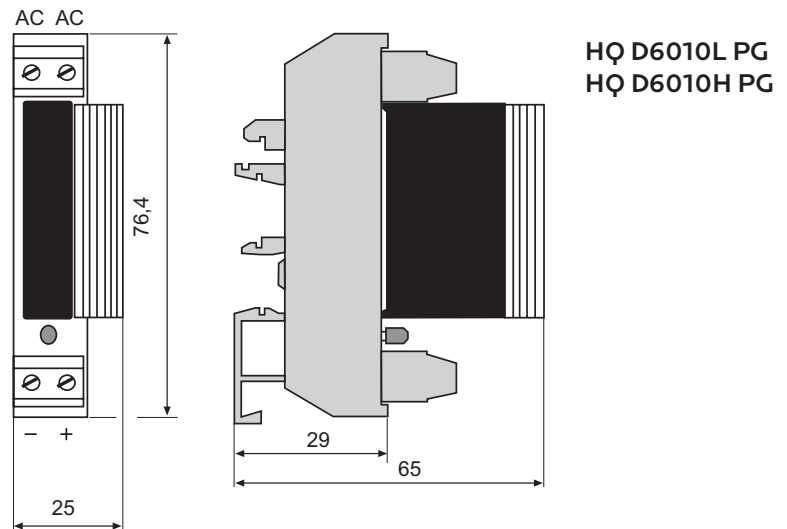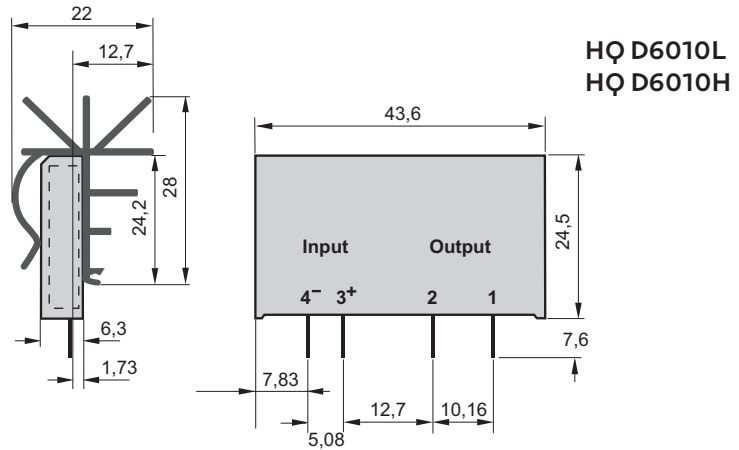
Printed circuit board mount
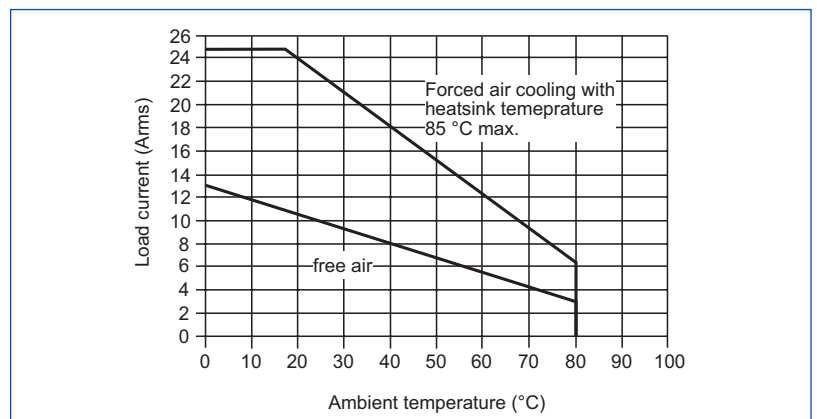
Solid-state relay HQ

Construction Q

- **Control voltage range: 4 ... 140 VDC, 8 ... 32 VDC**
- **Load voltage range: 24 ... 600 VAC**
- **Load current range: 5 mA ... 10 A (25 Arms)***

Dimensions

HQ D6010L
HQ D6010H

22
12,7
28
24,2
6,3
1,73

43,6
24,5
Input
Output
4⁻ 3⁺
2   1
7,6
7,83
12,7   10,16
5,08

HQ D6010L PG
HQ D6010H PG

AC AC
76,4
25
29
65
− +

Thermical diagrams

Load current (Arms)

Forced air cooling with heatsink temeprature 85 °C max.

free air

Ambient temperature (°C)

Up to 25 A can be switched with corresponding cooling.

Printed circuit board mount

Solid-state relay HQ

Technical data	HQ D6010L	HQ D6010H	ESG 8.11
Zero switching	Yes	Yes	
Instantaneous switching-on	–	–	
Control circuit	DC	DC	
Load circuit	AC	AC	
Load circuit			
Voltage range	24 ... 600 VAC	24 ... 600 VAC	
Operating frequency range	10 .... 440 Hz	10 ... 440 Hz	
Transient overvoltage	1200 V	1200 V	
Load current range	5 mA ... 10 A (25A)*	5 mA ... 10 A (25A)*	
Max. surge current (10 ms)	300 A	300 A	
Max. off-state leakage current (rated voltage)	1 mA	1 mA	
Min. off-state du/dt	500 V/µs	500 V/µs	
Max. on-state voltage drop	1,6 V	1,6 V	
Max. turn-on time	10 ms	10 ms	
Max. turn-off time	10 ms	10 ms	
Max. I^2t for fusing (10 ms)	260 A^2s	260 A^2s	
Control circuit			
Control voltage range	4 ... 14 VDC	8 ... 32 VDC	
Must release voltage	1 VDC	1 VDC	
Nominal input impedance	440 Ω	1640 Ω	
Typical input current at nominal voltage	25 mA	13,5 mA	
Generalities			
Insulation input/output	4000 Vrms	4000 Vrms	
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	
Ambient storage temperature range	-40 .. .+120 °C	-40 ... +120 °C	
Weight (typical)	30 g	30 g	
Approvals	–	–	
Article number	42310084	42310085	
(Order data see chapter 1)			

*   Up to 25 A can be switched with corresponding cooling. See thermal diagram

| Mounted on profile housing	HQ D6010L PG	HQ D6010H PG
Generalities		
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C
Ambient storage temperature range	-40 .. .+120 °C	-40 ... +120 °C
Weight (typical)	45 g	45 g
Approvals	–	–
Article number	42310091	42310092
(Order data see chapter 1)		

Standard panel mount package, 1-phase

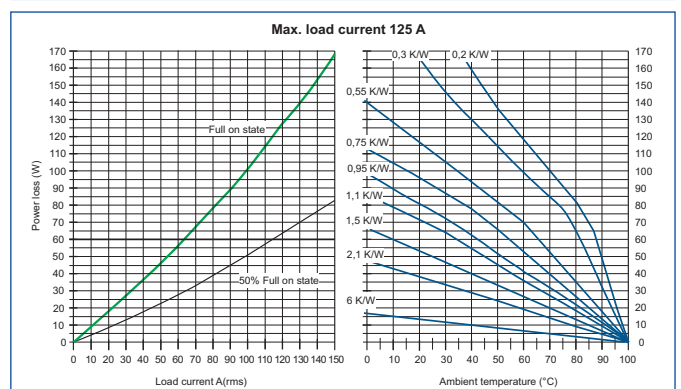**Solid-state relay HS, zero voltage switch**
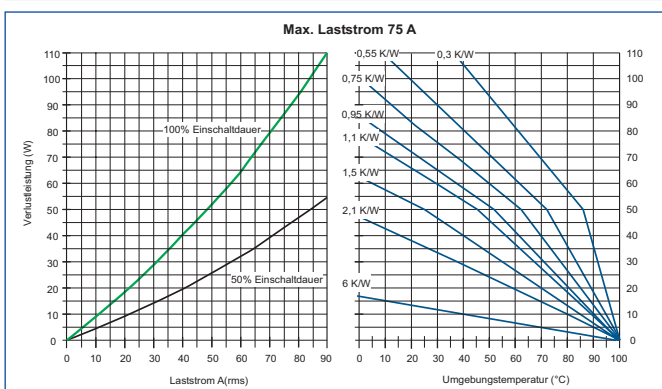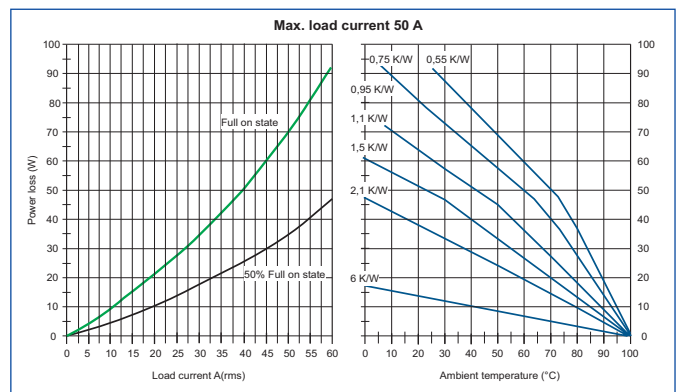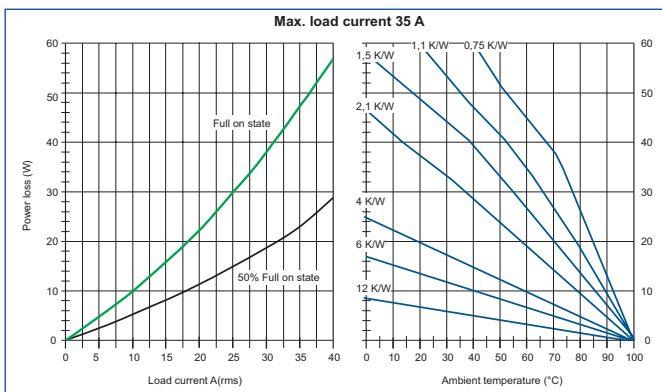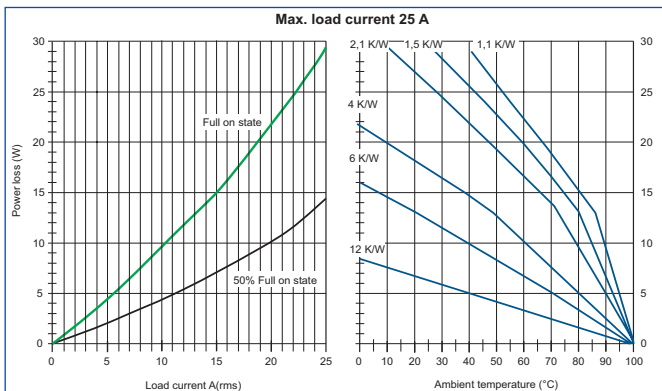

Construction S

- **Control voltage range: 3... 32 VDC, 20 ... 265 VAC/DC**
- **Load voltage range: 12 ... 660 VAC**
- **Load current range:5 mA ... 125 A**

Dimensions
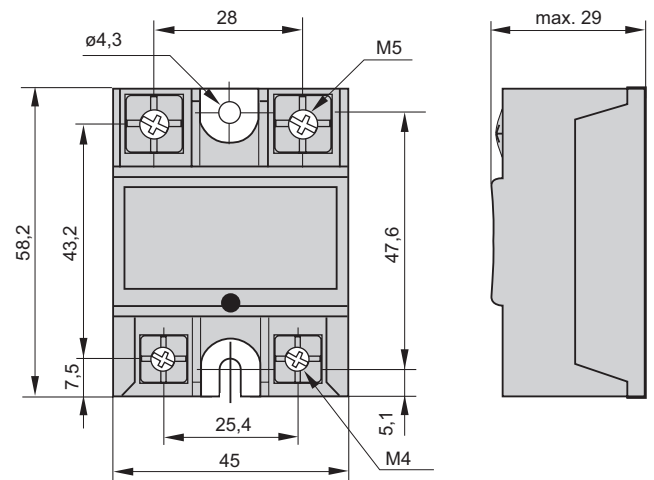
Heat sinks see on pages 32, 33 and 34

Thermal diagrams (all relays already have heat conduction foil)

Max. load current 25 A

Max. load current 35 A

Max. load current 50 A

Max. Laststrom 75 A

Max. load current 125 A

Standard panel mount package, 1-phase

Solid-state relay HS , zero voltage switch

Technical specifications	HS D2825	HS A2825	HS D6035
Zero switching	Yes	Yes	Yes
Instantaneous switching-on	–	–	–
Control circuit	DC	AC/DC	DC
Load circuit	AC	AC	AC
Load circuit			
Voltage range	12 ... 280 VAC	12 ... 280 VAC	24 ... 600 VAC
Operating frequency range	0,1 ... 800 Hz	0,1 ... 800 Hz	0,1 ... 800 Hz
Transient overvoltage	600 V	600 V	1200 V
Load current range	5 mA ... 25 A	5 mA ... 25 A	5 mA ... 35 A
Max. surge current (10 ms)	350 A	350 A	500 A
Max. off-state leakage current (rated voltage)	1 mA	1 mA	1 mA
Min. off-state du/dt	500 V/µs	500 V/µs	500 V/µs
Max. on-state voltage drop	0,85 V	0,85 V	0,9 V
Max. turn-on time	10 ms	30 ms	10 ms
Max. turn-off time	10 ms	30 ms	10 ms
Max. I^2t for fusing (10 ms)	600 A^{2}s	600 A^{2}s	1250 A^{2}s
Thermal resistance to base	1,7 K/W	1,7 K/W	0,6 K/W
Control circuit			
Control voltage range	3 ... 32 VDC	185 ... 265 VAC/DC	3,5 ... 32 VDC
Must release voltage	2 V	3 V	2 V
Max. reverse voltage	32 V	–	32 V
Typical input current at nominal voltage	< 13 mA	< 10 mA	< 13 mA
Generalities			
Insulation input/output/base	4000/2500 Vrms	4000/2500 Vrms	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-55 ... +100 °C	-55 ... +100 °C	-55 ... +100 °C
Ambient storage temperature range	-55 ... +125 °C	-55 ... +125 °C	-55 ... +125 °C
Weight (typical)	85 g	85 g	85 g
Approvals	UL	UL	UL
Screw torque requirements:			
M4 screws (Control circuit)	1,2 Nm	1,2 Nm	1,2 Nm
M5 screws (Load circuit)	2 Nm	2 Nm	2 Nm
Article number	42310203	42310200	42310204
(Order data see chapter 1)			

Standard panel mount package, 1-phase

Solid-state relay HS, zero voltage switch

Technical specifications	HS D2850	HS D6050	HS A5150
Zero switching	Yes	Yes	Yes
Instantaneous switching-on	–	–	–
Control circuit	DC	DC	AC/DC
Load circuit	AC	AC	AC
Load circuit			
Voltage range	12 ... 280 VAC	24 ... 600 VAC	24 ... 510 VAC
Operating frequency range	0,1 ... 800 Hz	0,1 ... 800 Hz	0,1 ... 800 Hz
Transient overvoltage	600 V	1200 V	950 V
Load current range	5 mA ... 50 A	5 mA ... 50 A	5 mA ... 50 A
Max. surge current (10 ms)	720 A	720 A	720 A
Max. off-state leakage current (rated voltage)	1 mA	1 mA	1 mA
Min. off-state du/dt	500 V/µs	500 V/µs	500 V/µs
Max. on-state voltage drop	0,9 V	0,9 V	0,9 V
Max. turn-on time	10 ms	10 ms	30 ms
Max. turn-off time	10 ms	10 ms	30 ms
Max. I^2t for fusing (10 ms)	2500 A^{2}s	2500 A^{2}s	2500 A^{2}s
Thermal resistance to base	0,45 K/W	0,45 K/W	0,45 K/W
Control circuit			
Control voltage range	3 ... 32 Vdc	3,5 ... 32 Vdc	20 ... 265 VAC/DC
Must release voltage	2 V	2 V	5 VDC
Max. reverse voltage	32 V	32 V	–
Typical input current at nominal voltage	< 13 mA	< 13 mA	< 10 mA
Generalities			
Insulation input/output/base	4000/4000 Vrms	4000/4000 Vrms	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC
Ambient operating temperature range	-40 ... +100 °C	-40 ... +100 °C	-40 ... +100 °C
Ambient storage temperature range	-40 ... +125 °C	-40 ... +125 °C	-40 ... +125 °C
Weight (typical)	85g	85 g	85 g
Approvals	UL	UL	UL
Screw torque requirements:			
M4 screws (Control circuit)	1,2 Nm	1,2 Nm	1,2 Nm
M5 screws (Load circuit)	2 Nm	2 Nm	2 Nm
Article number	42310206	42310207	42310201

(Order data see chapter 1)

Standard panel mount package, 1-phase

Solid-state relay HS, zero voltage switch

Technical specifications	HS D6075	HS A5175	HS D51125
Zero switching	Yes	Yes	Yes
Instantaneous switching-on	–	–	–
Control circuit	DC	AC/DC	DC
Load circuit	AC	AC	AC
Load circuit			
Voltage range	24 ... 600 VAC	24 ... 510 VAC	24 ... 510 VAC
Operating frequency range	0,1 ... 800 Hz	0,1 ... 800 Hz	0,1 ... 800 Hz
Transient overvoltage	1200 V	950 V	950 V
Load current range	5 mA ... 75 A	5 mA ... 75 A	5 mA ... 125 A
Max. surge current (10 ms)	1200 A	1200 A	2200 A
Max. off-state leakage current (rated voltage)	1 mA	1 mA	1 mA
Min. off-state du/dt	500 V/µs	500 V/µs	500 V/µs
Max. on-state voltage drop	0,9 V	0,9 V	0,9 V
Max. turn-on time	10 ms	30 ms	10 ms
Max. turn-off time	10 ms	30 ms	10 ms
Max. I^2t for fusing (10 ms)	7200 A^{2}s	7200 A^{2}s	24'000 A^{2}s
Thermal resistance to base	0,4 K/W	0,4 K/W	0,25 K/W
Control circuit			
Control voltage range	3,5 ... 32 VDC	20 ... 265 VAC/DC	3,5 ... 32 VDC
Must release voltage	2 V	5 V	2 V
Max. reverse voltage	32 V	–	32 V
Typical input current at nominal voltage	< 13 mA	< 10 mA	< 13 mA
Generalities			
Insulation input/output	4000/4000 Vrms	4000/4000 Vrms	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-40 ... +100 °C	-40 ... +100 °C	-40 ... +100 °C
Ambient storage temperature range	-40 ... +125 °C	-40 ... +125 °C	-40 ... +125 °C
Weight (typical)	85 g	85 g	85 g
Approvals	UL	UL	UL
Screw torque requirements:			
M4 screws (Control circuit)	1,2 Nm	1,2 Nm	1,2 Nm
M5 screws (Load circuit)	2 Nm	2 Nm	2 Nm
Article number	42310208	42310202	42310209
(Order data see chapter 1)			

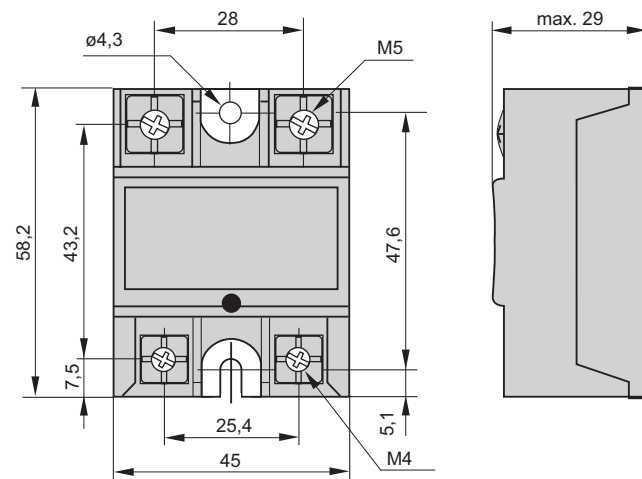# Standard panel mount package, 1-phase
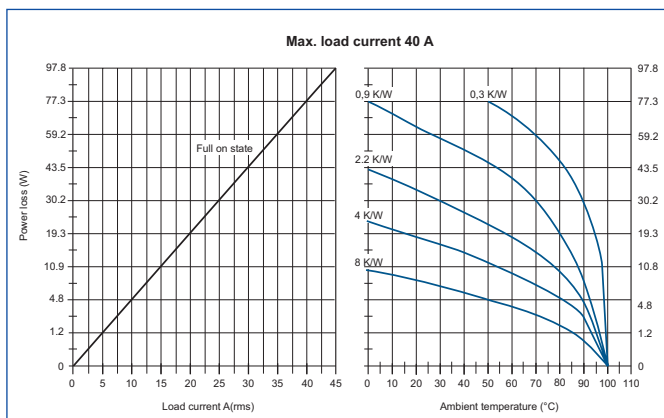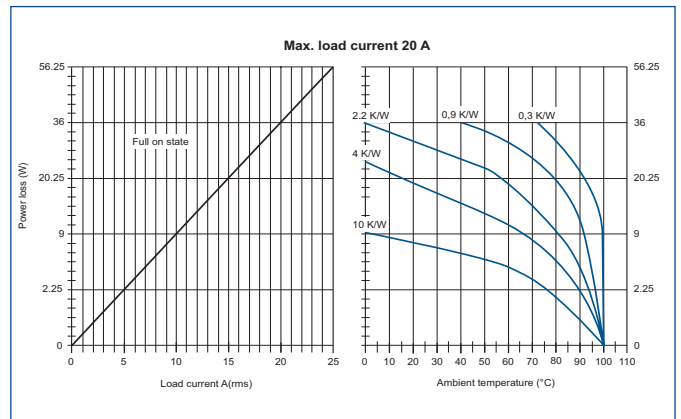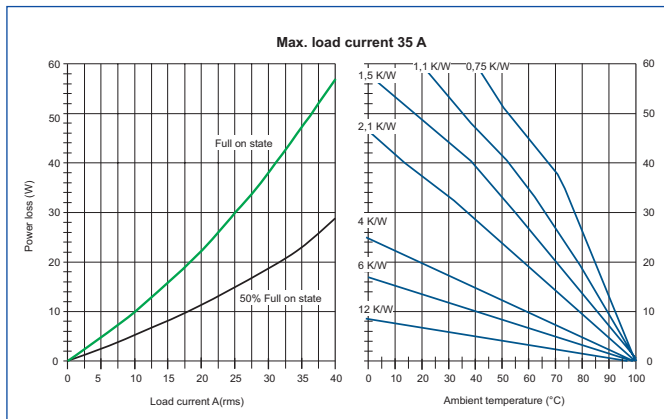
Solid-state relay HS, instantaneous switch

