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5975062 MELCHER INC 89D 00043 D

T-58-11-31

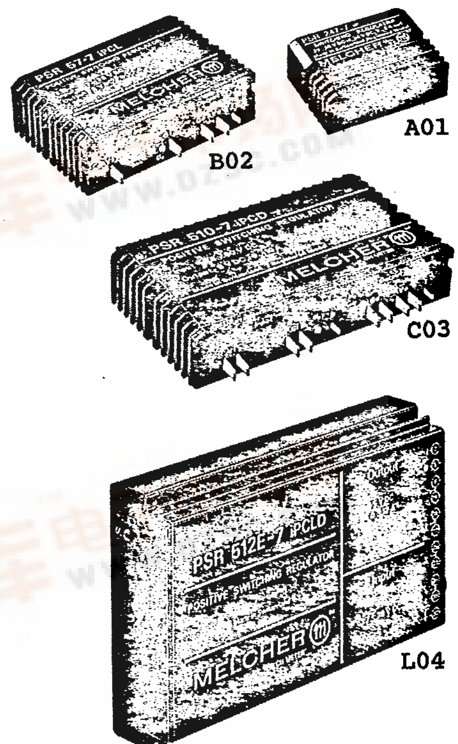
Positive Switching Regulators PSR 5 V, 12 V, 15 V, 24 V, 36 V

Negative Switching Regulators NSR -5 V, -12 V, -15 V, -24 V, -36 V

No input to output isolation

Special Features

- Exceptionally large input voltage range
- Low input-to-output differential voltage
- Direct replacement for linear regulators
- High efficiency, 77...94 %, depending on output voltage and case
- Output ratings 15...288 W, depending on output voltage and case
- No input capacitor required in battery operating mode*
- Metal case - self-cooling
- Continuously open-circuit and short-circuit-proof
- Can be wired in parallel configurations
- No derating
- Adjustable output voltage with option P or R
- PSRs compatible with SMR switching regulators
- Compact dimensions
- 150 kHz technology with power FETs
- High reliability
- Undervoltage cut-out
- Various options available



Made in Switzerland
Int. patents pending

MELCHER INC 89 DE 5975062 0000043 6

Block Diagrams

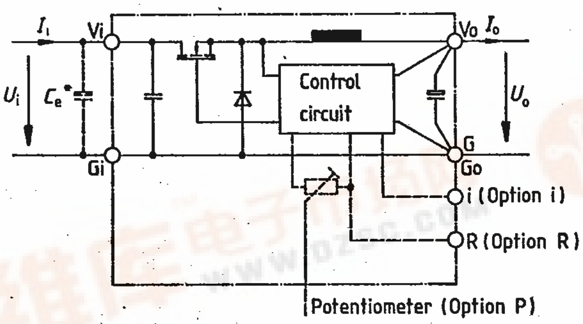


Fig. 1
Block diagram PSR

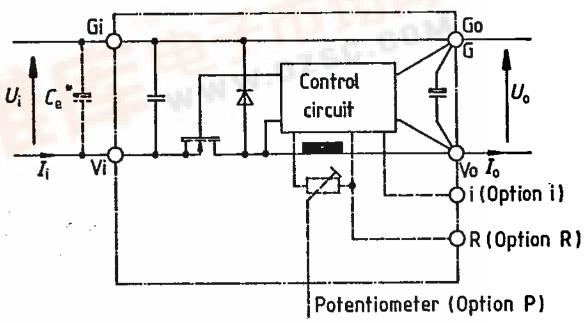


Fig. 2
Block diagram NSR

* External input circuitry required only in special cases:
- in rectifier mode or if the sum of the lengths of the two input lines is greater than
- 300 to 500 mm with case A01. See page 10 "2.1 Case A01"

urvey PSR

Nominal output voltage $U_{o\ n}$	Nominal output current $I_{o\ max}$	Input voltage range U_i [4])	Nominal input voltage $U_{i\ n}$	Efficiency η_{typ} at $U_{i\ n}$ and $I_{o\ max}$	Type T_A=0...+71 °C[1]) T_C=0...+95 °C[1])	Type T_A=-40...+71 °C[1]) T_C=-40...+95 °C[1])	Case	Available options [2]) Preferential types see price list
5 V	3 A	8...80 V	40 V	79 %	PSR 53-7	PSR 53-9	A01	i,P,R
	4 A	7...38 V	20 V	84 %	PSR 54-7	PSR 54-9		
	5 A	7...35 V		83 %	PSA 55-7[3])	PSA 55-9[3])		
		8...80 V	40 V	79 %	PSR 55-7	PSR 55-9	B02	L,i,P,R,C
	7 A	7...38 V	20 V	84 %	PSR 57-7	PSR 57-9		
	10 A	8...80 V	40 V	77 %	PSR 510-7	PSR 510-9	C03	L,i,P,R,C,D,D1,M
					PSR 510E-7	PSR 510E-9	L04	L,Q,i,P,R,C,D,D1,A,K
	12 A	7...38 V	20 V	82 %	PSR 512-7	PSR 512-9	C03	L,i,P,R,C,D,D1,M
					PSR 512E-7	PSR 512E-9	L04	L,Q,i,P,R,C,D,D1,A,K
12 V	2.5 A	15...80 V	40 V	89 %	PSR 122.5-7	PSR 122.5-9	A01	i,P,R
	4 A				PSR 124-7	PSR 124-9	B02	L,i,P,R,C
	8 A				PSR 128-7	PSR 128-9	C03	L,i,P,R,C,D,D1,M
					PSR 128E-7	PSR 128E-9	L04	L,Q,i,P,R,C,D,D1,A,K
15 V	2.5 A	19...80 V		91 %	PSR 152.5-7	PSR 152.5-9	A01	i,P,R
	4 A			90 %	PSR 154-7	PSR 154-9	B02	L,i,P,R,C
	8 A			91 %	PSR 158-7	PSR 158-9	C03	L,i,P,R,C,D,D1,M
					PSR 158E-7	PSR 158E-9	L04	L,Q,i,P,R,C,D,D1,A,K
24 V	2 A	29...80 V	50 V	94 %	PSR 242-7	PSR 242-9	A01	i,P,R
	4 A			93 %	PSR 244-7	PSR 244-9	B02	L,i,P,R,C
	8 A				PSR 248-7	PSR 248-9	C03	L,i,P,R,C,D,D1,M
					PSR 248E-7	PSR 248E-9	L04	L,i,P,R,C,D,D1,A,K
36 V	2 A	42...80 V	60 V	95 %	PSR 362-7	PSR 362-9	A01	i,P,R
	4 A				PSR 364-7	PSR 364-9	B02	L,i,P,R
	8 A			94 %	PSR 368-7	PSR 368-9	C03	L,i,P,R,D,D1,M
					PSR 368E-7	PSR 368E-9	L04	L,i,P,R, D,D1,A,K

T-58-11-31

urvey NSR

Nominal output voltage $U_{o\ n}$	Nominal output current $I_{o\ max}$	Input voltage range U_i 4)	Nominal input voltage $U_{i\ n}$	Efficiency η_{typ} at $U_{i\ n}$ and $I_{o\ max}$	Type T_A=0...+71 °C 1) T_C=0...+95 °C 1)	Type T_A=-40...+71 °C 1) T_C=-40...+95 °C 1)	Case	Available options 2) Preferential types see price list
-5 V	- 3 A	-8...-80 V	-40 V	79 %	NSR 53-7	NSR 53-9	A01	i,P,R
	- 4 A	-7...-38 V	-20 V	84 %	NSR 54-7	NSR 54-9		
	- 5 A	-7...-35 V		83 %	NSA 55-7 3)	NSA 55-9 3)		
		-8...-80 V	-40 V	79 %	NSR 55-7	NSR 55-9	B02	L,i,P,R,C
	- 7 A	-7...-38 V	-20 V	84 %	NSR 57-7	NSR 57-9		
	-10 A	-8...-80 V	-40 V	77 %	NSR 510-7	NSR 510-9	C03	L,i,P,R,C,D,D1,M
					NSR 510E-7	NSR 510E-9	L04	L,Q,i,P,R,C,D,D1,A,K
	-12 A	-7...-38 V	-20 V	82 %	NSR 512-7	NSR 512-9	C03	L,i,P,R,C,D,D1,M
					NSR 512E-7	NSR 512E-9	L04	L,Q,i,P,R,C,D,D1,A,K
-12 V	-2.5 A	-15...-80 V	-40 V	89 %	NSR 122.5-7	NSR 122.5-9	A01	i,P,R
	- 4 A				NSR 124-7	NSR 124-9	B02	L,i,P,R,C
	- 8 A				NSR 128-7	NSR 128-9	C03	L,i,P,R,C,D,D1,M
					NSR 128E-7	NSR 128E-9	L04	L,Q,i,P,R,C,D,D1,A,K
-15 V	-2.5 A	-19...-80 V		91 %	NSR 152.5-7	NSR 152.5-9	A01	i,P,R
	- 4 A			90 %	NSR 154-7	NSR 154-9	B02	L,i,P,R,C
	- 8 A			91 %	NSR 158-7	NSR 158-9	C03	L,i,P,R,C,D,D1,M
					NSR 158E-7	NSR 158E-9	L04	L,Q,i,P,R,C,D,D1,A,K
-24 V	- 2 A	-29...-80 V	-50 V	94 %	NSR 242-7	NSR 242-9	A01	i,P,R
	- 4 A			93 %	NSR 244-7	NSR 244-9	B02	L,i,P,R,C
	- 8 A				NSR 248-7	NSR 248-9	C03	L,i,P,R,C,D,D1,M
					NSR 248E-7	NSR 248E-9	L04	L,i,P,R,C,D,D1,A,K
-36 V	- 2 A	-42...-80 V	-60 V	95 %	NSR 362-7	NSR 362-9	A01	i,P,R
	- 4 A				NSR 364-7	NSR 364-9	B02	L,i,P,R
	- 8 A			94 %	NSR 368-7	NSR 368-9	C03	L,i,P,R,D,D1,M
					NSR 368E-7	NSR 368E-9	L04	L,i,P,R,D,D1,A,K