Construction S

- **Control voltage range: 3,5 ... 32 VDC**
- **Load voltage range: 24 ... 510 VAC, 5 ... 110 VDC**
- **Load current range: 5 mA ... 40 A**

Dimensions

ø4,3   28   M5

58,2   43,2   47,6   7,5   5,1

25,4   45   M4

max. 29

Thermal diagrams (all relays already have heat conduction foil)

Max. load current 35 A

Power loss (W)

Full on state

50% Full on state

Load current A(rms)

1,5 K/W   1,1 K/W   0,75 K/W   2,1 K/W   4 K/W   6 K/W   12 K/W

Ambient temperature (°C)

Max. load current 20 A

Full on state

Load current A(rms)

2,2 K/W   0,9 K/W   0,3 K/W   4 K/W   10 K/W

Ambient temperature (°C)

Max. load current 40 A

Power loss (W)

Full on state

Load current A(rms)

0,9 K/W   0,3 K/W   2,2 K/W   4 K/W   8 K/W

Ambient temperature (°C)

Heat sinks see on pages 32, 33 and 34

Standard panel mount package, 1-phase

Solid-state relay HS, instantaneous switch

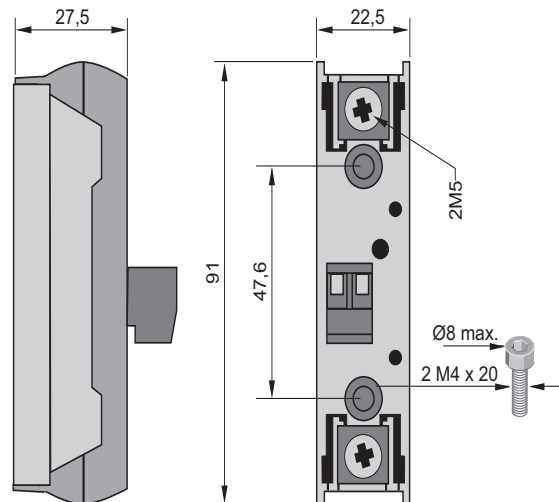| Technical specifications	HS D5135M	HS D1120D	HS D1140D
Zero switching	–	–	–
Instantaneous switching-on	Yes	Yes	Yes
Control circuit	DC	DC	DC
Load circuit	AC	DC	DC
Load circuit			
Voltage range	24 ... 510 VAC	5 ... 110 VDC	5 ... 110 VDC
Operating frequency range	0,1 ... 400 Hz	–	–
Transient overvoltage	1200 V	200 V	200 V
Load current range	5 mA ... 35 A	5 mA ... 20 A	5 mA ... 40 A
Max. surge current (10 ms)	500 A	65 A	90 A
Max. off-state leakage current (rated voltage)	3 mA	3 mA	3 mA
Min. off-state dv/dt	500 V/µs	–	–
Max. on-state voltage drop	0,9 V	1,5 V	1,5 V
Max. turn-on time	0,05 ms	40 µs	40 µs
Max. turn-off time	10 ms	40 µs	40 µs
Max. I^2t for fusing (10 ms)	1250 A^{2}s		
Max.peak current not repetitiv e 0,1 ms		160 A	280 A
Thermal resistance to base	0,6 K/W	1,2 K/W	0,7 K/W
Control circuit			
Control voltage range	3,5 ... 32 VDC	3,5 ... 32 VDC	3,5 ... 32 VDC
Must release voltage	2 V	1 V	1 V
Max. reverse voltage	32 V	32 V	32 V
Typical input current at nominal voltage	13 mA	35 mA	35 mA
Generalities			
Insulation input/output	4000/4000 Vrms	2500/2500 Vrms	2500/2500 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1 GΩ	1 GΩ
Ambient operating temperature range	-55 ... +100 °C	-25 ... +90 °C	-25 ... +90 °C
Ambient storage temperature range	-55 ... +125 °C	-40 ... +100 °C	-40 ... +100 °C
Weight (typical)	85 g	85 g	85 g
Approvals	–	–	–
Screw torque requirements:			
M4 screws (Control circuit)	1,2 Nm	1,2 Nm	1,2 Nm
M5 screws (Load circuit)	2 Nm	2 Nm	2 Nm
Article number	42310205	42310180	42310181
(Order data see chapter 1)			

Standard panel mount package
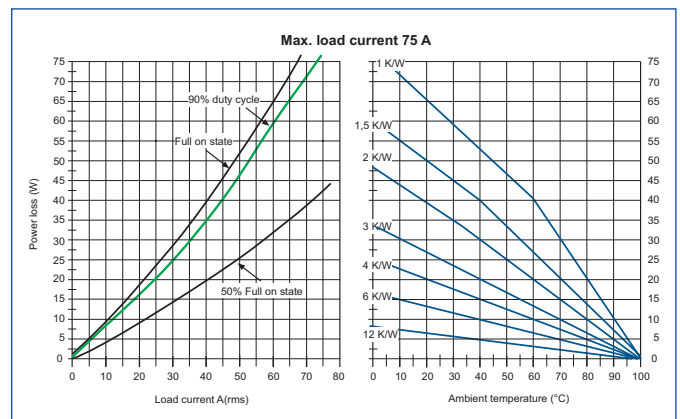
Solid-state relay HD
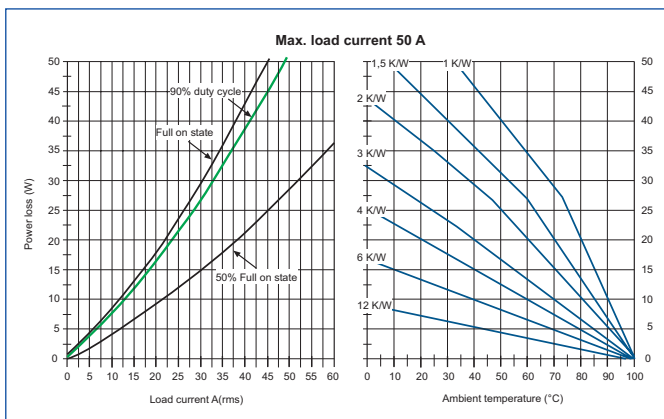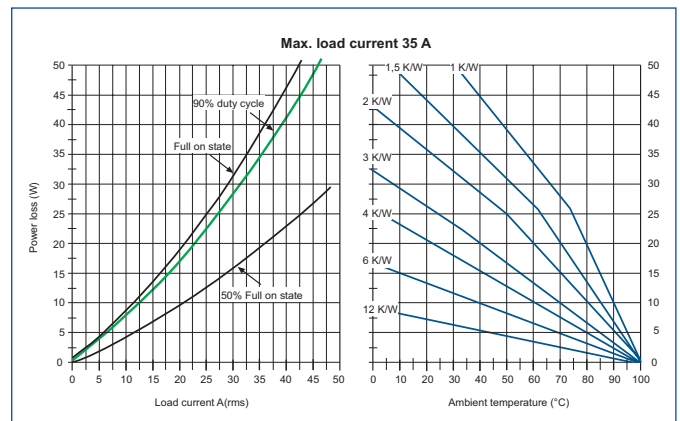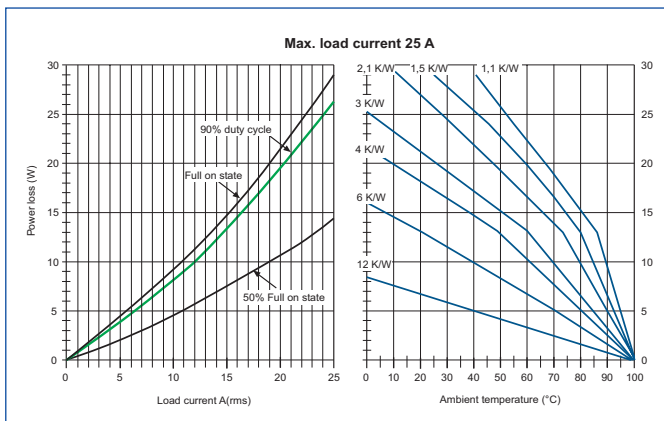

Construction D

- **Control voltage range: 3... 32 VDC**
- **Load voltage range: 12 ... 600 VAC**
- **Load current range: 5 mA ... 75 A**

Dimensions

Thermal diagrams

Heat sinks see on pages 32, 33 and 34

Max. load current 25 A

Max. load current 35 A

Max. load current 50 A

Max. load current 75 A

Standard panel mount package

Solid-state relay HD

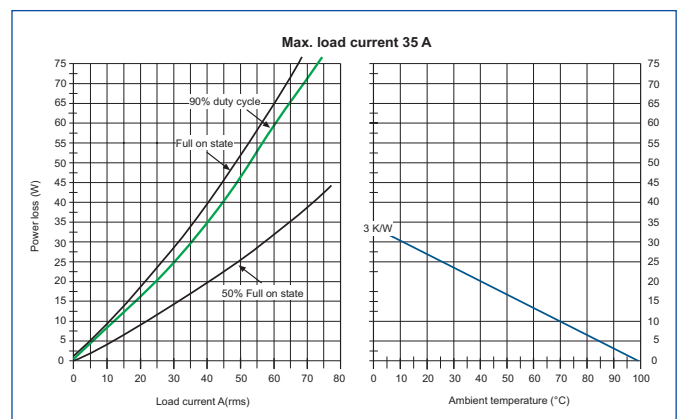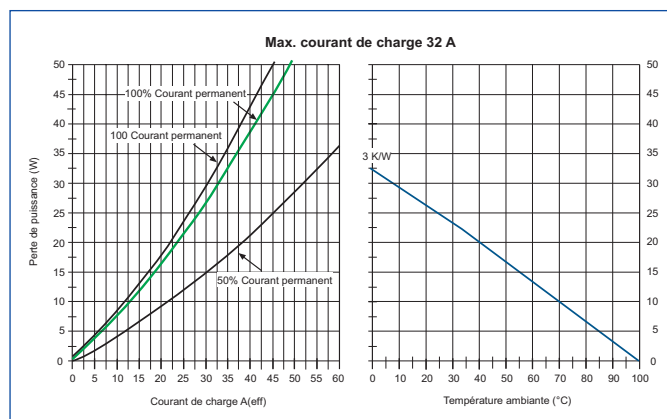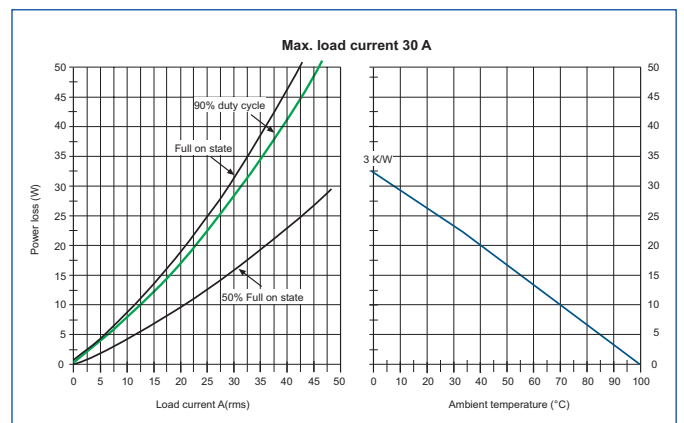| Technical specifications	HD D2825	HD D6035	HD D6050
Zero switching	Yes	Yes	Yes
Instantaneous switching-on	–	–	–
Control circuit	DC	DC	DC
Load circuit	AC	AC	AC
Load circuit			
Voltage range	12 ... 280 VAC	24 ... 600 VAC	24 ... 600 VAC
Operating frequency range	0,1 ... 800 Hz	0,1 ... 800 Hz	0,1 ... 800 Hz
Transient overvoltage	600 V	1200 V	1200 V
Load current range	5 mA ... 25 A	5 mA ... 35 A	5 mA ... 50 A
Max. surge current (10 ms)	250 A	420 A	580 A
Max. off-state leakage current (rated voltage)	1 mA	1 mA	1 mA
Min. off-state du/dt	500 V/µs	500 V/µs	500 V/µs
Max. on-state voltage drop	0,85 V	0,85 V	0,85 V
Max. turn-on time	10 ms	10 ms	10 ms
Max. turn-off time	10 ms	10 ms	10 ms
Max. I^2t for fusing (10 ms)	340 A^2s	882 A^2s	1680 A^2s
Thermal resistance to base	1,8 K/W	0,7 K/W	0,6 K/W
Control circuit			
Control voltage range	3 ... 32 VDC	3,5 ... 32 VDC	3,5 ... 32 VDC
Must release voltage	2 VDC	2 VDC	2 VDC
Max. reverse voltage	32 V	32 V	32 V
Typical input current at nominal voltage	14 mA	14 mA	14 mA
Generalities			
Insulation input/output/base	4000/4000 Vrms	4000/4000 Vrms	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	-40 ... +80 °C
Ambient storage temperature range	-40 ... +125 °C	-40 ... +125 °C	-40 ... +125 °C
Weight (typical)	75 g	75 g	75 g
Approvals	UL	UL	UL
Screw torque requirements:			
Load circuit M5	2 Nm	2 Nm	2 Nm
Control circuit	Depending on the plug terminal used		
Article number	42310250	42310251	42310252
(Order data see chapter 1)			

Standard panel mount package

Solid-state relay HD

Technical specifications	HD D6075
Zero switching	Yes
Instantaneous switching-on	–
Control circuit	DC
Load circuit	AC
Load circuit	
Voltage range	24 ... 600 VAC
Operating frequency range	0,1 ... 800 Hz
Transient overvoltage	1200 V
Load current range	5 mA ... 75 A
Max. surge current (10 ms)	1200 A
Max. off-state leakage current (rated voltage)	1 mA
Min. off-state du/dt	500 V/µs
Max. on-state voltage drop	0,85 V
Max. turn-on time	10 ms
Max. turn-off time	10 ms
Max. I^2t for fusing (10 ms)	7200 A^{2}s
Thermal resistance to base	0,4 K/W
Control circuit	
Control voltage range	3,5 ... 32 VDC
Must release voltage	2 VDC
Max. reverse voltage	32 V
Typical input current at nominal voltage	14 mA
Generalities	
Insulation input/output/base	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-40 ... +80 °C
Ambient storage temperature range	-40 ... +125 °C
Weight (typical)	75 g
Approvals	UL
Screw torque requirements:	
Load circuit M5	2 Nm
Control circuit	Depending on the plug terminal used
Article number	42310253
(Order data see chapter 1)	

DIN rail or panel mount with integrated heat sink
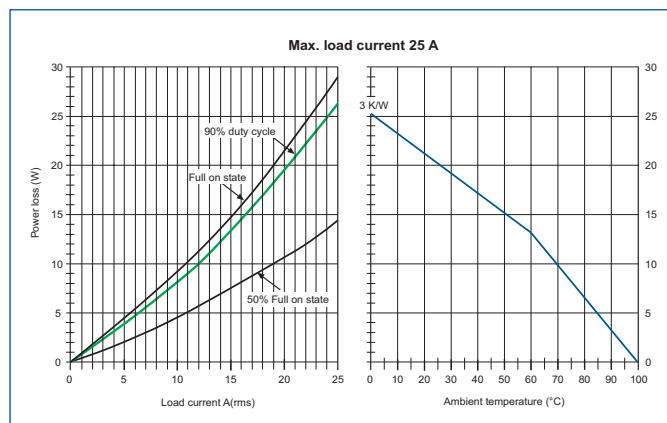
Solid-state relay HD

Construction C

- **Control voltage range: 3 ... 32 VDC**
- **Load voltage range: 12 ... 600 VAC**
- **Load current range: 5 mA ... 35 A**

Dimensions
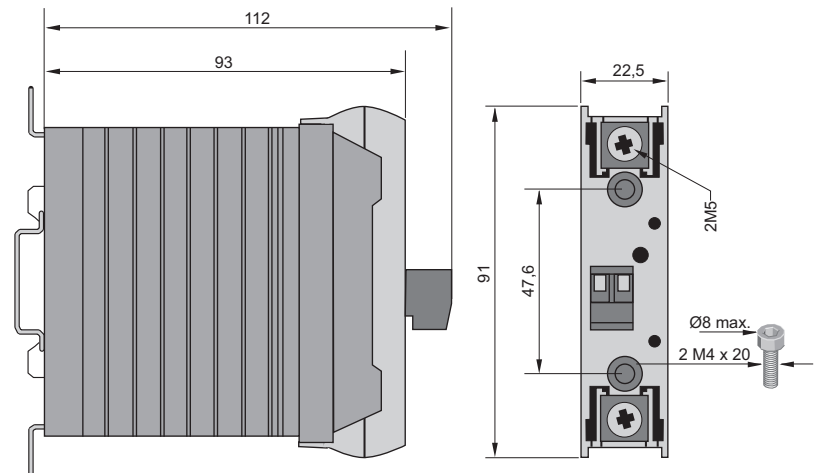
Thermal diagrams

Max. load current 25 A

Max. load current 30 A

Max. courant de charge 32 A

Max. load current 35 A

DIN rail or panel mount with integrated heat sink

Solid-state relay HD

Technical specifications	HD D2825K	HD D6035K	HD D6050K
Zero switching	Yes	Yes	Yes
Instantaneous switching-on	–	–	–
Control circuit	DC	DC	DC
Load circuit	AC	AC	AC
Load circuit			
Voltage range	12 ... 280 VAC	24 ... 600 VAC	24 ... 600 VAC
Operating frequency range	0,1 ... 800 Hz	0,1 ... 800 Hz	0,1 ... 800 Hz
Transient overvoltage	600 V	1200 V	1200 V
Load current range	5 mA ... 25 A	5 mA ... 30 A	5 mA ... 32 A
Thyristor value	5 mA ... 25 A	5 mA ... 35 A	5 mA ... 50 A
Max. surge current (10 ms)	250 A	420 A	580 A
Max. off-state leakage current (rated voltage)	1 mA	1 mA	1 mA
Min. off-state du/dt	500 V/µs	500 V/µs	500 V/µs
Max. on-state voltage drop	0,85 V	0,85 V	0,85 V
Max. turn-on time	10 ms	10 ms	10 ms
Max. turn-off time	10 ms	10 ms	10 ms
Max. I^2t for fusing (10 ms)	340 A^2s	882 A^2s	1680 A^2s
Thermal resistance to base	1,8 K/W	0,7 K/W	0,6 K/W
Control circuit			
Control voltage range	3 ... 32 VDC	3,5 ... 32 VDC	3,5 ... 32 VDC
Must release voltage	2 VDC	2 VDC	2 VDC
Max. reverse voltage	32 V	32 V	32 V
Typical input current at nominal voltage	14 mA	14 mA	14 mA
Generalities			
Insulation input/output/base	4000/4000 Vrms	4000/4000 Vrms	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-40 ... +80 °C	-40 ... +80 °C	-40 ... +80 °C
Ambient storage temperature range	-40 ... +125 °C	-40 ... +125 °C	-40 ... +125 °C
Weight (typical)	230 g	230 g	230 g
Approvals	UL	UL	UL
Screw torque requirements:			
Load circuit M5	2 Nm	2 Nm	2 Nm
Control circuit	Depending on the plug terminal used		
Article number	42310260	42310261	42310262
(Order data see chapter 1)			

Standard panel mount package

Solid-state relay HD

Technical specifications	HD D6075K
Zero switching	Yes
Instantaneous switching-on	–
Control circuit	DC
Load circuit	AC
Load circuit	
Voltage range	24 ... 600 VAC
Operating frequency range	0,1 ... 800 Hz
Transient overvoltage	1200 V
Load current range	5 mA ... 35 A
Thyristor value	5 mA ... 75 A
Max. surge current (10 ms)	1200 A
Max. off-state leakage current (rated voltage)	1 mA
Min. off-state du/dt	500 V/µs
Max. on-state voltage drop	0,85 V
Max. turn-on time	10 ms
Max. turn-off time	10 ms
Max. I^2t for fusing (10 ms)	7200 A^{2}s
Thermal resistance to base	0,4 K/W
Control circuit	
Control voltage range	3,5 ... 32 VDC
Must release voltage	2 VDC
Max. reverse voltage	32 V
Typical input current at nominal voltage	14 mA
Generalities	
Insulation input/output/base	4000/4000 Vrms
Insulation resistance	1000 MΩ (@ 500 VDC)
Ambient operating temperature range	-40 ... +80 °C
Ambient storage temperature range	-40 ... +125 °C
Weight (typical)	230 g
Approvals	UL
Screw torque requirements:	
Load circuit M5	2 Nm
Control circuit	Depending on the plug terminal used
Article number	42310263
(Order data see chapter 1)	

Standard panel mount package, 3-phases

Solid-state relay HL

Construction V

- **Control voltage range: 8,5 ... 30 VDC, 90 ... 240 VAC/DC**
- **Load voltage range: 24 ... 520 VAC**
- **Load current range: 3 x 50 A**

Dimensions
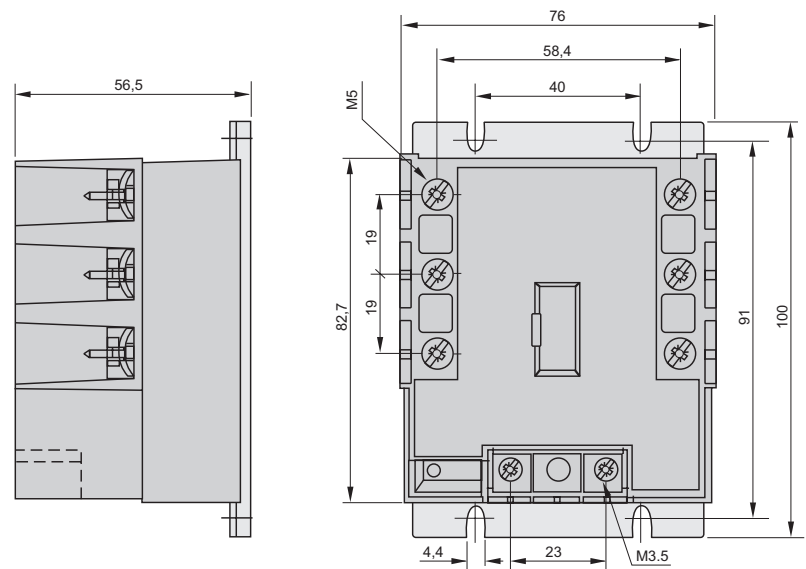
Thermial diagrams
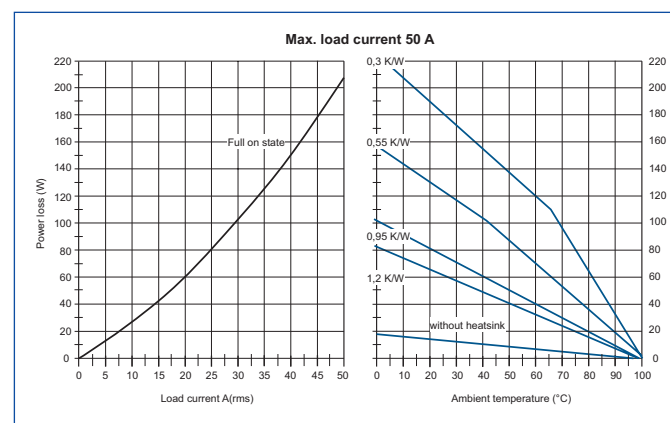
Heat sinks see on pages 32, 33 and 34

Standard panel mount package, 3-phases

Solid-state relay HL

Technical specifications	HL D5250	HL A5250	
Zero switching	Yes	Yes	
Instantaneous switching-on	–	–	
Control circuit	DC	AC	
Load circuit	AC	AC	
Load circuit			
Voltage range	24 ... 520 VAC	24 ... 520 VAC	
Operating frequency range	10 ... 440 Hz	10 ... 440 Hz	
Transient overvoltage	1200 V	1200 V	
Load current range	3x 5 mA ... 50 A	3x 5 mA ... 50 A	
Max. surge current (10 ms)	550 A	550 A	
Max. off-state leakage current (rated voltage)	5 mA	5 mA	
Min. off-state du/dt	500 V/µs	500 V/µs	
Max. on-state voltage drop	1,4 V	1,4 V	
Max. turn-on time	10 ms	10 ms	
Max. turn-off time	10 ms	10 ms	
Max. I^2t for fusing (10 ms)	1500 A^{2}s	1500 A^{2}s	
Thermal resistance to base	0,7 K/W	0,7 K/W	
Control circuit			
Control voltage range	8,5 ... 30 VDC	90 ... 240 VAC/DC	
Must release voltage	4 V	4 V	
Max. reverse voltage	30 V	–	
Typical input current at nominal voltage	35 mA	11 mA	
Generalities			
Insulation input/output/base	4000/3300 Vrms	4000/3300 Vrms	
Insulation resistance	620 Ω	21 KΩ	
Ambient operating temperature range	-40 ... +100 °C	-40 ... +100 °C	
Ambient storage temperature range	-40 ... +100 °C	-40 ... +100 °C	
Weight (typical)	410 g	410 g	
Approvals	UL	UL	
Screw torque requirements:			
M3,5screws (Control circuit)	1,2 Nm	1,2 Nm	
M5 screws (Load circuit)	1,8 Nm	1,8 Nm	
Article number	42310143	42310142	
(Order data see chapter 1)			
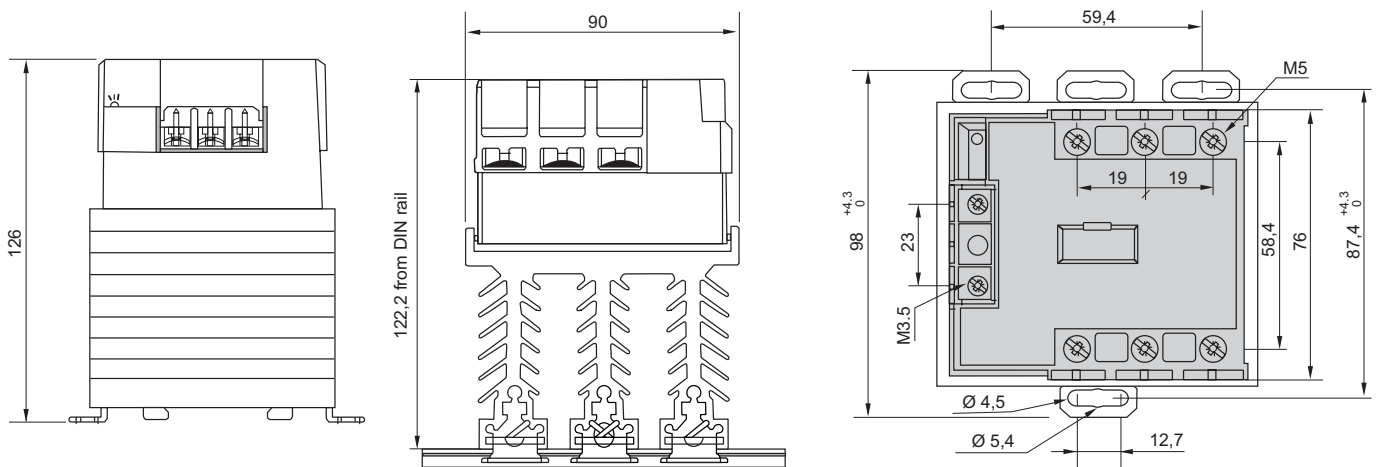
3-phases with integrated heat sink

Solid-state relay HL

Construction V

- **Control voltage range: 10 ... 30 VDC**
- **Load voltage range: 24 ... 520 VAC**
- **Load current range: 3 x 22 A**

Dimensions

Thermial diagrams

curve 1:
with ventilation in the heatsink (> 1m/s)

curve 2:
working in normal conditions with a small ventilation in the cabinet

curve 3:
according with IEC60947-4-2
in a closed cabinet without any ventilation

3-phases with with integrated heat sink

Solid-state relay HL

Technical specifications	HL D5222K
Zero switching	Yes
Instantaneous switching-on	–
Control circuit	DC
Load circuit	AC
Load circuit	
Voltage range	24 ... 520 VAC
Operating frequency range	10 ... 440 Hz
Transient overvoltage	1200 V (integrated surge voltage protection 850 V)
Load current range	3x 5 mA ... 22 A
Max. surge current (10 ms)	550 A
Max. off-state leakage current (rated voltage)	1 mA
Min. off-state du/dt	500 V/µs
Max. on-state voltage drop	1,4 V
Max. turn-on time	10 ms
Max. turn-off time	10 ms
Max. I^2t for fusing (10 ms)	1500 A^2s
Thermal resistance to base	–
Control circuit	
Control voltage range	10 ... 30 VDC
Must release voltage	4 VDC
Max. reverse voltage	30 V
Typical input current at nominal voltage	32 mA
Generalities	
Insulation input/output/base	4000/3300 Vrms
Insulation resistance	560 Ω
Ambient operating temperature range	-40 ... +80 °C
Ambient storage temperature range	-40 ... +108 °C
Weight (typical)	1000 g
Approvals	UL
Screw torque requirements:	
M3.5screws (Control circuit)	1,2 Nm
M4 screws (Load circuit)	1,8 Nm
Article number	42310144
(Order data see chapter 1)	

Standard panel mount package, 3-phases reversing contactor

Solid-state relay HL

Bauform L

- **Control voltage range: 12 ... 30 VDC**
- **Load voltage range: 24 ... 520 VAC**
- **Load current range: 3 x 8,5 A**
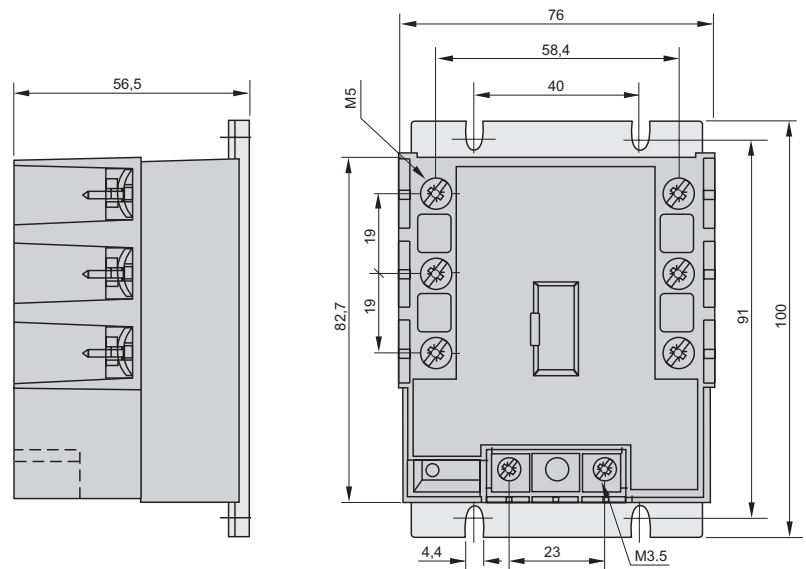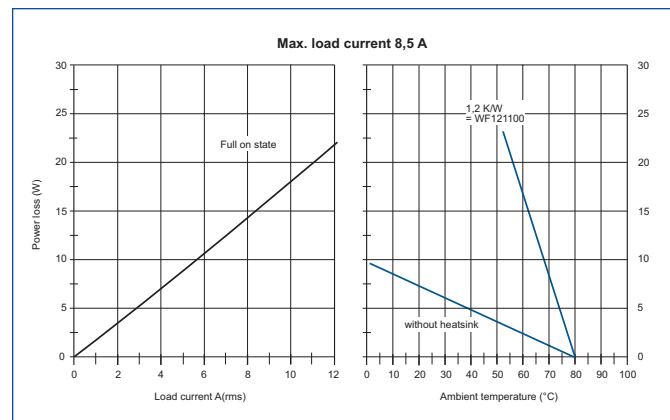
Dimensions

## Thermal diagrams

Heat sinks see on pages 32, 33 and 34

Standard panel mount package, 3-phases reversing contactor

Solid-state relay HL

Technical specifications	HL D5208R
Zero switching	Yes
Instantaneous switching-on	–
Control circuit	DC
Load circuit	AC
Load circuit	
Voltage range	24 ... 520 V
Operating frequency range	25 ... 440 Hz
Transient overvoltage	1600 V
Load current range	100 mA ... 8,5 A
Max. surge current (10 ms)	550 A
Max. off-state leakage current (rated voltage)	5 mA
Min. off-state du/dt	500 V/µs
Max. on-state voltage drop	1,4 V
Max. turn-on time	20 ms/100 ms
Max. turn-off time	10 ms
Max. I^2t for fusing (10 ms)	1500 A^2s
Thermal resistance to base	0,5 K/W
Integrated overvoltage protection	Yes
Control circuit	
Control voltage range	12 ... 30 VDC
Must release voltage	6 V
Max. reverse voltage	30 V
Typical input current at nominal voltage	15 ... 25 mA
Generalities	
Insulation input/output/base	3300/30000 Vrms
Ambient operating temperature range	-40 ... +100 °C
Ambient storage temperature range	-40 ... +100 °C
Weight (typical)	410 g
Approvals	UL
Screw torque requirements:	
M3 screws (Control circuit)	1,2 Nm
M5 screws (Load circuit)	1,8 Nm
Article number	42310141
(Order data see chapter 1)	
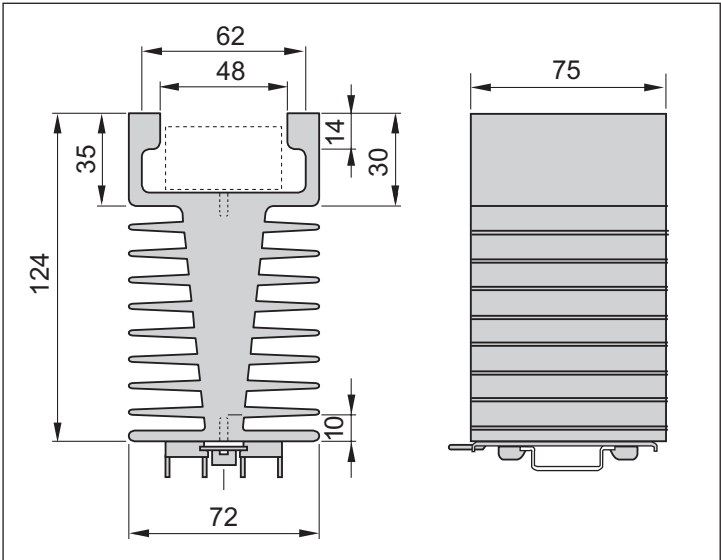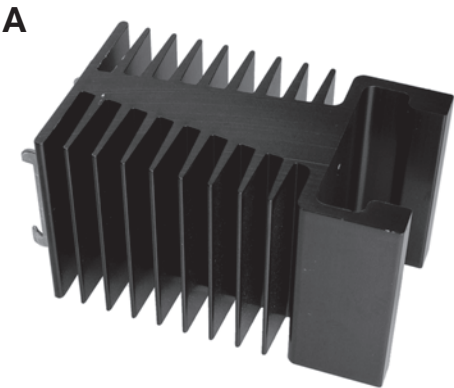
Accessories

Heat sink for 1- and 3-phases solid-state relays

A

It is essential to use heat conduction foil or heat conductive paste between the solid-state relay and the heat sink.

Heat conduction foil is already applied on or supplied with all Selectron semiconductor relays!
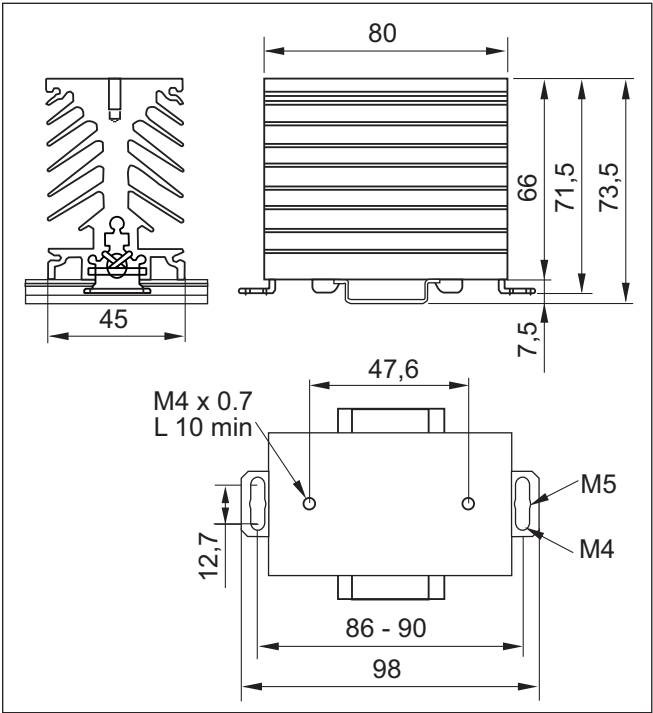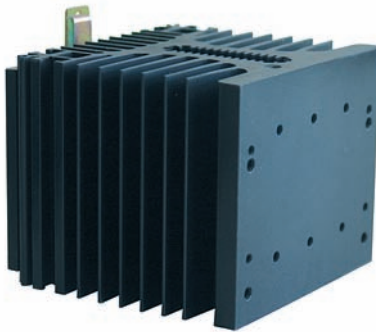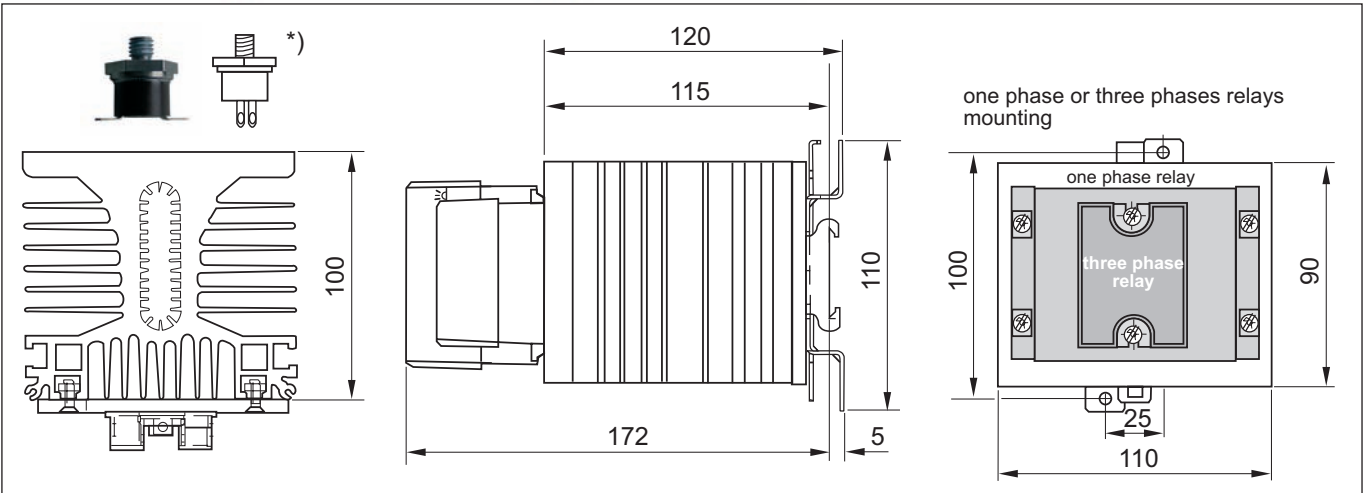
B
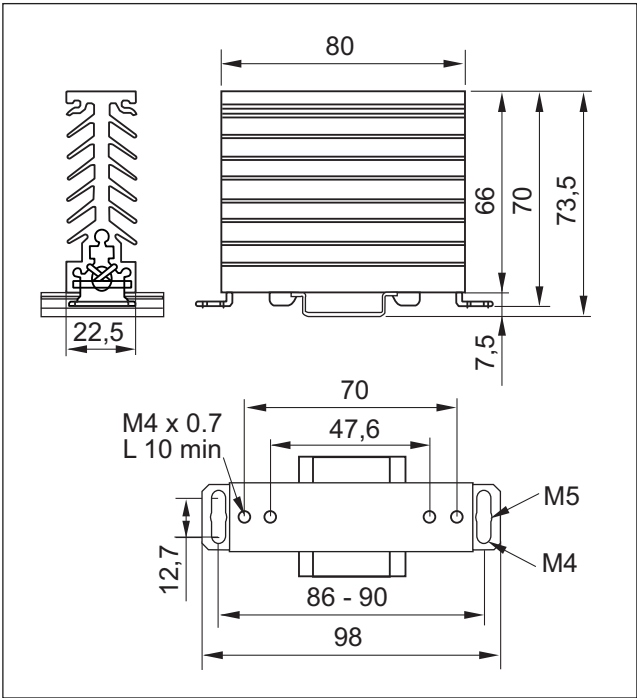
Description	Type	Dimension	Weight	Article number
Heat sink 0,7 °C/W	HRK 0,7 C	A	915 g	41920003
Heat sink 3,0 °C/W	HK 3,0C	B	150 g	42310300
(Order data see chapter 1)				

Accessories

Heat sink for 1- and 3-phases solid-state relays

C

80

66
71,5
73,5

45

7,5

47,6

M4 x 0.7
L 10 min

M5

M4

12,7

86 - 90

98

D

It is essential to use heat conduction foil or heat conductive paste between the solid-state relay and the heat sink.