) T_A = ambient temperature range, T_C = case temperature range. See page 7 "Temperature".
) See page 4 for description of options.
) In contrast to our general specifications, these types have a linear derating of the maximum output current from 5 A to 4 A between T_A = 61 °C and 71 °C (T_C = 85 °C and 95 °C).
) See table page 4 "Minimum Differential Voltage $\Delta U_{io\ min}$".

ther output voltages and currents on request.

Electrical Data

General conditions:
T_A = +25°C if T_C is not specified.
With options P and R, output voltage U_o is set to $U_{o\ n}$ at $U_{i\ n}$ and $I_{o\ max}$.
With option i, terminal i is open or connected with Go.

Parameter	Condition	Value for devices with $\lvert U_{o\ n} \rvert$					Unit
		5 V	12 V	15 V	24 V	36 V	
Output voltage $\lvert U_o \rvert$ min / max	$U_{i\ n}$, $I_{o\ max}$	4.97 / 5.03	11.92 / 12.07	14.91 / 15.09	23.85 / 24.14	35.78 / 36.22	V
Output ripple u_{o} typ (approx. 150 kHz)	$U_{i\ n}$, $I_{o\ max}$	30	70	100	200	200	mV_{pp}
Static control deviation $\Delta U_{o\ U}$ versus input voltage	$U_{i\ min} \ldots U_{i\ max}$ $I_{o\ max}$	20	60	70	150	200	mV
Static control deviation $\Delta U_{o\ I}$ versus output current	$I_o = 0 \ldots I_{o\ max}$ $U_{i\ n}$	10	30	40	100	100	mV
Dynamic control deviation $u_{o\ d}$ typ	$U_{i\ n}$ $I_o = {}^2/_3 I_{o\ max}$ $\Delta I_o = \mp {}^1/_3 I_{o\ max}$	±70	±140	±150	±180	±200	mV
Load transient recovery time t_{rr} typ	$U_{i\ n}$ $I_o = {}^2/_3 I_{o\ max}$ $\Delta I_o = \mp {}^1/_3 I_{o\ max}$	20	20	20	20	70	µs
Output current limitation response $I_{o\ L}$	$U_{i\ min} \ldots U_{i\ max}$ $T_{C\ min} \ldots T_{C\ max}$	1 ...1.3					$I_{o\ max}$
Minimum voltage differential $\Delta U_{i\ o\ min} = U_i - U_o$	$I_o = 0 \ldots I_{o\ max}$ 3)	2 1) / 3 2)	3	4	5	6	V
Undervoltage cut-out $U_{i\ 0}$ typ	$T_{C\ min} \ldots T_{C\ max}$	6.3 1) / 7.3 2)	7.3	7.3	12	19	V
Idle input current $I_{i\ 0}$ typ	$I_o = 0$ $U_{i\ min} \ldots U_{i\ max}$	30...9					mA
Isolation test voltage circuit to case	All inputs and outputs interconnected	500					V DC

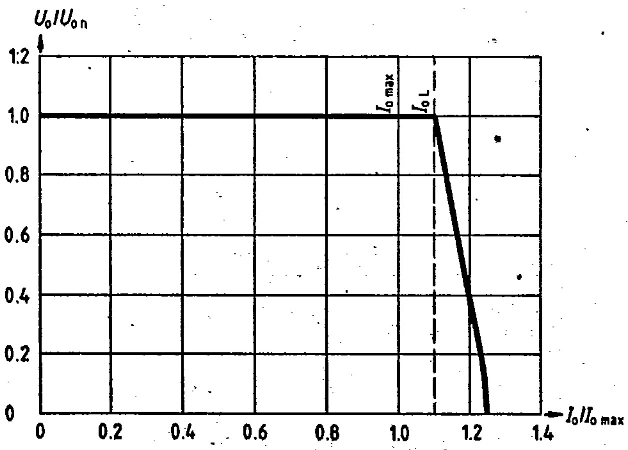


Fig. 3
Short-circuit behavior
Output voltage U_o vs. output current I_o

Electrical Options

Option L: Input filter; available for cases B02, C03, and L04
Option L is recommended for the prevention of oscillations if input lines exceeding approx. 5 m in length (see page 12 "4.2 Long Input Lines") are used and to reduce superimposed interference voltages.