Heat conduction foil is already applied on or supplied with all Selectron semiconductor relays!

*)

120

115

100

110

100

172

5

one phase or three phases relays mounting

one phase relay

three phase relay

90

25

110

Description	Type	Dimension	Weight	Article number
Heat sink 2,2 °C/W	HK 2,2C	C	300 g	42310304
Heat sink 0,9 °C/W	HK 0,9C	D	1'400 g	42310302
*) Thermostat	TS 90 M6 for heat sink HK 0,9		10 g	42310320
(Order data see chapter 1)				

Accessories

Heat sink for 3-phases solid-state relays

A

B
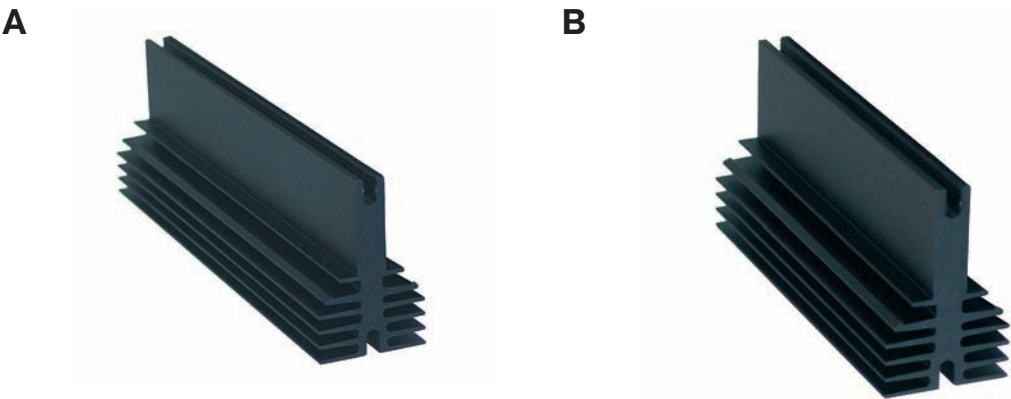
Dimension A:	height x width x length	45 x 30 x 100 mm
Dimension B:	height x width x length	45 x 30 x 150 mm

Mounting examples

Thermal heatsinks with clip mounting system

Heatsinks references:
HKT 3.0: L = 100 mm about 4 K/W (1 relay) without ventilation (3,6 K/W with 4 relays)
HKT 4.0: L = 150 mm about 3 K/W (1 relay) without ventilation (2,5 K/W with 6 relays)
other heatsinks on request

C

Clip reference : CKT K1

Complementary heatsink if necessary

Thermal grease

7,9 mm ± 0,15

51

4 mm to respect insulation

D
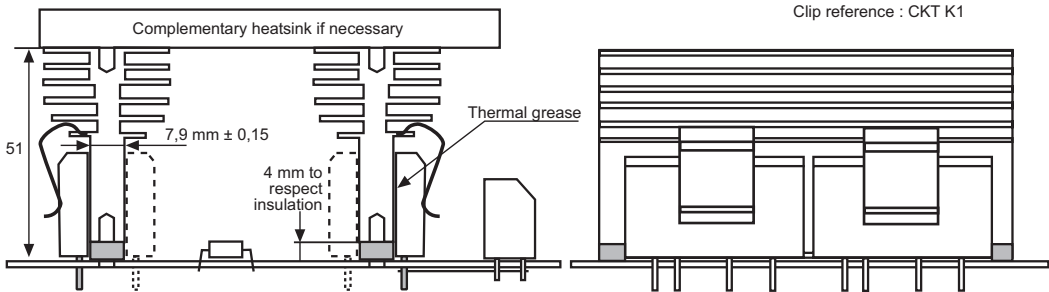
Clips with screws on standard heatsinks

4 mm to respect insulation

M3

26,5 mm

Clip reference: CKT S1

Thermal grease

Printed circuit board
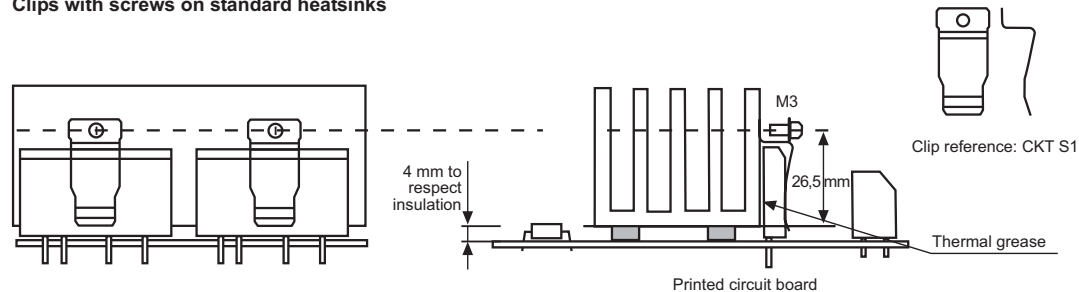
In each case, 4 mm must be respected between the printed circuit board and the heatsink, to keep a correct insulation between input and output (4 mm insulated washer).
Mind to good contact between the relay and the heatsink. Use thermal grease.

Description	Type	Dimension	Weight	Article number
Heat sink 3,0 °C/W	HKT 3,0	B	190 g	42310306
Heat sink 4,0 °C/W	HKT 4,0	A	130 g	42310307
Mounting clip	CKT K1		10 g	42310310
Mounting clip	CKT S1		10 g	42310311
(Order data see chapter 1)				

Accessories

Ventilator for 1- and 3-phases solid-state relays
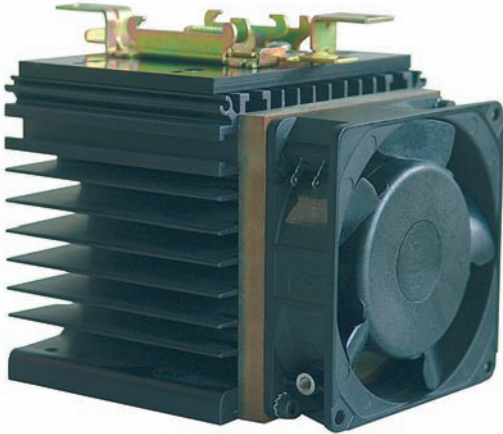
Heat sink with fan for all screw-on relays	
Type	HK 0,3 LB 230
Operating voltage	230 Vac
Power consumption	9 W
Heat dissipation with HRK 0,5	0,3 °C/W
Weight without heat sink	1'770 g
Fasteningscrews for 3-phases relays are included in delivery	
Article number	42310305
(Order data see chapter 1)	

one phase or three phases relays mounting

Thermostat open if θ>85° C

one phase relay

1 or 2 three phase relay

Fan supply 200/240 Vac - 50Hz/60Hz

120
115
100
110
5
172
110
90
126
145
93
100
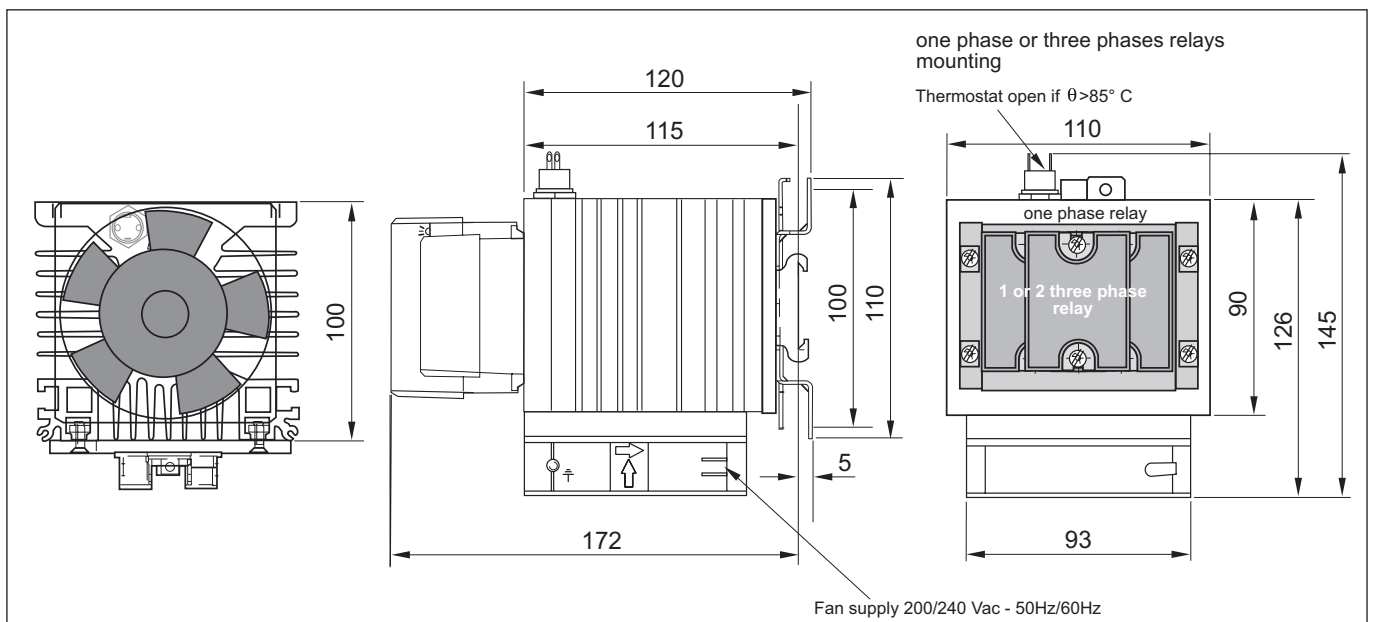
Accessories

DIN-mounting
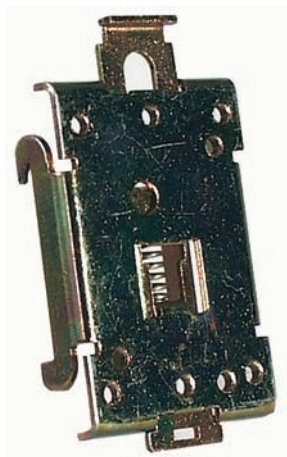
DIN-mounting DB 2	Weight	Article no.
for construction HRS	60 g	41920013
(Order data see chapter 1)		
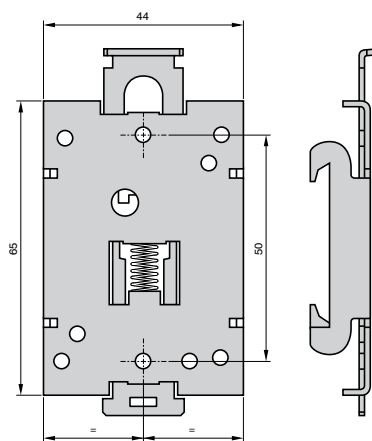
Application notes

Contact free switching in all domains

Solid state relays from Selectron Systems AG are particularly suitable for ranges where high currents have to be switched fast, such as e.g. in regard of the temperature control on heatings or where there are strong vibrations (no moving mechanical parts), or when there are heavy environmental conditions such as high humidity, extreme temperatures etc.

- Ac load voltage range up to 660Vac
- Ac load current range up to 125A
- Dc load voltage range up to 110Vdc
- Dc load current range up to 40A
- Zero cross turn-on
- Random turn-on
- Maintenance-free
- High switching frequency
- Operating temperature -55°C bis +100°C
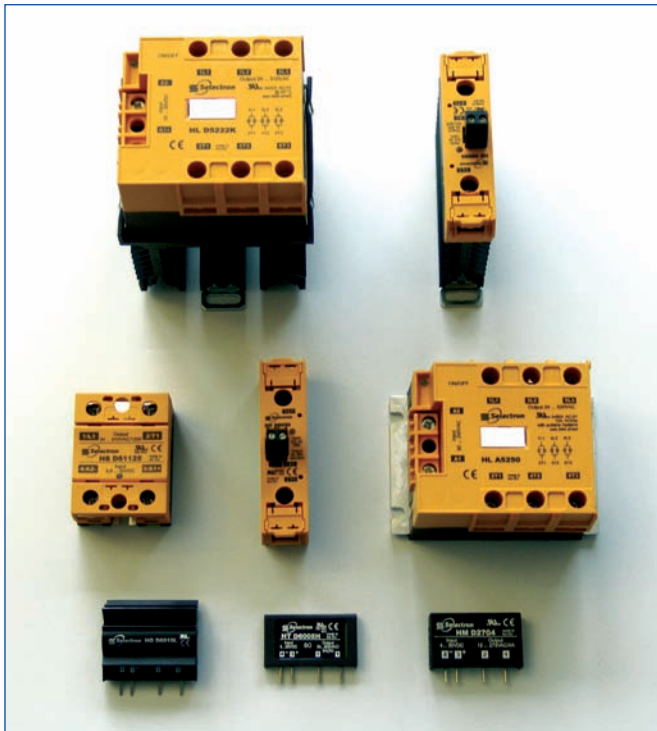
The Surface Mount Technology SMT

All relays from Selectron Systems AG are based on SMT technology. Due to an up to date equipping technique the error rates could be decisively decreased. All result in unsurpassed reliability.

SSRs exceed 2.000.000 operating hours

The reliability levels achieved through this and other refinements of manufacturing are reflected in quality assurance calculations for "observed" mean time between failures (MTBF).

The calculation is done by estimating the number of device operating hours for a particular relay family and dividing this figure by the number of non-misapplication related field failures. A conservative assumption is used in which we assume 10% of non-misapplication related field failures are actually returned to us.

Calculated mean time between failures is, depending upon the family or type involved, between 2.000.000 and 40.000.000 operating hours.

The Test Advantage

All Selectron Systems AG SSRs are subjected to the following comprehensive series of tests (with conservative guard bands) on 100% of all products both before and after encapsulation. The quality assurance test steps are as follows:

- Verify true Kelvin sense connections fpr Vf measurement
- Forward voltage drop
- Blocking voltage
- Turn-on voltage (ac or dc depending on model)
- Turn-off voltage (ac or dc depending on model)
- Proper operation with resistive load
- Proper operation at 0.5 power factor, inductive load
- Leakage current at rated voltage
- Isolation voltage input-output and output-base

Technical safety advice

This manual contains the information necessary for the correct utilisation of the products described therein. It is intended for technically qualified persons who are involved as either

- planning engineers familiar with the safety concepts of automation technology;
- or, operating personnel, who have been instructed in handling automation equipment and have a knowledge of the contents of this manual concerning operation;
- or, installation and servicing personnel possessing the necessary training to repair such an automation system or who have the authority to put such circuits and equipment/systems into operation, to earth or label them according to the relevant safety standards.

The products are constructed, manufactured and tested in compliance with the relevant VDE standards, VDE specifications and IEC recommendations.

Danger warning

These warnings serve both as a guide for those persons involved in a project and as safety advice to prevent damage to the products themselves or to associated equipment.

Due to advancements in technology, the wiring diagram on the actual device may be different than shown in this catalogue. In all instances where the actual device diagram is different, the wiring diagram on the device must be used when electrical connections are made.

Correct utilisation, configuration and assembly

The equipment is to be used only for the applications stated in the catalogue and technical literature, and only in conjunction with auxiliary equipment and devices that are recommended or approved by Selectron Systems Ltd.

Further, it should be noted that:

- the automation equipment must be disconnected from any power supply before it is assembled, disassembled or the configuration modified.
- Solid state electronic switches must not be tested with incandescent lamps or connected to a load that exceeds its rating.
- trouble-free and safe operation of the

products requires correct transportation as well as appropriate storage, assembly and wiring.

- the systems may only be installed by trained personnel. In doing so, the relevant requirements contained in VDE 0100, VDE 0113, IEC 364, etc. must be complied with.

Prevention of material damage or personal injury

Additional external safety devices or facilities must be provided wherever significant material damage or even personal injury could result from a fault occurring in an automation system. A defined operating status must be ensured or forced by such devices or facilities (e.g. by independent limit switches, mechanical interlocks, etc.).

Advice concerning planning and installation of the products

- The safety and accident prevention measures applicable to a specific application are to be observed.
- In the case of mains-operated equipment, a check is to be made before putting it into operation to ensure that the preset mains voltage range is suitable for the local supply.
- In the case of a 24 V supply, care must be taken to ensure sufficient electrical insulation of the secondary side. Use only mains power supply units that conform to IEC 364-4-41 or HD 384.04.41 (VDE 0100 Part 410).
- Automation systems and their operating elements are to be installed in such a way that they are sufficiently protected against accidental operation.

Warranty

Selectron Systems Ltd. warrants its products to be free from defects in material and workmanship for a period of one year from the date of shipment. All claims under this warranty must be made within thirty (30) days of the discovery of the defect, and all defective products must be returned at the buyer's expense. Buyer's sole and exclusive right will be limited to, at the option of Selectron Systems Ltd., the repair or replacement by Selectron Systems Ltd., of any defective products for witch a claim is made.

In all other matters please refer to the "General terms of business" concerning Selectron Systems Ltd.

Note

The information given in this documentation corresponds to the state of development at the time of going to press and is therefore not binding. Selectron Systems Ltd. reserves the right to make alterations in the interests of technical advancement or product improvement at any time without giving reasons for doing so.

Application notes (SSR)

General

Definition

A SSR (solid state relay) is able to perform many tasks that an EMR (electromechanical relay) can perform. The SSR differs in that it has no moving mechanical parts within it. It is essentially an electronic device that relies on the electrical, magnetic and optical properties of semiconductors, and electrical components to achieve its Isolation and relay switching function.

Over the last ten years many standards have been set regarding SSR packages, most notably the rectangular package which has now become an industry standard for power switching using SSRs, with models ranging from 1 to 125 A.

Applications

Since its introduction the SSR, as a technology, has gained acceotance in many areas, which had previously been the sole domain of the EMR or the Contactor. The major growth areas have come from Industrial Process Control applications, particularly heat/cool temperature control, motors, lamps, solenoids, valves, transformers.

The following are typical examples of SSR applications: manufacturing equipment, food equipment, security systems, industrial lighting, fire and security systems, dispensing machines, production equipment, on-board power control, traffic control, instrumentation systems, vending machines, test systems, office machines, medical equipment, display lighting, elevator control, metrology equipment, entertainment lighting.

The Advantages of the Solid State Relay

When utilised in the correct manner for the intended application, the SSR provides many of the characteristics that are often elusive in the EMR; a high degree of reliability, long service life, significantly reduced electro-magnetic interference, fast response and high vibration resistance are significant benefits from SSRs.

In today's environment we have all come demande, rather than to expect, improved performance from the components that we use. The SSR offers Designers, Engineers and Maintenance Engineers significant advantages over alternative technologioes, further enhanced by the use of Surface Mount Solid State circuitry.

These advantages are namely consistency of operation and longer usable liftime. The SSR has no moving parts to wear out or arcing contacts to deteriorate, which are often the primary cause of failure within an EMR. The long term reliability of components used within SSRs has become well established throughout industry, and with no moving parts to become fractured, detached, or to resonate during operation, makes the SSR solution

more robust when used in unfriendly environments.

- Zero voltage turn-on, low EMI/RFI
- Random turn-on, proportional control
- Long life (reliability) > 10^9 operations
- No contacts - handles high inrush current loads
- No acoustical noise
- High switching frequency
- Microprocessor compatible
- Design flexibility
- Fast response
- No moving parts
- No contact bounce

In terms of internal design, the SSR and the EMR are fundamentally similar in that each has an input electrically isolated from the output that control a load. Fig. 1 shows the basic configurations of both the SSR and EMR. In the case of the SSR, the isolation is achieved by photocoupling and transformer coupling, and in the
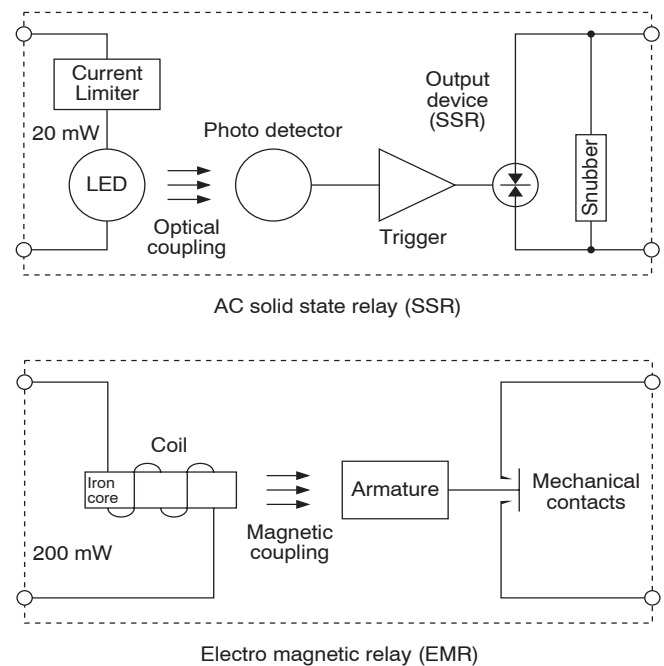

AC solid state relay (SSR)

Electro magnetic relay (EMR)

Fig. 1 Solid state relay and electromagnetic configurations

EMR by means of a magnetic coupling.

Comparing the two technologies, the input control of the SSR is functionally equivalent to the EMR, while the output device of the SSR performs the switching function of the EMR contacts.

The operating speed of the EMR is dependent upon the time it takes for its mechanical mass to react to the application and removal of a magnetic field. Operating speed of the SSR is primarily determined by the switching speed of the output device, typically much faster - microseconds for DC SSRs compared to milliseconds for EMRs. In most ac SSRs, response time is related to

phase angle and frequency of the line, and in the case of the zero voltage/current types, may be deliberately prolonged. In the case of ac input control, the operating speeds of both the EMR and SSR are similarly extended due to phase angle and filtering considerations.

SSR Operation

For a better understanding of SSRs, an SSR Operational description is included. It has to be said that an in-depth understanding of the internal circuitry of an SSR and how it functions are not in themselves a prerequisite to the use of SSR in many applications.

Most SSRs in the higher current ranges are offered with either ac or dc control options. Indeed many have some form of current limiting at their input in order to provide a practical operating voltage range.

dc inputs

Figs. 2A und 2B illustrate two typical dc input circuits for controlling current through the photocoupler LED. The low end of the input range is tailored to provide the minimum input current required to operate the SSR, at the specified turn-on (must on) voltage (typically 3 volts dc). The high end of the range by dissipation in the current limiting component (typically 32 Vdc).
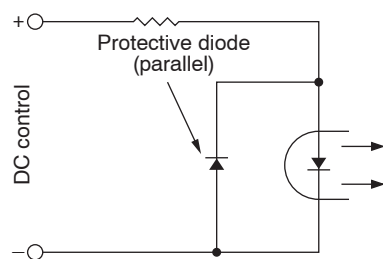
Fig. 2A Dropping resistor
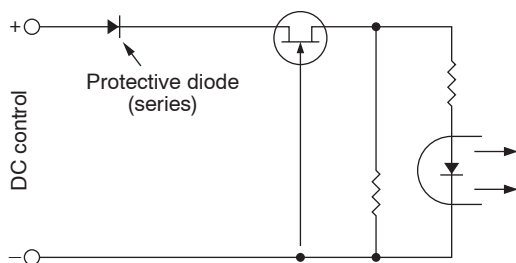
Fig. 2B Constant-current resistor

As a precaution against inadvertent voltage reversal, a series or inverse parallel diode is usually included in the input circuit. With an inverse parallel diode resistor, so brief voltage transients of a higher magnitude will not damage the diode or LED. However, the series diode is favoured because it also raises the level of voltage noise immunity by a value equal to its forward voltage drop.

ac inputs

ac inputs models are usually suitable for both 120 und 240 Vac line voltages, with a typical operating range of 90 to 280 Vac and 60 kΩ input impedance. Full wave rectification is used, followed by capacitive filtering and dropping resistors, as shown in Figs. 3A und 3B. While both circuits work equally well, the circuit in Fig. 3B is favoured as being more reliable and fail safe, since two or more components would have to fail to create an unsafe situation.

In the circuit of Fig. 3A, a single diode breakdown would place a dead short across the incoming line, thus creating a possible heat hazard.
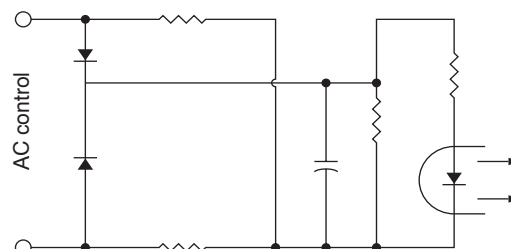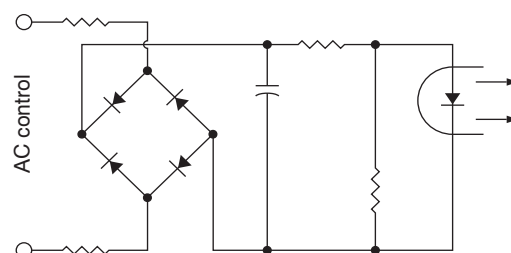

Fig. 3A: Two-diode input

Fig. 3B: Bridge input

Either of the ac input circuits in Fig. 3 is also capable of operating from a dc source and, therefore, might be considered as ac-dc; however, SSR inputs are rarely characterised in that way. The circuit of Fig. 3B should operate with a dc control range similar to that of the ac (RMS) source. On the other hand, the circuit of Fig. 10A might have dissipation problems with the input resistors, since they would no longer operate at a 50% duty cycle. In both cases, the SSR would have the uniqueness of operating from a dc signal of either polarity.

Well designed ac input-output SSRs can operate from separate power sources operating at different frequencies, as long as they are both within the specified limits of voltage, frequency and isolation. Line frequency for both input and outputs is typically specified as 47 to 63 hertz, the upper limit of which is not critical for the input control power since the input is rectified and filtered. However, the upper frquency limit for an output is less flexible, especially for a triac, which has definite limitations, related to its ability to commutate off. An SCR

output pair is capable of operating at much higher frequencies. Wowever, because of circuit time constraints in the drive circuitry, other SSR parameters become the limiting factors (e.g. the zero switching window may be extended and/or turn-delayed each half cycle with eventual lock.on or lockout).

Zero switching

Zero voltage turn-on (or zero crossing), as illustrated in Fig 4, is used in some ac SSRs to reduce electromagnetic interference and high inrush currents. Without zero crossing, the load voltage is applied randomly to the load at any point in the line voltage cycle.

With the zero crossing feature, the line voltage is switched to the load only when it is close to zero, typically specified with a maximum value of ±15V volts peak. Thus, a very small change in power results, and proportionally lower EMI levels are generated. After zero crossing, the "Zero" switching voltage, which defines the switching window limits, may also be expressed in terms of phase angle, or time, converted as follows:

Voltage to phase angle (15 volts) or phase angle to time (5°):

Zero voltage turn-off is an inherent characteristic of the thyristors used in ac SSRs, whether zero votlae is emplyoed or not. Once triggered, the thyristor stays on for the balance of the half cycle, until switching load current drops below ist "holding" level, where it turns off. For a resistive load, this point is also close to zero voltage, as shown in Fig. 5. With an inductive load, the amount of stored energy

in the load is a function of the current flowing through it, which in this case is so small that inductive kickback is virtually eliminated. This is probably the most desirable feature of the SSR, when compared to the destructive effects of "arcing" contacts when switching inductive loads with an EMR.
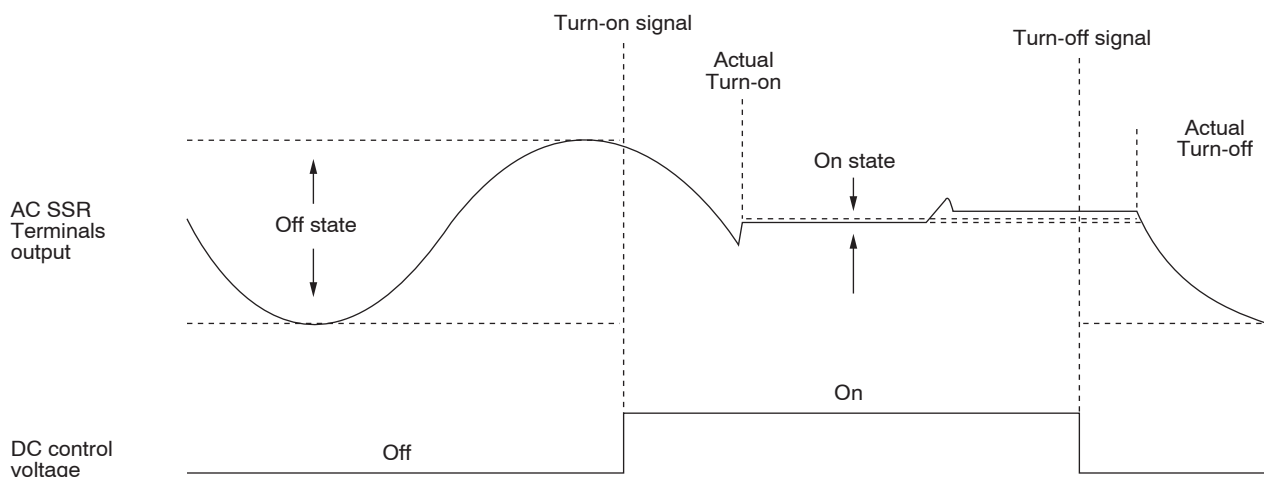
$$\phi = \sin^{-1} \frac{Z \text{ sw. max.}}{\text{Line V RMS } (\sqrt{2})} \qquad T = \frac{\frac{1}{2} \text{ cyc. ms}}{\frac{1}{2} \text{ cyc. deg}} \times \phi$$

$$\phi = \sin^{-1} \frac{15}{120 \times 1{,}41} \qquad T = \frac{8{,}3}{180} \times 5$$

$$\underline{\underline{\phi = 5°}} \qquad \underline{\underline{T = 0{,}23 \text{ ms}}}$$

Fig. 4: Zero voltage turn-on

Solid State Relay characteristics

Systems offers an extensive range of Solid State Relays in various package styles, mounting options, terminal types and switching capability.

Selecting the ideal SSR

In a bid to specify the exact SSR for an application, it is important to consider the:

- input drive requirement
- output current
- load or output current
- the isolation and installation requirements

In many instances the load power will dictate whether the SSR is PCB, panel, or DIN rail mounted. In loads higher than 5 to 7 amps, a heat sink becomes necessary to remove heat from the SSR body. Certain SIG Positec Systems designs include integral heath sinks, while others have dissipation characteristics that are inherently within the products.

Driving the SSR

To activate an SSR output, a voltage greater than that specified for maximum turn-on is applied to the input (3 volt dc typical). The off state occurs when zero or less than the minimum turn-off voltage is applied (1 volt dc typical). For an AC input type, the typical values would be 90 volts RMS for on, and 10 volts RMS for off. For an SSR designated as normally closed or form B, the previous on-off conditions would be reversed. Generally, normally open is the accepted, but undesignated, standard for the SSR.

dc is considered as being a steady-state dc voltage of one polarity, and ac is a reasonably well shaped sinusoidal waveform.

Due to consideration of input to output isolation, the switch controlling the input to an SSR can be placed in series with either of the two input terminals, assuming polarity is observed (dc). The same flexibility applies to the output side, where the load may also be placed in series with either output terminal. There are a few specialised types, usually with more than two input or ouptut terminals, that have dedicated functions (i.e. Vcc logic input and common).

The activating signal may be derived from mechanical contacts or solid state devices such as those shown in figure 6 The minimum supply voltage through these contacts may be equal to the SSR turn-on voltage (3 volts dc typical), whereas the positively or negatively referenced transistors require a minimum supply voltage a few tenths of a volt above the specified turn-on threshold, say 3.5 volts

dc. This is because of their approximate 0.2-0.4 volt on state voltage drop when driven in the grounded emitter (saturating) mode.
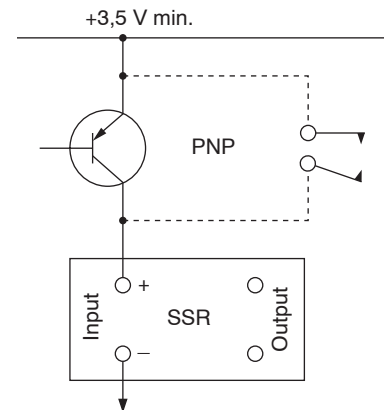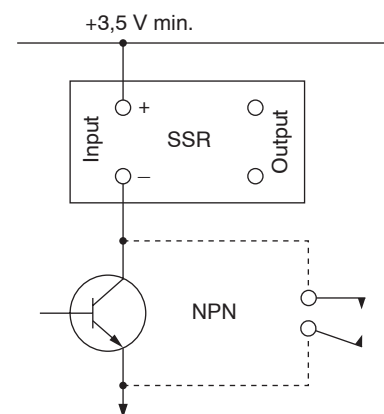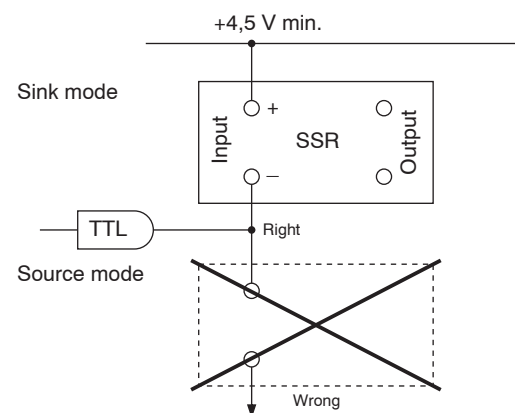

Fig. 5A: PNP transistor

Fig. 5B: NPN transistor

Fig. 5C: TTL gate

TTL drive methods

A standard TTL gate can drive most SSRs with ist 16 mA sink capability. However, very few SSRs can be driven reliably with the gates' available source current of only 400 μA. Also, the SSR minimum voltage threshold requirements are not met in the source mode (i.e. gate output in the positive leg of the SSR).

The relationship of the TTL gate to an SSR is illustrated schematically in Fig. 6. In this configuration the SSR supply voltage and the gate Vcc should be common and comply with the TTL specified limits of say 5 volts +/- 10%. It can be seen that with a positively referenced SSR and the gate at logical (0), Q2 is operating much like a discrete NPN transistor in the grounded-emitter saturated state. In this mode the gate can sink up to 16 mA with

volts, which is 0.6 volt below the SSR turn-on threshold (assuming a 3 volt turn-on). Although some SSRs may operate satisfactorily in this mode, it is not recommended that this be done. Both the available current and the minimum voltage are considered inadequate for the typical optically isolated SSR.

It should be noted that the 2,4 volt gate output in the logical 1 state relates only to a negatively referenced load. It does not represent a voltage source to a positively referenced load (SSR), where it would appear to be greater than the off state voltage. Referring again to Fig. 6, Q2 would be off and CR 1 is reverse biased, thus presenting essentially an open circuit with virtually zero potential across the SSR.
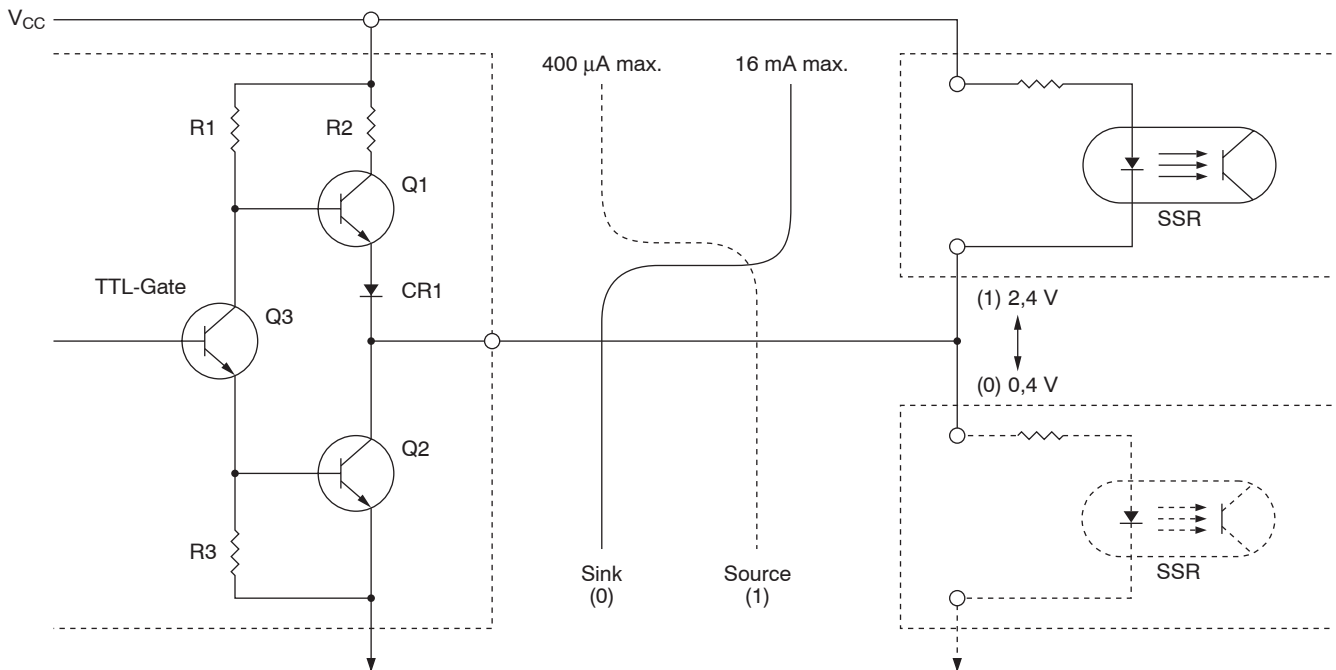

Fig. 6: Typical circuit of a TTL gate driving SSR

a maximum 0.4 volt drop. Subtracting 0.4 volt from the worst case Vcc of 4.5 volts, a minimum of 4.1 volts will appear across the SSR input terminals, which is sufficient to turn on most SSRs. For different supply voltage tolerances, the values would be adjusted accordingly.

With a negatively referenced SSR and the gate at logical (1), Q1 conducts, but does not saturate, since it is operating as an emitter follower (common collector). In this mode the gate can source up to 400 microamps; however, the accumulated voltage drops are

$$ R_{1 (IR \, Drop)} + Q_{1 VBE} + CR_{1 VF} $$

The sum of these values subtracted from the worst case Vcc results in a minimum output voltage specified as 2.4

IC and other drive sources

Most CMOS and NMOS logic families will not directly interface with SSRs, except for a few specially designed types. However, a CMOS buffered gate can reliably drive an SSR that has low input power requirements (i.e. >1500 ohms at 5 volts) and is also driven in the sink mode the same as TTL.

Fig. 7 shows 1/6 of 4049 (inverting) or a 4050 (non-inverting) CMOS hex buffer driving such an SSR with a common 5 volt supply. CMOS can, of course, operate at higher voltages, but care must be taken not to overstress the gate with excessive dissipation.

Integrated circuits with open collector outputs are also commonly used to drive SSRs, as in Fig. 8. The open collector IC has an output transistor without an active

(transistor) or passive (resistor) pull-up and generally has enough power to drive an SSR directly. Open collector outputs can also be logically ORed like discretes, so that the SSR may be controlled by any one of the many outputs. Furthermore, the SSR supply voltage does not have to be the same as the IC Vcc, provided that one side is common and the transistor and SSR maximum voltages and currents are not exceeded.