The fundamental wave (approx. 150 kHz) of the reduced interference voltage between Vi and Gi has the following maximum magnitude with an input line inductance of 5 µH:
60 mV_{rms} with case B02; 4 mV_{rms} with cases C03 and L04.
The input impedance of the switching regulator at 150 kHz is about 17 Ω with case B02; 50 mΩ with cases C03 and L04.
With case B02, the insertion of a capacitance of 1 µF (plastic foil capacitor), for example, between Vi and Gi can achieve a further reduction to approx. 4 mV_{rms}.
The harmonics are small in comparison with the fundamental wave.

1) Applicable to PSR 54, NSR 54, PSA 55, NSA 55, PSR 57, NSR 57, PSR 512 and NSR 512
2) [illegible]

With option L, the maximum permissible additionally superimposed ripple u of the input voltage (rectifier mode) has the following value:

For PSR 57, NSR 57, PSR 512 and NSR 512: $u_{i\ max} = 12\ V_{pp}$ at 100 Hz,

$u_{i\ max} = \frac{1200\ Hz}{f}\ V_{pp}$ at other frequencies f.

For the other switching regulators: $u_{i\ max} = 22\ V_{pp}$ at 100 Hz,

$u_{i\ max} = \frac{2200\ Hz}{f}\ V_{pp}$ at other frequencies f.

The rectifier circuits described on page 11 under "3. Rectifier Operation" fulfill the above requirements.

<u>Option Q</u>: Center-tap rectifier; available with case L04 with nominal output voltage $|U_{o\ n}|$ = 5 V, 12 V, or 15 V.

The switching regulator with the center-tap rectifier can be powered directly by a center-tap transformer with two identical secondary windings. The ratings of the windings should be in the following ranges (assumed mains tolerance -15/+10 %):

For PSR 512E and NSR 512E: 2 x 16 V, 5.4 A...2 x 23 V, 3.8 A
For PSR 510E and NSR 510E: 2 x 28 V, 2.9 A...2 x 48 V, 1.6 A
For PSR 128E and NSR 128E: 2 x 37 V, 3.4 A...2 x 48 V, 2.5 A
For PSR 158E and NSR 158E: 2 x 42 V, 3.6 A...2 x 48 V, 3.0 A

The ambient temperature T_A should not exceed 46 °C at maximum output power. The output power must be derated linearly from 100 % to 35 % between T_A = 46 °C and 71 °C (T_C = 70 °C and 95 °C). See also page 11 "3.1 Dimensioning of Transformer".

With option Q, the terminals for DC power are accessible simultaneously. This allows a battery back-up mode, etc.

With option Q, an input filter is a standard feature. Therefore, it is not necessary to order option L also.

<u>Option i</u>: Inhibit terminal

The inhibit terminal i is used to switch the regulator output voltage U_o on and off with a control signal.

When the output is inhibited, the regulator input current $|I_{i\ inh}|$ is typically 8 ... 15 mA.
When the inhibit terminal is open (I_{inh} = 0) the output voltage is switched on.

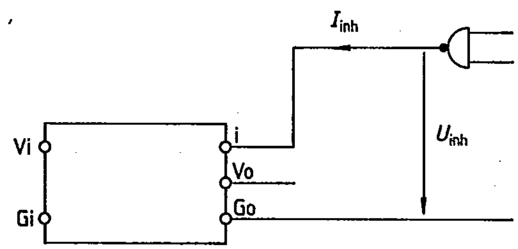


Fig. 4
Characteristics

Parameter	Device	Case A01 min	Case A01 max	Other cases min	Other cases max	Unit
Inhibit input voltage U_{inh}	PSR	-10	+50	-50	+50	V
	NSR	-50	+10	-50	+50	

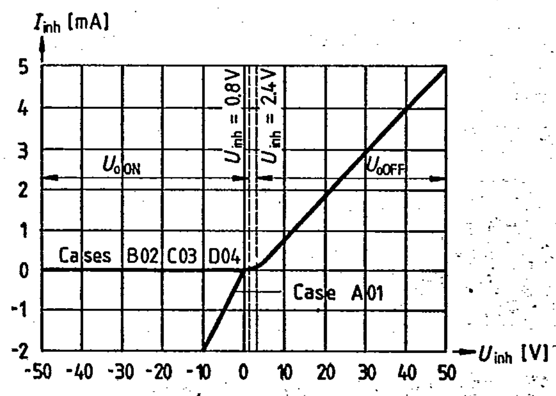


Fig. 5
Inhibit current I_{inh} vs. inhibit voltage U_{inh} for PSR

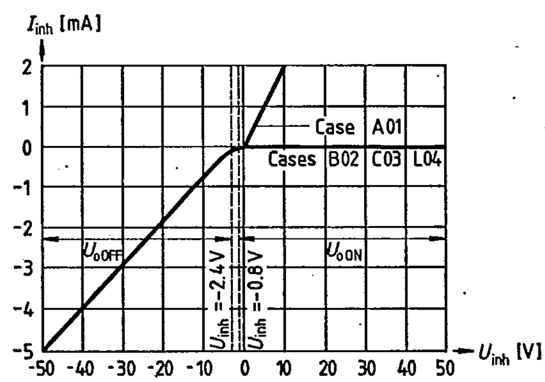


Fig. 6
Inhibit current I_{inh} vs. inhibit voltage U_{inh} for NSR

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Option P: Screwdriver-operable potentiometer

The output voltage U_o can be adjusted with a potentiometer in the range from 0.92...1.08 $U_{o\ n}$. When this is done, the minimal differential ΔU_{io} between input and output voltages specified on page 4 must be maintained.