SSRs do not generally require pull-up or shunt resistors for noise reduction or any other functional reason. An open input, if not assigned to a particular logic level, produces an open or off state in the output (unless otherwise designated). Input lines would have to be extremely long and through noisy environments before noise of any significance would appear at the input terminals to cause the SSR to change state.
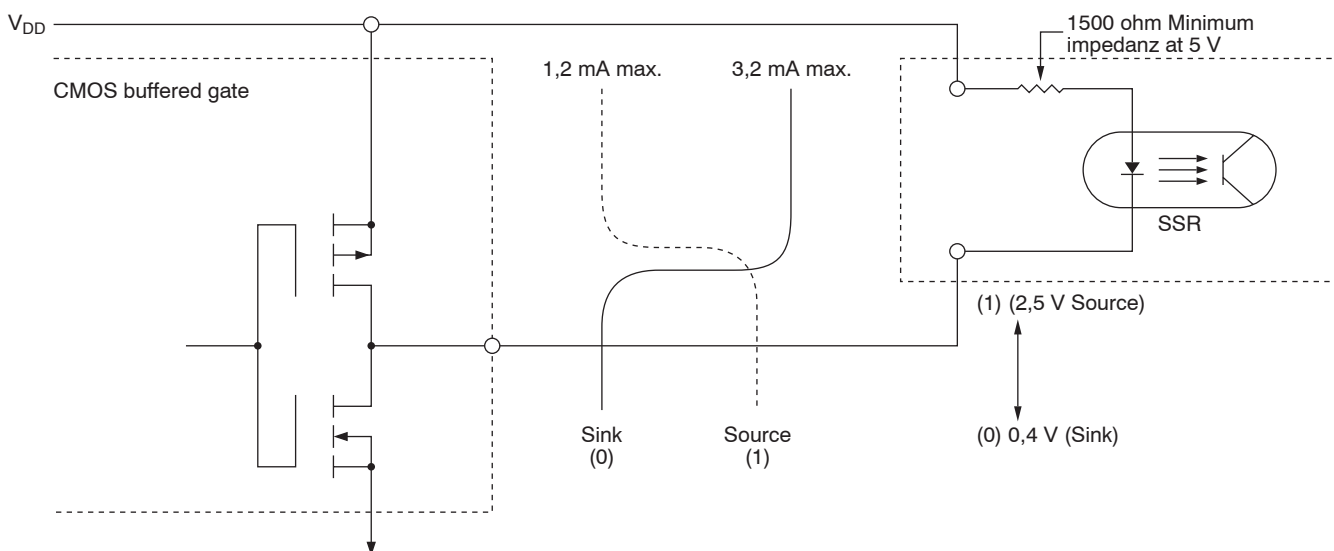

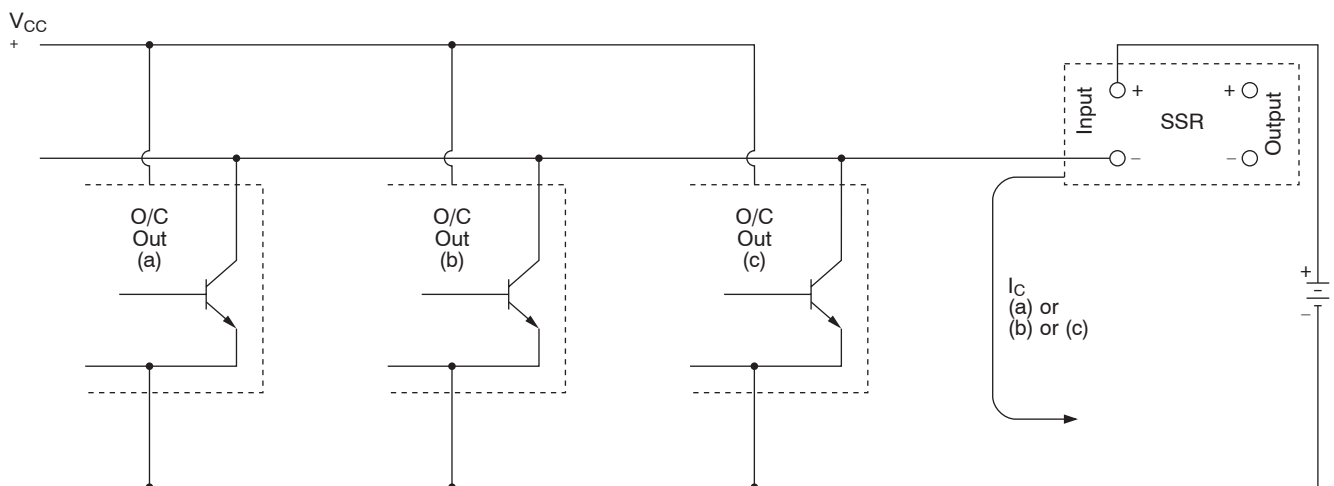Fig. 7: Buffered CMOS gate driving a high input impedance SSR

Fig. 8: Open collector IC driving SSR in logically ORed configuration

Leakage from the drive source

The off state leakage current in the driving semicoonductors shown in Figs. 6 to 8 is significant, just a few microamperes, which could not possibly turn on the SSRs. However, the off state (output leakage current of any packaged solid state driving device (e.g. temperature controller, etc.) should first be checked for compatibility with the SSR.

One method is to multiply the maximum leakage current (amps) by the maximum input impedance (ohms) of the SSR. This should result in a voltage that is less than the specified turn-off voltage. If it is not, a resistive shunt across the SSR input may be required.

Thermal considerations

One of the major considerations when using a SSR, is that an effective method of removing heat from the SSR package must be employed. SSRs have a relatively high "contact" dissipation, in excess of 1 watt per amp. Usual methods for heat dissipation are cooling by flowing air or forced airflow around the SSR or the application of heat sink.

With loads of less than 5 amps, cooling by free flowing air or forced airflow around the SSR is usually sufficient. At higher currents it will become necessary to make sure the radiating surface is in good contact with a heat sink. Essentially this involves mounting the base plate of the SSR onto a good heat conductor, usually aluminium; good thermal transfer between the SSR and the heat sink can be achieved with thermal grease or heat sink thermal resistance ($R_{\theta CS}$) is reduced to a negligible value of 0,1°C/W (celsius per watt) or less. The simplified thermal model in Fig. 9 indicates the basic elements to

be considered in the thermal design. The values that are determinable by the user are the case to heat sink interface ($R_{\theta CS}$), as previously mentioned, and the heat sink to ambient interface ($R_{\theta SA}$).

Thermal calculations

Fig. 9 illustrates the thermal relationships between the output semiconductor junction and the surrounding ambient. T_J -T_A is the temperature gradient or drop from junction to ambient, which is the sum of the thermal resistances multiplied by the junction power dissipation (P [watts]).

Hence:
$$T_J - T_A = P\ (R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$$

whereas:

T_J	=	Junction temperature, [°C]
T_A	=	Ambient temperature, [°C]
P	=	Power dissipation (I_{LOAD} x E_{DROP}), [W]
($R_{\theta JC}$)	=	Thermal resistance, junction to case, [°C/W]
($R_{\theta CS}$)	=	Thermal resistance, case to sink, [°C/W]
($R_{\theta SA}$)	=	Thermal resistance, sink to ambient, [°C/W]

To use the equation, the maximum junction temperature must be known, typically 125°C, together with the actual power dissipation, say 12 watts for a 10 amp SSR, assuming a 1,2 volt effective (not actual) voltage drop across the output semiconductor. The power dissipation (P watts) is determined by multiplying the effective voltage drop (E_{DROP}) by the load current (I_{LOAD}).

Assuming a thermal resistance from junction to case of say, 1,3°C/W and inserting the above typical values ($R_{\theta CS}$) into the equation, solutions can be found for unknown parameters, such as maximum load current, maximum operating temperature, and the appropriate heat sink thermal resistance.

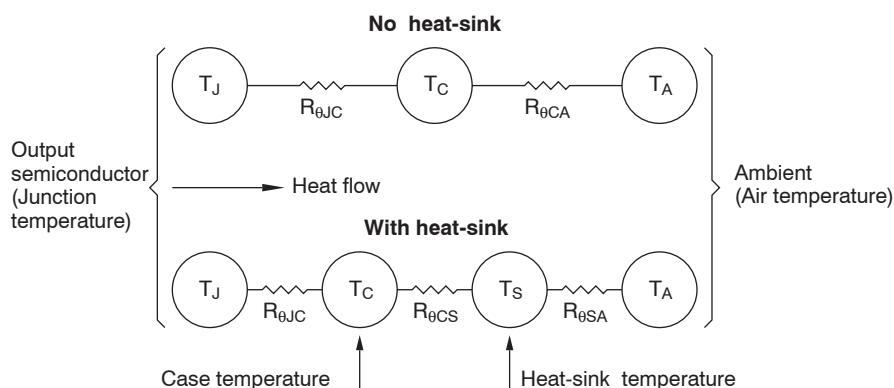Where two of these parameters are known, the third can be found as shown in the following examples:

Fig. 9: A simplified thermal model

(a) To determine the maximum allowable ambient temperature: Heat sink = 1°C/W, Load = 10 A (12 W), T_J-max. = 100 °C

$T_J - T_A = P (R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$ hence, $T_A = T_J - 28,8$

$T_J - T_A = 12 (1,3 + 0,1 + 1,0)$ $T_A = 100 - 28,8$

$T_J - T_A = 28,8$ $T_A = 71,2 °C$

(b) To determine required heat sink thermal resistance: Maximum ambient temperature = 71,2 °C, Load = 10 A (12 W):

$$R_{\theta SA} = \frac{T_J - T_A}{P} - (R_{\theta JC} + R_{\theta CS})$$

$$R_{\theta SA} = \frac{100 - 71,2}{12} - (1,3 + 0,1)$$

$$R_{\theta SA} = 1 °C/W$$

(c) To determine maximum load current: Heat sink = 1 °C/W, ambient temperature = 71,2 °C:

$$P = \frac{T_J - T_A}{R_{\theta JC} + R_{\theta CS} + R_{\theta SA}}$$ hence, $$I_{Load} = \frac{P}{E_{Drop}}$$

$$P = \frac{100 - 71,2}{1,3 + 0,1 + 1,0}$$ $$I_{Load} = \frac{12}{1,2}$$

$$P = 12 W$$ $$I_{Load} = 10 A$$

Regardless of whether the SSR is used on a heat sink or the case is cooled by other means, it is possible to confirm proper operating conditions by making a direct base plate temperature measure-ment when certain parameters are known. The same basic equation is used except that base plate temperature (T_C) is substituted for ambient temperature (T_A) and $R_{\theta CS}$ and $R_{\theta SA}$ are deleted. The temperature gradient now becomes $T_J - T_C$, that is the thermal resistance ($R_{\theta JC}$), multiplied by the junction power dissipation (P watts). Hence:

$$T_J - T_C = P (R_{\theta JC})$$

Parameter relationships are similar in that solutions can be found for maximum allowable case temperature, maximum load current, and required junction to case ($R_{\theta JC}$) thermal resistance. Again, where two parameters are known, the third can be found as shown in the following examples (using previous values):

(d) To determine maximum allowable case temperature for $R_{\theta JC}$ = 1,3 °C/W and Load = 10 A (12 W):

$T_J - T_C = P (R_{\theta JC})$ hence, $T_C = T_J - 15,6$

$T_J - T_C = 12 × 1,3$ $T_C = 100 - 15,6$

$T_J - T_C = 15,6$ $T_C = 84,4 °C$

(e) To determine maximum load current for $R_{\theta JC}$ = 1,3 °C/W and case temperature = 84,4 °C:

$$P = \frac{T_J - T_C}{R_{\theta JC}}$$ hence, $$I_{Load} = \frac{P}{E_{Drop}}$$

$$P = \frac{100 - 84,4}{1,3}$$ $$I_{Load} = \frac{12}{1,2}$$

$$P = 12 W$$ $$I_{Load} = 10 A$$

(f) To determine required thermal resistance ($R_{\theta JC}$) for 84,4 °C case temperature and 10 amp load (12 watts):

$$R_{\theta JC} = \frac{T_J - T_C}{P}$$

$$R_{\theta JC} = \frac{100 - 84,4}{12}$$

$$R_{\theta JC} = 1,3 °C/W$$

In the examples (a) through (c) SSR operating conditions are determined as they relate to ambient air temperature using a heat sink. Similarly, conditions can be determined for an SSR operating in free air without a heat sink, provided that a value is given for the radiating characteristics of the package ($R_{\theta CA}$). This value is rarely given and when it is, it is more commonly combined with ($R_{\theta JC}$) and stated as ($R_{\theta JA}$). The equation would appear as follows:

$$T_J - T_A = P \, (R_{\theta JC} + R_{\theta JA})$$

$$\text{or} \qquad T_J - T_A = P \, (R_{\theta JA})$$

where:

($R_{\theta CA}$) = Thermal resistance, case to ambient, [°C/W]

($R_{\theta JA}$) = Thermal resistance, junction to ambient, [°C/W]

The equation can be used to calculate maximum load current and maximum ambient temperature as before.

However, the resultant values are inclined to be less precise due to the many variable that affect the case to air relationship (i.e., positioning, mounting, stacking, air movement, etc).

Generally, free air performance is associated with PCB or plug-in SSRs of 5 amps or less, which have no metallic base to measure. The question is often raised as to where the air temperature is measured. There is no clear-cut answer for this. Measurement is made more difficult when the SSRs are closely stacked, each creating a false environment for ist neighbour. One suggested approach is to place a temperature probe or thermocouple in the horizontal plane approximately 1 inch away from the subject SSR. This technique is reasonably accurate and permits repeatability.

Ratings

The free air performance of lower powered SSRs is usually defined in the catalogue by means of a single derating curve, current versus ambient temperature based on the foregoing formulas, which is adequate for most situations.
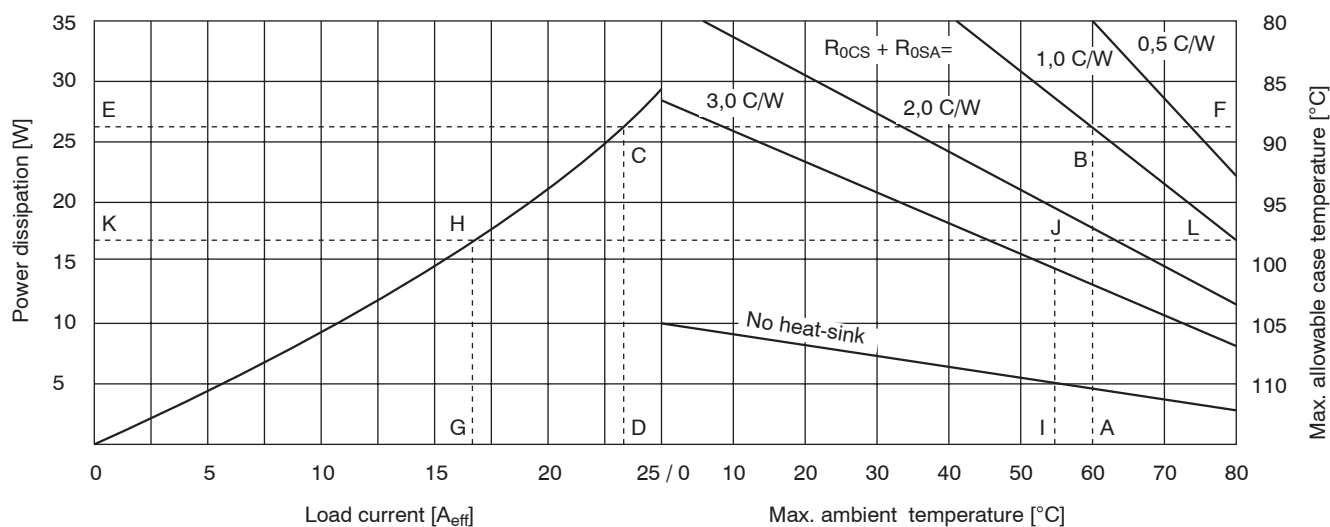

Fig. 10: Thermal derating curves

Surge ratings and high inrush current loads

After improper heat sinking, surge current is one of the more common causes of SSR failure. Overstress of this type can also seriously impair the life of the SSR. Therefore, in a new application it would be wise to carefully examine the surge characteristics of the load.

There are very few completely surgeless SSR loads. Resistive loads, such as heating elements and incandescent lamps, can prove problematic. Capacitive loads can also prove equally problematic because of their initial appearance as short circuits. High surge currents can occur while charging, limited only by circuit resistance. Inductive loads, on the other hand, tend to impede high inrush currents, in fact, inductance is often inserted into a circuit for the express purpose of limiting high fast rising peak currents (e.g. EMI filters, chokes, etc.). However, inductive loads can give rise to high inrush currents.

Inductive loads have traditionally created more problems on turn-off rather than turn-on due to stored energy and "back EMF". The inherent zero current turn-off characteristics of thyristors used in ac SSRs is most beneficial in this regard.

Surge ratings

The highest surge current rating (As) of an SSR is typically 10 times the steady-state RMS value, and it is usually given as the maximum nonrepetitive peak current for one line cycle. It should be noted that a surge of this magnitude is allowable only 100 times during the SSR lifetime. The preceding cautionary notes would tend to reduce the attractiveness of the high surge capability (100%) of the ac SSR; however, they apply only to the extreme limits where the SSR should not be designed to operate anyway. When a reasonable surge safety margin is used, conditions rapidly improve.

Generally, dc SSRs do not have an overcurrent surge capability, since the output transistors (non regenerative) are usually rated for continuous operation at their maximum capacity. The tendency is for the dc SSR to cut off (current limit), thus impeding the flow of excessive current. However, the resultant over-dissipation may destroy the relay if the surge is prolonged. If overcurrent carrying capacity is required, as may be the case when designing fuse protection, the SSR could be over specified (have a higher current capability).

To aid in the proper design of SSR fusing, an I^2t rating is usually given. This parameter expressed in A^2s is useful since it can relate directly to the published fuse characteristics.

It is generally derived from the peak surge (one cycle) output thyristor ratings as follows:

where:
$$I^2t = \frac{I^2_{PK}t}{2}$$

I = peak surge current – (sinusoidal)

t = duration of surge (normally 8,3 µs)
    (0,0083 seconds in the formula)

For example, for a 25 amp SSR with a 250 amp one-cycle surge rating, the value would be 260 A^2s.

Inductive loads

High inrush lamp and capacitive loads sometimes include a series inductor such as a choke or transformer.

This will tend to limit the initial inrush current, but the combination will primarily be seen by the SSR as an inductive load. While most SSR loads, even lamps, include some inductance, its effect with resistive loads is usually negligible. Only those loads that utilize magnetics to perform their function, such as transformers and chokes, are likely to have any significant influence on SSR operation.

The majority of SSRs will operate inductive loads with power factors as low as cosφ 0,3, especially if they are switching medium to high current loads relative to their rating. SIG Positec Systems relays are 100% tested for operation at cosφ 0,5. When a load is so light that its rating is close to the minimum current rating of the SSR, the off state leakage may become significant when compared to the load current. The leakage may have a deleterious effect on certain loads such as small solenoids that fail to drop out, or motors that buzz or even continue to run. The solution is to reduce the load impedance by means of a shunt or parallel impedance, thus reducing this voltage below the drop out or off threshold of the load.

A saturating inductive load can also cause switching problems with the SSR. The ac impedance of such a load is relatively high under normal conditions. However, when saturation occurs the inductance falls to a very low value, resulting in a fall in impedance close to that of the Copper resistance of the coil winding. This can cause several cycles of surge currents in excess of 30 times the steady-state value, which may serioulsy affect the lifetime.

Transformer switching

Extremely high current surges are commonly associated with transformers, especially those with a penchant for saturation. The zero voltage turn-on feature of standard SSRs can increase this possibility and might require that special precautions be taken.

At the instant turn-on, transformer current is essentially zero, with the highest peak usually occurring within a half cycle, depending on the line phase angle, load power factor, and magnetic state of the core. When the SSR is energized at the ideal phase angle, as dictated by power factor, a maximum back EMF is generated that will tend to counter the magnetising current, thereby reducing or eliminating the surge.

However, when switched on at, or near, zero voltage, the back EMF is reduced, allowing an increase in magnetizing current that can be further enhanced by residual magnetism in the core which almost always exists since ferromagnetic core material has a natural tendency to remain magnetized at turn-off.

If a random turn-on SSR is used to switch transformer load, the likelihood of transformer core saturation is greatly reduced.

Switching

Dynamic loads, such as motors and solenoids, etc., can create special problems for SSRs, in addition to those discussed for passive inductors. High initial surge current is drawn because their stationary impedance is usually very low. For example, after the initial surge, a solenoid core will pull in and "seal" at a much lower steady-state current, possibly by dropping to less than 25%. With motors, the change in current from stall to run can be even greater, possibly dropping to less than 20%, depending on the type.

As a motor rotor rotates, it develops a back EMF that reduces the flow of current. This same back EMF can also add to the applied line voltage and create "overvoltage" conditions during turn-off. Mechanical loads with a high starting torque or high inertia, such as fans and flywheels, will, of course, prolong the start-up surge period, which should be taken into account when selecting the driving SSR. When the mechanical load is unknown, as may be the case with a power tool, worst case conditions should apply.

The inrush current characteristic of tungsten filament (incandescent) lamps is somewhat similar to the surge characteristic of the thyristors used in ac SSR outputs, making them a good match. The typical ten times steady-state ratings which apply to both parameters from a cold start allow many SSRs to switch lamps with current ratings close to their own steady-state ratings. Some lamps have even higher instantaneous inrush currents. This is rarely seen in practice, since line and source impedances and filament inductance become significant at higher currents, all of which tend to limit the peak current. Generally the ten times steady-state rating is considered a safe number for lamps.

Protective measures

Electromagnetic compatibility

Noise, or more properly defined as Electromagnetic Interference (EMI), does not generally cause SSRs to fail catastrophically. Some of the techniques used to reduce noise in the coupler and drive circuits are also effective against false triggering caused by voltage transients on the input lines. When a capacitor is added, for example, the response time which is not critical for ac SSRs may be lengthened, possibly from a few microseconds to tenths of milliseconds. Due to the induced delay, voltage transients or bursts of shorter duration are rejected, thus improving noise immunity.

Most ac SSRs use thyristors in their drive and output circuits which, due to their regenerative nature, can latch on for a whole half cycle when triggered by a brief voltage transient, thus acting as a pulse stretcher. In addition to responding to the amplitude of the transient, a thyristor can also mistrigger when the rate of rise (dv/dt) of a transient or applied voltage exceeds certain limits. Transient suppressors are effective against the former, and the RC snubber improves the tolerance of an SSR to the latter.

du/dt (Rate effect)

The expression du/dt defines a rising voltage versus time expressed in volts per microsecond (V/µS). When applied to an ac SSR as "static" or "off state" du/dt, it is a parameter that defines the minimum dv/dt withstand capability of the SSR or, in other words, the maximum allowable rate of rise of voltage across the output terminals that will not turn on the SSR (typically 500 V/µs).