Option R: Voltage adjustment terminals

The output voltage U_o can be adjusted with an external resistance R_{ex} or an external reference voltage U_{ex}. The adjustment range is 0...1.08 $U_{o\ n}$, for PSR and 0.65...1.08 $U_{o\ n}$ for NSR.

The minimal differential voltage ΔU_{io} between input and output voltage as specified on page 4 must be maintained. Options P and R cannot be installed together. Case L04 does not support options R and i simultaneously.

Voltage adjustment with U_{ex}

$$U_o = U_{ex} \cdot K$$

$$K = \frac{1.08\ U_{on}}{U_{ref}}$$

$$U_{ref} = 2.49\ \text{V} \pm 4\ \%\ \text{(PSR)}$$

$$U_{ref} = -2.49\ \text{V} \pm 4\ \%\ \text{(NSR)}$$

Voltage adjustment with R_{ex}

$$U_o = U_{o\ n} \cdot 1.08 \frac{R_{ex}}{R_{ex} + 4020\ \Omega}$$

$$R_{ex} = 4020\ \Omega \cdot \frac{U_o}{1.08\ U_{o\ n} - U_o}$$

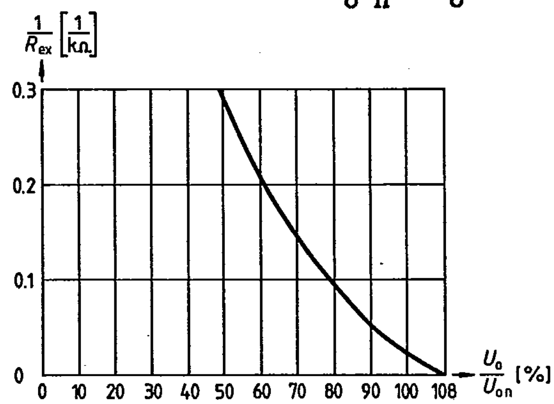

Fig. 7
Adjusting conductance $1/R_{ex}$ vs. output voltage U_o

PSR

$0 \leq U_{ex} \leq U_{ref}$
$\hat{=}\ 0 \leq U_o \leq 1.08\ U_{o\ n}$

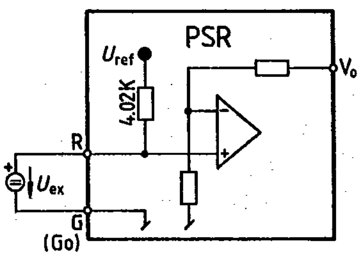

Fig. 8

PSR

$0 \leq R_{ex} < \infty$
$\hat{=}\ 0 \leq U_o \leq 1.08\ U_{o\ n}$

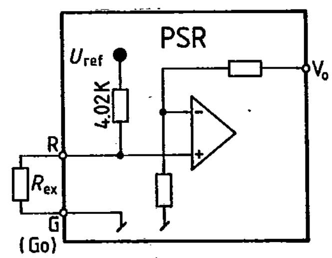

Fig. 9

NSR

$-1.5\ \text{V} \geq U_{ex} \geq U_{ref}$
$\hat{=}\ 0.65\ U_{o\ n} \geq U_o \geq 1.08\ U_{o\ n}$

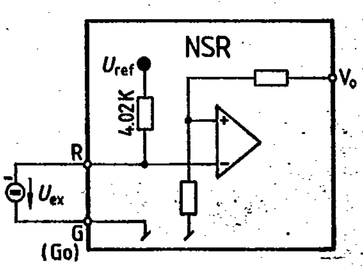

Fig. 10

NSR

$6.1\ \text{k}\Omega \leq R_{ex} < \infty$
$\hat{=}\ 0.65\ U_{o\ n} \geq U_o \geq 1.08\ U_{o\ n}$

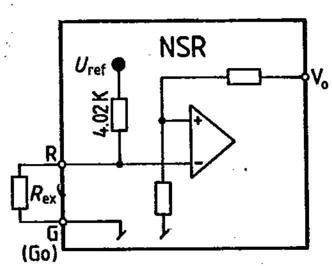

Fig. 11

Option C: Thyristor crowbar; available with cases B02, C03, and L04.

If voltage $|U_{o\ s}|$ at the regulator output is exceeded, a thyristor is fired to discharge a continuous short-circuit current of 8 A (case B02) or 15 A (case C03 and L04). The output voltage $|U_o|$ is less than 1 V.
The thyristor is thermally connected with a temperature sensor which inhibits the regulator output if the temperature becomes too high.
If a defective switching transistor has caused the overvoltage, a fuse incorporated in the regulator will respond to prevent excess current.
Option C is not available for $|U_{o\ n}|$ = 36 V.

Parameter	for $\|U_{o\ n}\|$ =				Unit
	5 V	12 V	15 V	24 V	
Response voltage $\|U_{o\ s}\|$ for $T_{C\ min}...T_{C\ max}$	5.8...6.58	13.5...15.2	16.9...19	27...31	V

Option D: Input undervoltage monitor; available with cases C03 and L04.

Terminal D is connected with the drain of an FET whose source is wired to Go. If the input voltage is sufficient, it is highly resistive ($R_{DS\ OFF}$ > 10 MΩ), if it is insufficient, it has low resistance ($R_{DS\ ON}$ < 200 Ω).
In the battery operating mode, for example, this feature can be used to indicate the status of the battery. In the rectifier operating mode (with a charging capacitor of sufficiently large capacity), this feature will guarantee a minimum hold time of the output voltage after the transition to low resistance in the event of a power failure (save data).

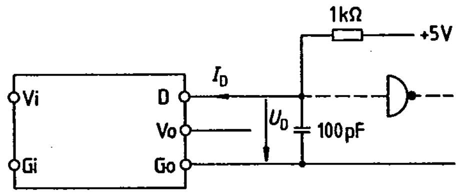

Fig. 12
Definitions

The threshold voltage U_t can be adjusted via a potentiometer using a screwdriver.

Permissible voltage U_D: 0...+8 V (PSR); -8...0 V (NSR)
Permissible current I_D: 0...+5 mA (PSR); -5...0 mA (NSR)

Option D1: Output undervoltage monitor; available for cases C03 and L04.

Same circuit principle as option D, but response to output undervoltage instead of to input undervoltage.
Options D and D1 cannot be implemented simultaneously.

Option A: Test socket; available with case L04

The device has a test socket accepting 2 mm diameter plugs on the front side for measuring the output voltage U_o.

Environmental Conditions

Temperature

Ambient air operating temperature T_A and switching regulator case operating temperature T_C are specified on pages 2 and 3. The storage temperature range T_S is from -40 to +100 °C for all types.
When a switching regulator is located in free, quasi-stationary air at a temperature T_A of +71 °C and is operated at its nominal output power, the case temperature T_C will be about 95 °C after the warmup phase (measured at the measuring point of case temperature T_C, see page 8f "Mechanical Data").
Under practical operating conditions the ambient temperature T_A may exceed +71 °C provided additional measures are taken to ensure that the case temperature T_C does not exceed 95 °C.

Vibration

The switching regulators have passed the following vibration test (type test):
Vibration (sinusoidal) test Fc according to DIN 40 046 Part 8 and IEC 68-2-6, 3 axes, 2 h 30 min. each.

Case A01 : 0.7 mm (10...60 Hz), 10 g_n (60 ...2000 Hz)
Case B02, C03 and L04: 0.35 mm (10...60 Hz), 5 g_n (60 ...2000 Hz)

Mechanical Data

Dimensions in mm. Tolerances ± 0.3 mm unless otherwise specified.

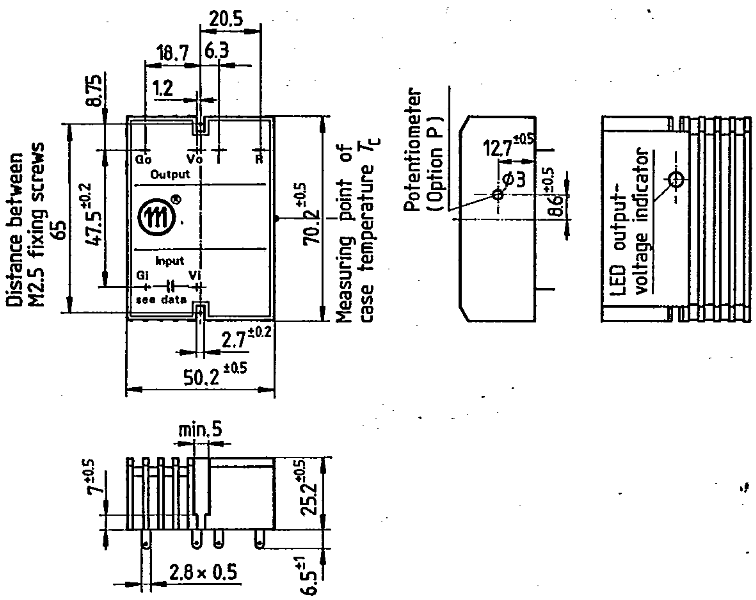

Fig. 13
Case A01 (Weight 100 g)