Snubber

The internal RC network (snubber) used in ac SSRs is a major factor in transient voltage and dv/dt suppression. It deals effectively with two facets of a voltage transient. Not only does the network slow down the rate of rise as seen by the output thyristors and sensitive drive circuits, but it also limits the amplitude to which it can rise. While the typical internal snubber value and the typical dv/dt specification are adequate for most applications, they may not prevent what is commonly referred to as the "blip" or "bleep" problem which occurs during start-up. That is, when power is initially applied to the SSR/load combination usually by means of a mechanical switch, the resultant fast rising transient may mistrigger the SSR and possibly "let through" a half cycle pulse, fortunately, most loads are not troubled by this pulse.

Suppressors

When overvoltage transients occur, another form of suppression may be required beyond the capabilities of the snubber. One popular technique is to add a clamping device across the SSR terminals that will absorb the transient energy above a predetermined level.

Devices, such as zeners and MOVs, will conduct only at the predetermined level and above, thereby sharing the transient with the load. If it is unacceptable for the load to receive any transient energy, the only solutions may be suppression of the transient source, or an SSR with a blocking capability higher than the transient.

Fig. 11 illustrates typical methods of suppressing transients across the SSR output "contacts" as well as suppression of transients at the source which can be the load itself for dc inductive type loads.
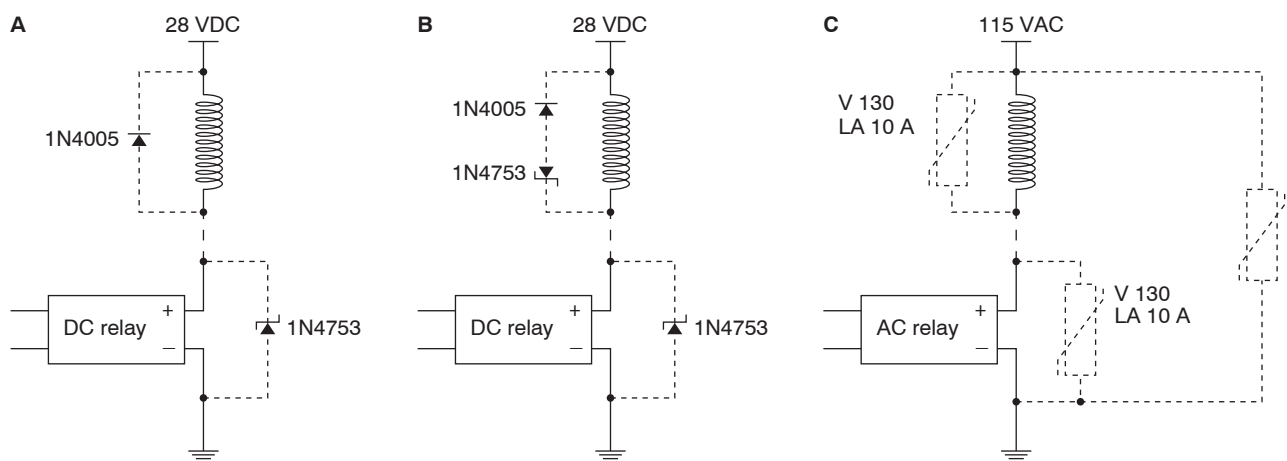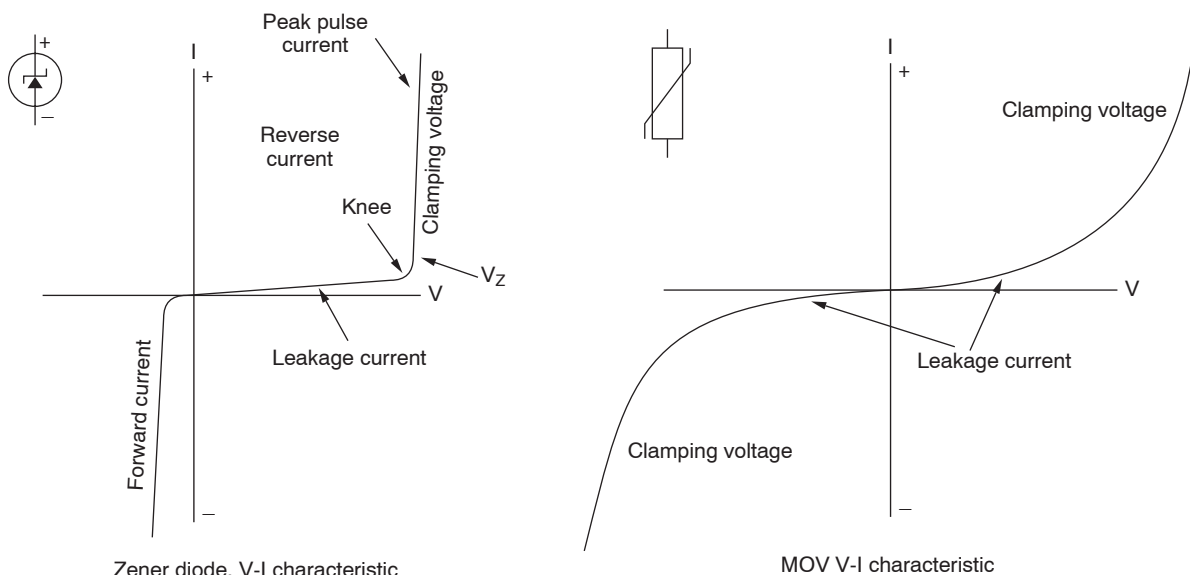

Fig. 11: Transient suppression techniques

Fig. 12: Comparison of zener diode and MOV characteristics

Diodes and Zeners

The diode shown across the load in A of Fig. 12 is the most effective way of suppressing the possibly hundreds of volts of bak EMF that can be generated by the coil at turn-off. The disadvantages of this method are the SSR is not protected from other transient sources, and the dropout time of the load may be extended by several milliseconds.

The general rule in the selection of protective diodes and zeners is that their peak nonrepetitive (pulse) current ratings (Fig. 12) should be equal to, or greater than, the minumum load current. Conservative steady-state power ratings for these devices may be ascertained from the following equation:

$$P_{Watt} = \frac{I_L^2 L}{t_r}$$

where:

I_L = Load current in dc Amperes

L = Load inductance in Henry

t_r = On/Off repetition rate in seconds

Example: A load with a resistance of 4 ohms and an inductance of 0.0025 henry is driven from a 28 volt dc supply while being switched on and off 5 times a second:

$$I_L = \frac{28 \text{ volts}}{4 \text{ ohms}} \qquad t_r = \frac{1}{5} \qquad P = \frac{7^2 \times 0,0025}{0,2}$$

$$I_L = 7 \text{ amperes} \qquad t_r = 0,2 \text{ second} \qquad P = 0,613 \text{ watt}$$

A protective diode or zener with a ❖ watt rating would suffice.

The zener diode is the ideal choice for protecting low voltage dc SSRs (less than 100 volts dc) used in parallel with the output. In the forward current mode (reverse for the SSR), the zener diode typically clamps as a single diode would at approximately one volt, thereby providing added reverse-voltage protection. When two zeners are used back-to-back (in series) with equal stand-off voltages, they can be used to protect SSR outputs bidirectionally when switching ac loads. At higher voltages (greater than 100 volts) ac or dc, economics versus performance may suggest another transient protective device such as the MOV (metal oxide varistor) being the most popular.

MOVs (Metal Oxide Varistors)

For more hostile environments, the MOV can be used as follows:

across the incoming line to suppress external transients before they can enter the system;

across the load to suppress load generated transients; or, more frequently, across the SSR to protect it from all transient sources. In the latter case, the MOV can be conveniently mounted to the same SSR output terminals as the load wiring. With the impedance of the load in series with the MOV to limit current, a 30 joule unit is usually adequate for brief spikes and also small enough to be supported by its own leads.

If a MOV is connected directly across the power line, the current limiting impedance will only be that of the power generating source plus the wiring. In order to absorb the possibility of high energy line transients form such a low impedance source, the larger panel mount (300 - 600 joule) variety of MOV may be required. The greater expense of such a device might be justified in that suppression across the line is required in one place only.

Individual MOV specifications should be consulted for precise information regarding energy absorption, clamping properties and physical size, since the relationships of these parameters will vary from one manufacturer to the next.

Fuses

Semiconductor fuses are usually used in conjunction wiht SSRs and are specialist fuses designed to protect while operating at close to their full ratings.

They are sometimes referred to as current limiting fuses, providing extremely fast opening, while restricting let through current far below the available fault current that could destroy the SSR. Although these fuses are not low cost, they do provide a means of protecting SSRs against high current overloads where survival of the SSR is of prime importance.

The following are the main parameters used in the selection of a semiconductor fuse:

- Fuse voltage rating
- Fuse current rating
- Available system fault current
- Fuse peak let through current
- Fuse total clearing (or let through)
- Surge withstand capability of the SSR

SSR Applications

The diagrams in this section are conceptual illustrations of just a few typical SSR applications. They are intended as design guides to steer the user in the right direction and to stimulate further design ideas. Some of the diagrams provide problem solving or circuit protection and others enhance relay operation.

Latching SSR (Fig. 13)

Momentary push-button control allows the SSR to self-latch for on-off, stop-start operations. It may be similarly configured for DC in/DC out type SSRs.

Resistor R1 (10 kΩ) is required to prevent line short only if alternate (NO = normaly open) switch is used.
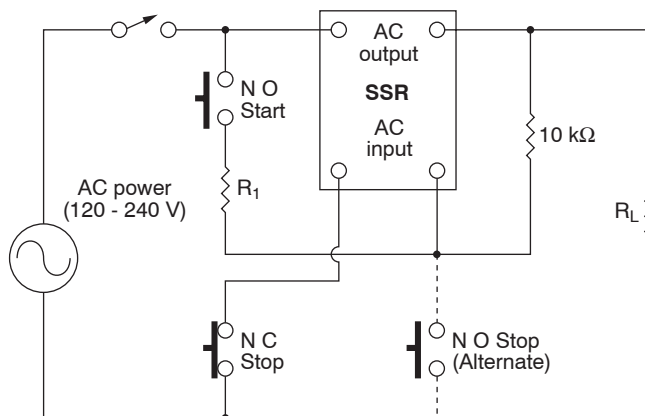

Fig. 13: Latching SSR circuit

Latching SSR with short-circuit protection (Fig. 14)

Push-button control as in the previous example, but R2 is tailored to limit the load shorting current to SSR surge rating (for turn-off time), thus preserving SSR while the control signal is removed. Latching characteristic permits lock-out until the circuit is reset.
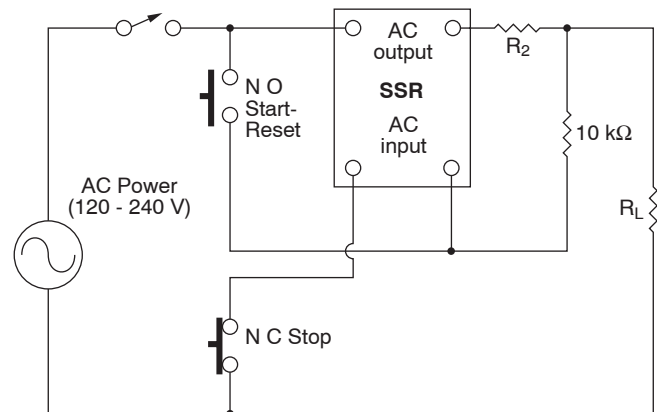

Fig. 14: Latching SSR with short-circuit protection

Motor starter switch (Fig. 15)

Initial locked rotor current flowing through R1 creates a voltage that, when rectified and filtered, turns on the SSR, which in turn activates the start winding. As the motor comes to speed, the voltage across R1 is reduced until the start winding is de-energized.

The SSR should have a voltage rating approximately twice that of the applied line to withstand overvoltage generated by the current LC.
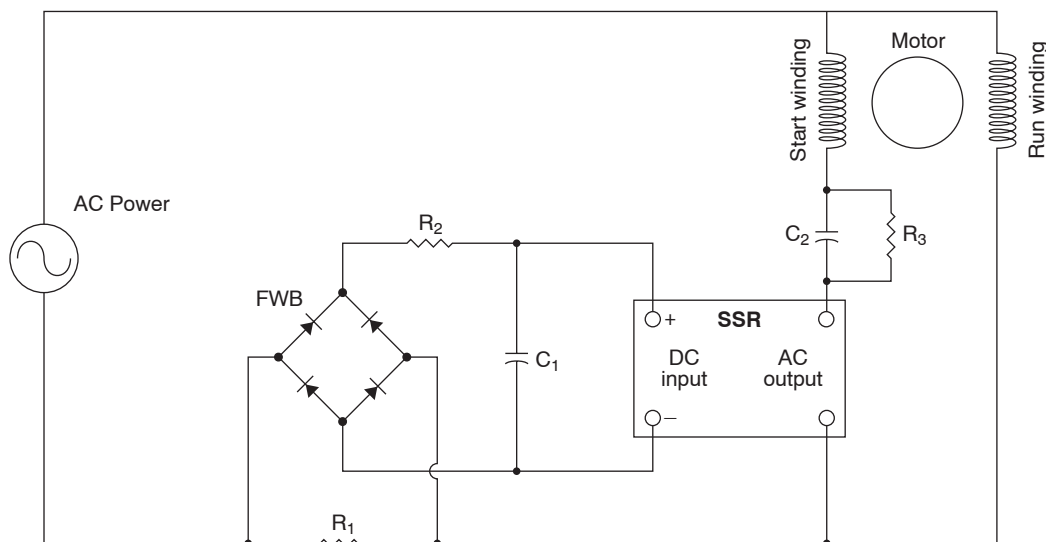

Fig. 15: Motor starter switch

Functional Three-phase switch for Three-wire system (Fig. 16)

Two SSRs may be used to control a Y or a delta load in a three-wire system. A third SSR would be required in phase C if the centre of the Y load were grounded, as in a four-wire system. SSR voltage rating must be greater than line to line voltage for three-wire systems and line to ground voltage for four-wire systems (with neutral ground).

SSRs are most commonly used in three-phase applications to control motors, where their current ratings depend as much on locked motor current as they do on normal run current and proper heat sinking. Where a motor rating is not given, a minimum SSR current value can be estimated from the device surge curves, using the general rule of six times the motor run current for one second. This value must also be commensurated with thermal and lifetime requirements.
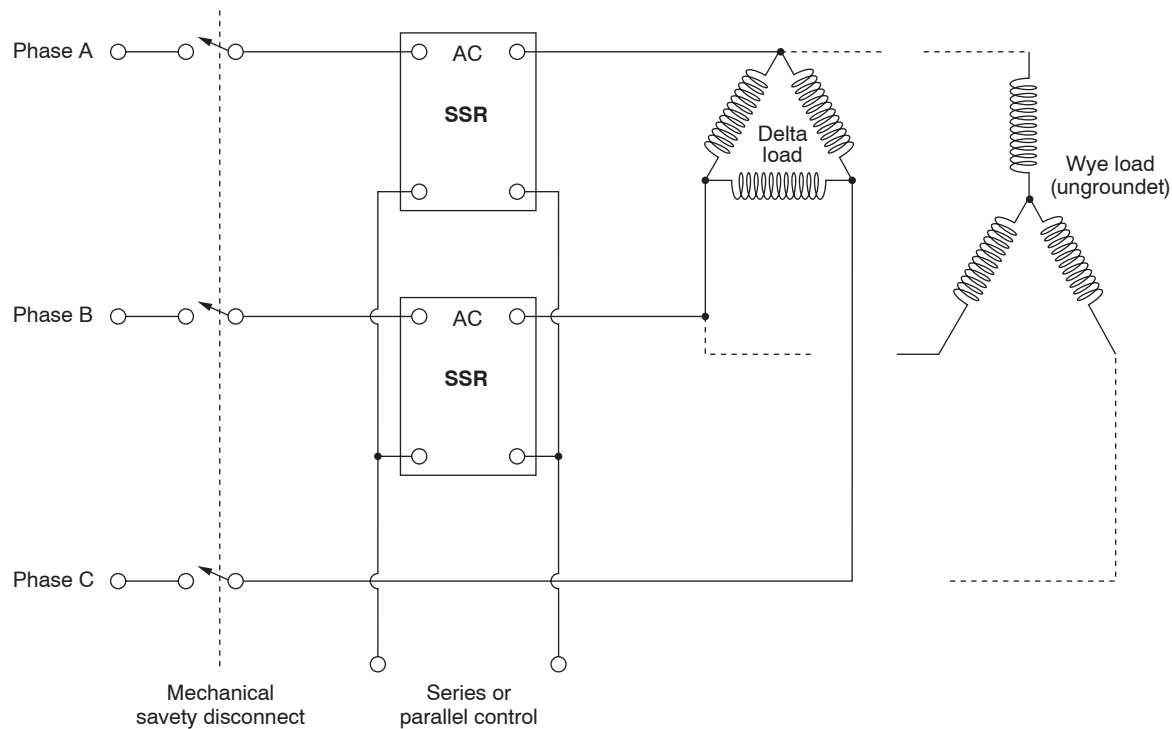

Fig. 16: Functional three-phase switch for three-wire system

Three-phase motor reversal (Fig. 17)

For ac SSRs can provide a reversing function for a three-phase motor, using the drive logic suggested. The half cycle time delay before enabling the drive, in either direction, prevents make before break which would result in a line to line short. Two opposing SSRs (nos. 1 and 4, or 2 and 3) could still mistrigger simultaneously due to dv/dt or high voltage transients; therefore, resistors R1 through R4 are inserted to limit the resultant surge current. The sum of any two resistors plus the source impedance should limit the shorting current to less than a peak one cycle surge rating of each relay.

Semiconductor type fuses should be chosen to permit such a condition for one cycle and open as soon as possible thereafter.