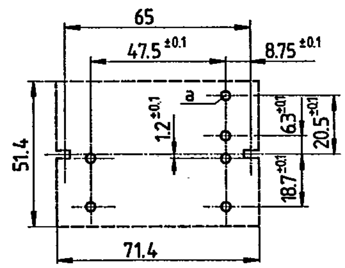

Fig. 14
Case A01 hole locations for circuit board mounting.
Viewed from component side.
---- = space reserved for switching regulator
a for manual soldering = 3.0 dia
a for machine or manual soldering = 3.0 x 0.7 slot or = 3.0 dia. through-plated

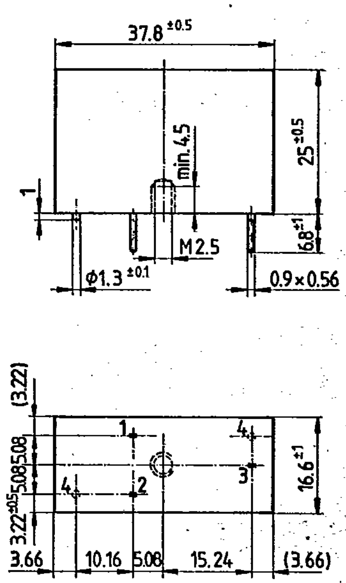

Fig. 15
Melcher input filter (weight 30 g) for switching regulator in case A01, see Fig. 22

1 = Vio
2 = Vii
3 = Gi
4 = Positioning pins

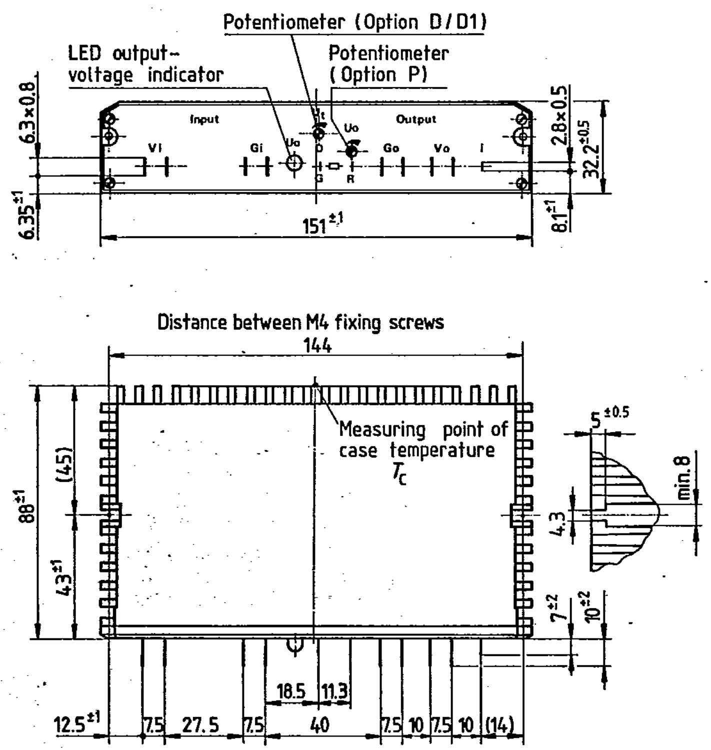

Fig. 16
Case C03 (weight 440 g)

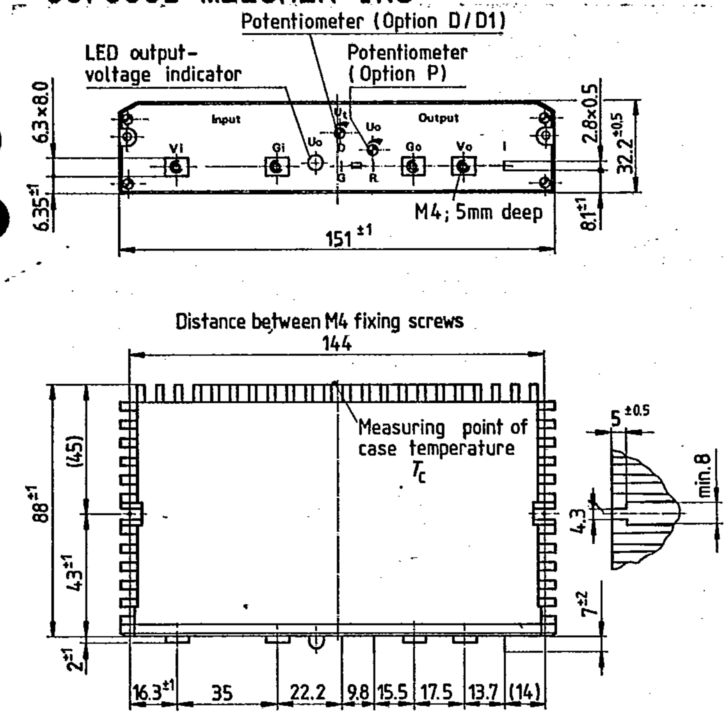

Fig. 17
Case C03 with option M (weight 450 g)