SSRs should have a transient (blocking) rating equal to twice the line to line voltage to withstand the combined line and back EMF generated at the moment of reversal.
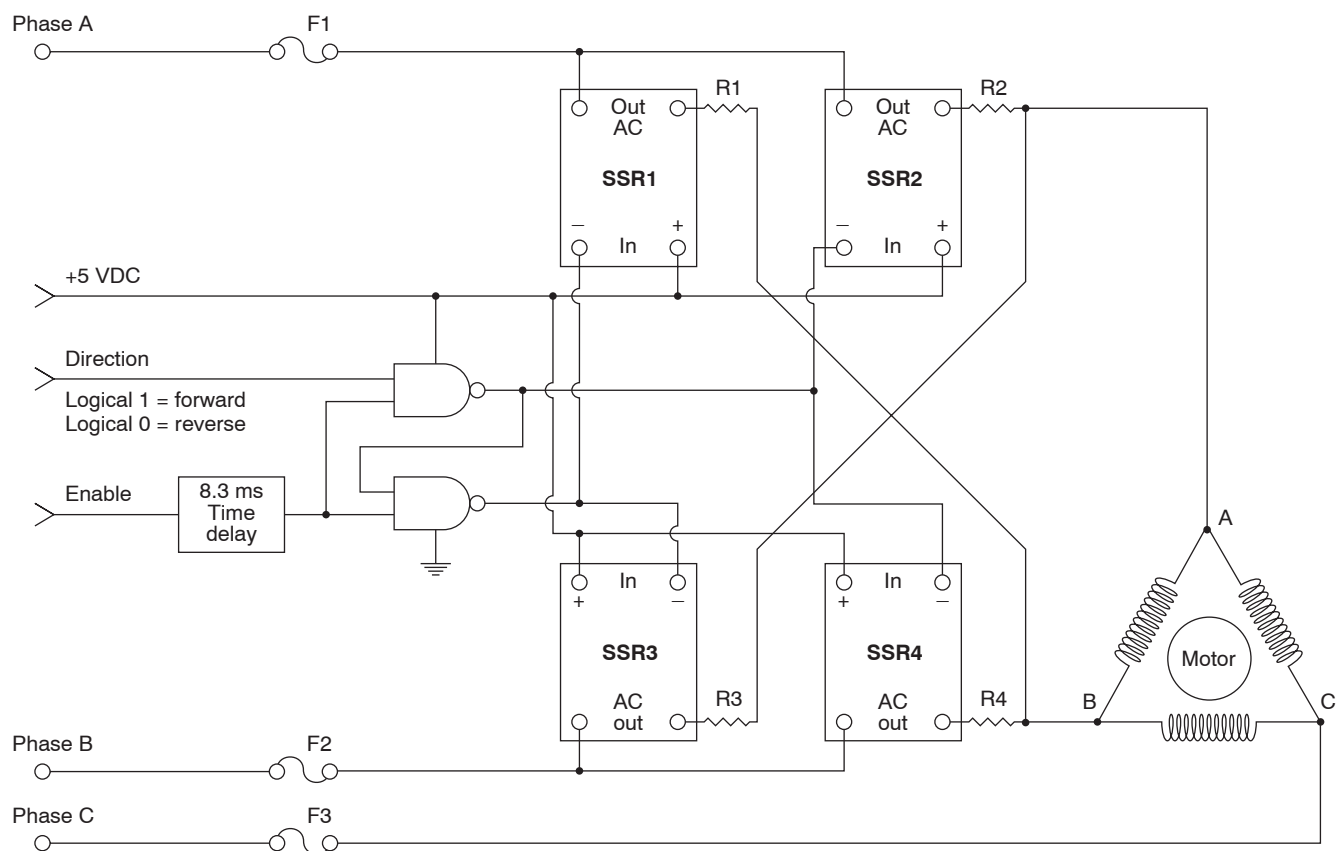

Fig. 17: Three-phase motor reversal

Reversing motor drive for dc Motors (Fig. 18)

In this configuration, four dc SSRs are used for motor reversal from a single power supply. The time delay before enabling the drive in either direction must be greater than the SSR turn-off time to preclude the possibility of a hazardous make before break condition. Internal reverse diodes or zeners in the SSRs will suppress inductive transients across the low impedance of the power supply. If no internal suppressors exist, a reverse diode should be installed across each SSR output or, alternatively, SSRs with blocking ratings at least twice that of the supply voltage may be used. The circuit should be current limited or fused to protect the wiring in the event of a short circuits.
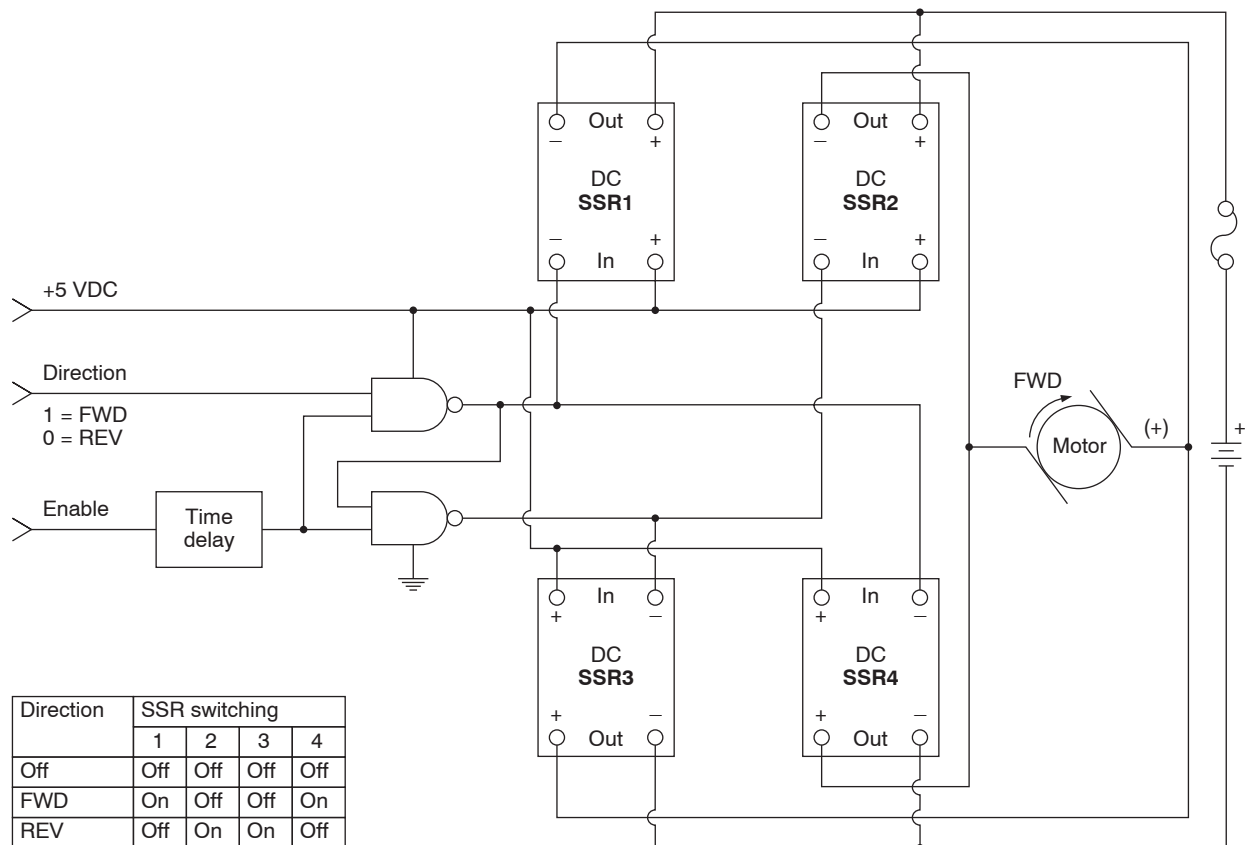

Direction	SSR switching			
	1	2	3	4
Off	Off	Off	Off	Off
FWD	On	Off	Off	On
REV	Off	On	On	Off

Fig. 18: Reversing motor drive for DC motors

Paralleling SSRs (Fig. 19)

SSRs with MOSFET outputs are self balancing and easily paralleled, whereas most others with bipolar or thyristor outputs require special attention. Ideally, the forward voltage drops should be matched to achieve thermal balance and lowest dissipation; alternatively, balancing resistors (Rx) are used to force current sharing as shown, For example-le, with 40 amps allowed through SSR1, SSR2 must carry 32 amps.

Assuming V1 = 1,3 volts and V2 = 1,5 volts (worst case):

$$R_X = \frac{\Delta V}{\Delta I} = \frac{V2 - V1}{I1 - I2} = \frac{1,5 - 1,3}{40 - 32} =$$

$$\underline{R_X = 0,025 \text{ Ohm}}$$

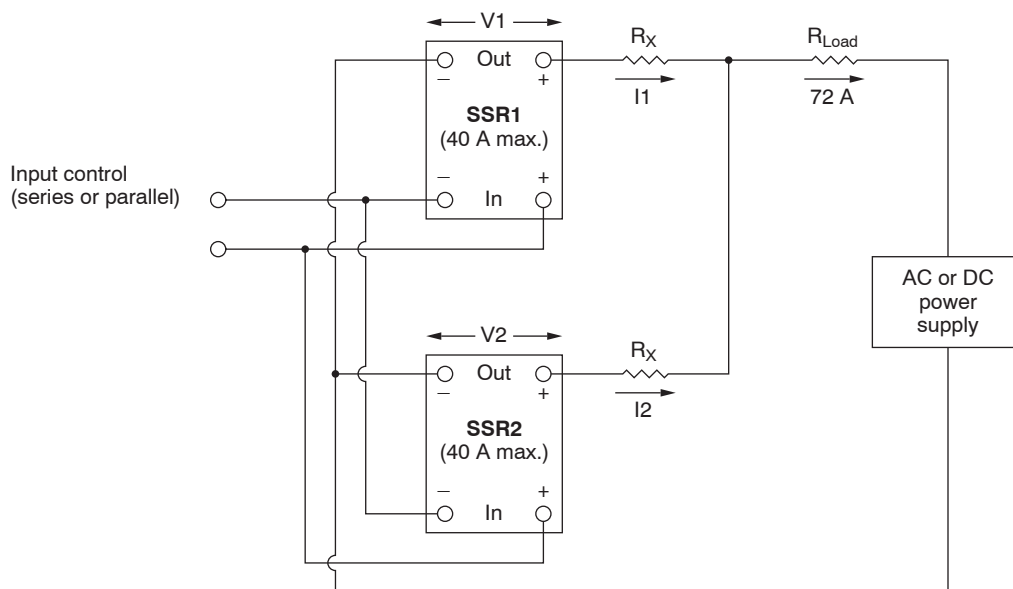Thus producing a total voltage drop of 2,3 V.

Fig. 19: Paralleling SSRs

For zero voltage turn-on thyristor types, either one of the SSRs must be capable of handling the initial full load surge alone because of a possible half cycle mismatch. Thyristor SSRs have additional turn-on problems that can prevent paralleling.

Transformer Tap switching (Fig. 20)

If a momentary interruption in power is acceptable, a time delay on operate is suggested to prevent overlap and the resulting high current surge form a shorted winding. Two times Rx plus the winding resistance must be sufficcient to limit the surge current to the one cycle surge rating of the SSRs.

As an additional precaution, the SSR blocking (breakdown) voltage should exceed the main winding voltage plus the highest tap voltage. For multi-tap switching the SSRs are generally logic driven dc controlled ac output types without special requirements. For Figs. 36B and C, they are 250 Vac output with 120 Vac input for SSR1 and 240 Vac input for SSR2 in each case. An important requirement of SSR2 is that it must be off below the highest expected 120 Vac line swing, say 150 Vac. When SSR2 is off, SSR1 will be on and vice versa, thus activating the apporopriate winding.
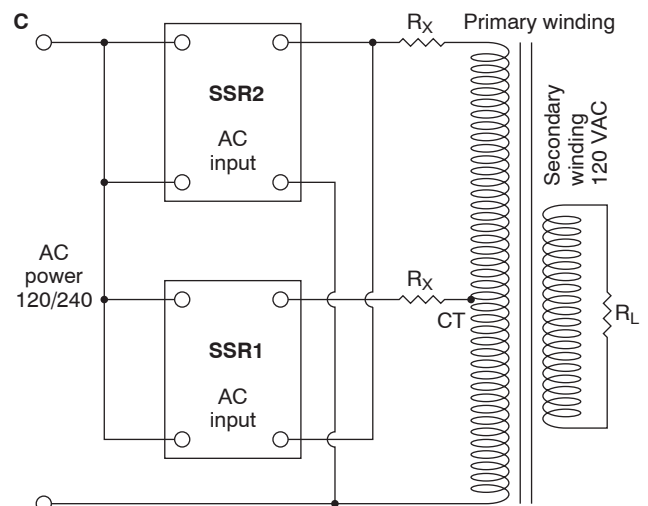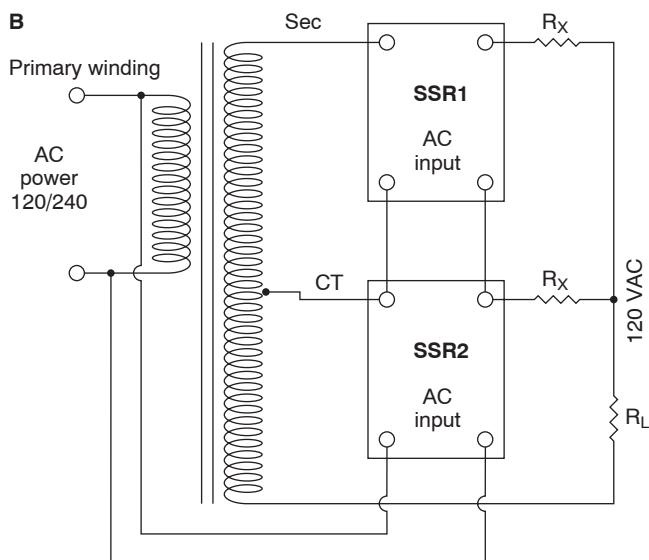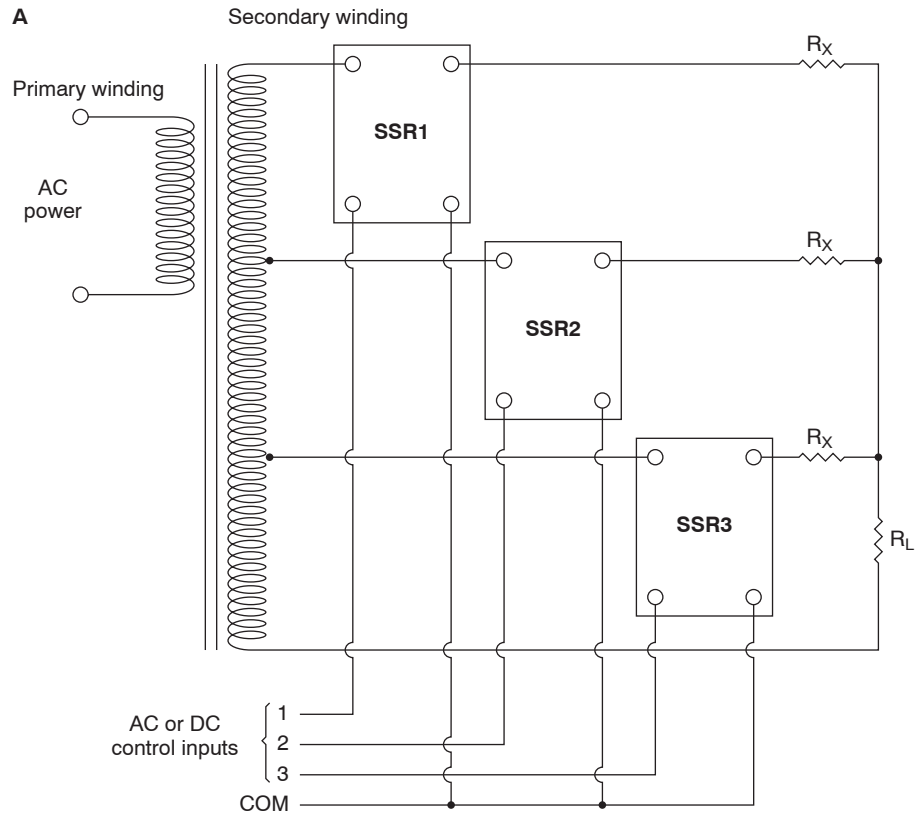

Fig. 20: Transformer tab switching

Testing the SSR (Fig. 21)

Many of the tests required to verify SSR performance are inherently hazardous and caution should be exercised, using adequate safeguards for the personnel conducting such tests.

Possibly the simplest of all field tests that can be made to determine proper function of an AC SSR is by means of a 3 volt battery, a light bulb, and a piece of insulated wire. This simple go/no-go test is illustrated by Fig. 21.
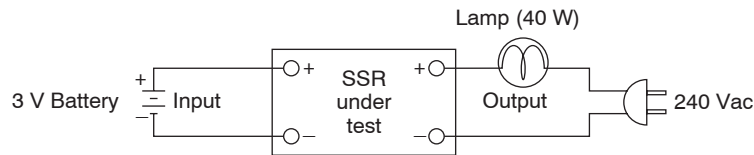

Fig. 21: Simple go/no-go SSR test

A more complete performance check might include operating the SSR in position with its actual load, while exercising the system installation functionally through all of its specified environmental and power combinations.

When connecting test equipment directly to the power circuit of an SSR output, protective fusing would be a wise precaution. Also remember that with some equipment such as an oscilloscope, the case must be "floated" (ungrounded) and may be at line potential. In some test circuits an isolated current probe or an isolation transformer can be used to avoid this hazard. The output functions of an SSR should not ever be checked by a multimeter in the ohms mode, since the minimum voltages and bias currents necessary for proper SSR operation are not present, thus producing errneous readings.

Glossary of terms

Ambient temperature range. The surrounding air temperature limits, usually given for both operating and storage conditions. The maximum operating temperature may require close consideration by the thermal dictates of heat dissipation and the possible requirement of a heat sink.

Anode - Connection of a thyrisor. High potential terminal on an SCR. Positive in respect to gate and cathode when conducting (blocking when negative).

Base. The control terminal of a bipolar transistor.

Bipolar. Generally used to describe a transistor type in which a dc current flow between collector and emitter is modulated by a smaller current flowing between base and emitter. The gain of the transistor relates to the ratio of these two current defined as beta or hfe in common-emitter configurations.

Bistable. A two state device that will remain in its last operated state after control power power is removed (e.g. latching relay).

Blocking voltage. Maximum allowable standoff voltage before breakdown.

Breakdown (Breakover). The point at which blocking capability in an SSR colapses as voltage is increased beyond its maximum (transient) rating.

Capacity. The ability to store an electrical charge. Also given as an SSR isolation parameter, measured input to output, or both to case, provided as a means of determining high frequency noise coupling.

Cathode. SCR terminal associated with gate terminal. Negative in respect to anode when conducting.

Collector. A main current terminal and also high voltage terminal of a transistor relative to the base and emitter.

Control voltage. Specified as a range of voltages which, when applied across the SSR input terminals, will maintain an on condition accross the output terminals.

di/dt. Maximum rate of rise of on state load current that an SSR can withstand without damage. A characteristic of thyristors used in ac SSRs.

du/dt (rate of rise of voltage) in blocking state (static). Maximum rate of rise of voltage applied across the output terminals that the SSR can withstand without turning on. A characteristic of thyristors used in ac SSRs.

Emitter. A main current terminal of a transistor, also associated with the base terminal and its control current.

FET. Field Effect Transistor. Principle of operation differs from that of bipolar types. Voltage applied between gate and source terminals modulates the device resistance to current flow between drain and source terminals, by means of a field set up in the channel region.

Holding current. The minimum (load) current required to maintain a thyristor in its conducting state.

I²t (Maximum). Nonrepetitive pulse current capability of SSR given for fuse selection. Expressed as "ampere squared seconds" with typical half cycle pulse width.

Inductance. An electrical property which can oppose a current change and also store a charge. The unit of inductance is called the Henry [H].

Input current (Maximum). Current drain on the control source at specified SSR input voltages and on-off conditions.

Input Impedance/Resistance. Minimum effective SSR input resistance at a given voltage which defines input power and sensitivity.

Instantaneous turning on. After applied control power the SSR switches to on independently of the momentary phase-angle.

Insulation Resistance (Minimum). Resistive value usually measured at 500 volts dc, input to output, or both to case.

Leakage current. The current conducted through the SSR output terminals, in the off state.

Load Current (Maximum). The maximum steady-state load current capability of an SSR, which may be further restricted by the thermal dictates of heat sink and ambient temperature conditions.

Load Current (Minimum). The minimum load current required by the SSR to perform as specified.

Load voltage (Maximum). The range of minimum to maximum mains voltage, that can be applied to the outputs of the SSR.

Maximum capacity input to output. Maximum value of capacitive coupling between control terminals and power output terminals.

Maximum overcurrent (not repetitive). Maximum allowable SSR momentary current flow for a specific time duration. (Typically expressed as an RMS value for a one second duration).

MOSFET. Metal Oxyde Semiconductor Field-Effect Transistor. The control electrode (gate) is generally isolated from the source electrode by a layer of silicon oxide. A voltage applied between the gate and the source will provide a current flow between drain and source.

MOV. Metal Oxide Varistor, commonly used with ac SSRs to suppress bidirectional voltage-dependent resistive characteristic that drop rapidly with increasing voltage.

MTBF. Mean Time between failure.

On State Voltage (Maximum). The peak voltage that appears across the SSR output terminals at full rated load.

Phase control. Turn-on of a nonzero switching SSR (each half cycle), at a phase angle determined by the control signal source.

Power dissipation. The maximum average power dissipation [watts] resulting from the effective voltage drop (power loss) in the SSR output semiconductor.

RMS Voltage (Root-Mean-Square). The value of alternating voltage (ac) that would produce the same power dissipation as continuous voltage (dc) in a resistive load. For a sine wave, RMS is 0,707 times the peak value.

Semiconductor fuse. A specially constructed fast-acting fuse capable of protecting semiconductor devices, with opening times typically less than 10 milliseconds.

Snubber. A resistor-capacitor combination placed across the SSR output terminals to control dv/dt and transients in thyristor circuits.

Solid-State-Relay, SSR. Isolated On-Off-Switch composed of non-moving electrical parts (i.e., primarily semiconductors, transformer and passive components).

Surge current. The maximum allowawble SSR momentary current flow for a specific time duration. (Typically specified as a peak value for one line cycle for ac).

Thermal resistance (Rθ). Expressed in "degrees celsius per watt" [$^{\circ}$C/W]. This value defines the temperature gradient in the path between the power generated in the ouptut SSR semiconductor and the final dissipating medium (heat sink/air).

Thyristor. A semiconductor bistable device comprising three or more junctions (PNPN, etc.). The generic name for a family of gate controlled switches including SCRs and triacs.

Transient. Brief overvoltage or overcurrent excursion from normal condition.

Transient overvoltage. The maximum allowable brief excursion of applied voltage that an SSR can withstand without damage or malfunction while maintaining its off state.

Transistor. Generally a three-terminal semiconductor device with dc current flow between two terminals modulated by the third. A bipolar transistor is essentially a current-controlled device, while a field-effect transistor is a voltage-controlled device.

Triac. Bidirectional semiconductor of the thyristor family. Performance is similar to that of an inverse pair of SCRs, triggered by a single gate electrode.

Turn-off time (Maximum). The maximum time between the removal of the turn-on control signal and the transition of the output device to its blocking (off) state.

Turn-off voltage. The voltage applied to the input at or below which the output is guaranteed to be in the off state.

Turn-on time (Maximum). The time between the application of a turn-on control signal and the transition of the SSR output to its fully conducting state.

Turn-on voltage (Must Operate). The voltage applied to the SSR input at or above which the output must be in the on state (normally open).

Varistor. See Metall Oxid Varistor (MOV).

Zero Voltage Turn-On. The maximum (peak) off state voltage that appears across the SSR output terminals immediately prior to initial turn-on, following a turn-on control signal.