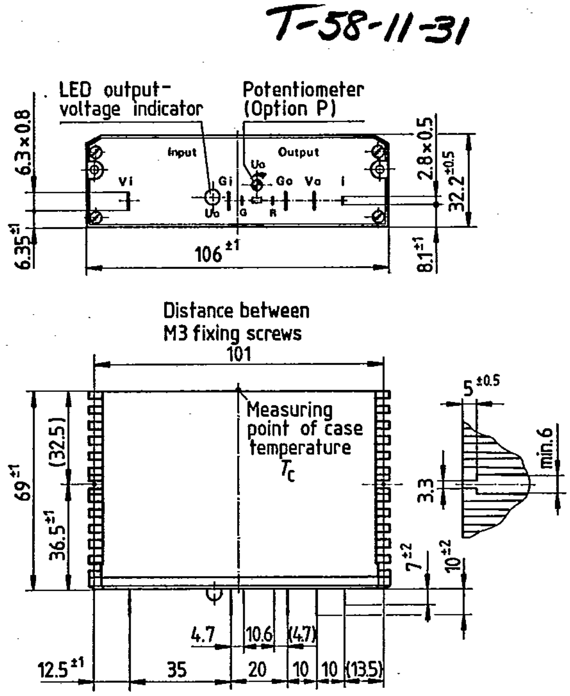

Fig. 18
Case B02 (weight 230 g)

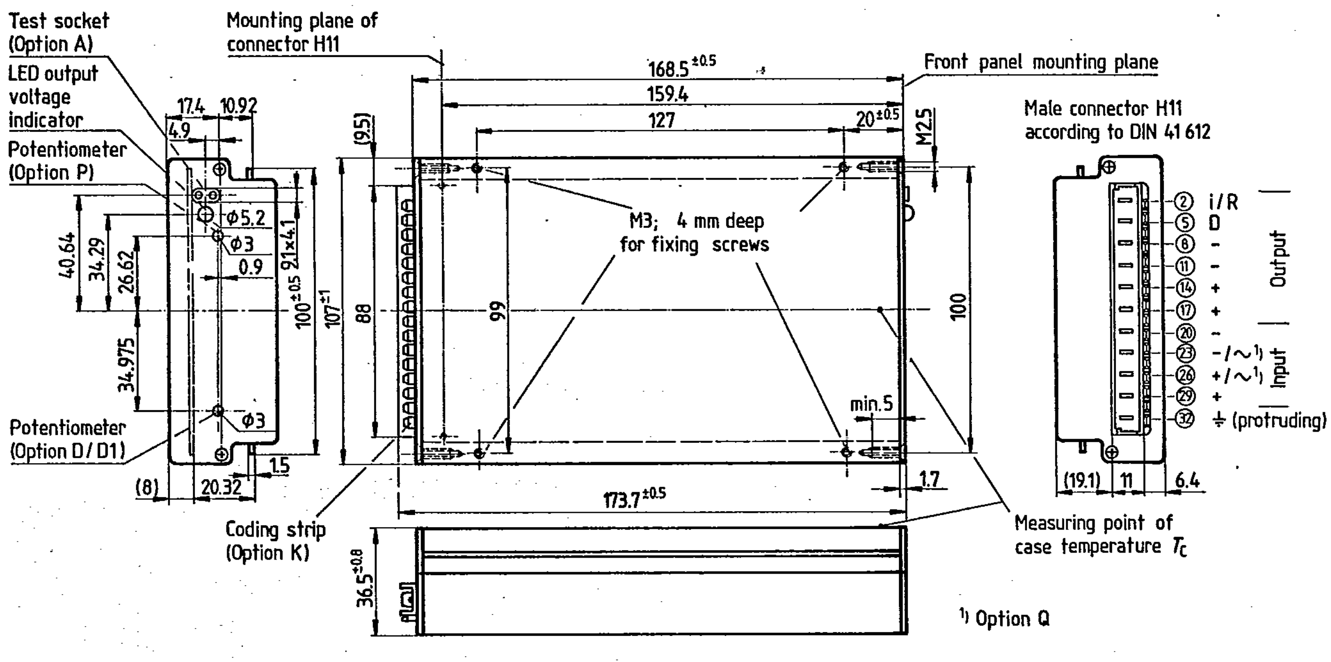

Fig. 19
Case L04 (weight 550 g)

Accessories for Case L04	Designation
□ Female connector (mates with built-in male connector H11)	STV-N-311
□ Coding strip (mates with coding strip for option K)	Coding strip F
□ Front panel Schroff system, width 8 units (40.3), height 128.4	Front panel G08-L04*
□ Front panel Intermas system, width C08 (40.3), height 128.4	Front panel F08-L04*

Mechanical Options

Option M: Screw terminals instead of Faston connectors for Vi, Gi, Vo and Go; available for case C03. See Fig. 17.

Option K: Coding strip to prevent insertion of wrong device; available for case L04. See Fig. 19.

* If device incorporates option(s) P and/or D or D1 and/or A, add hyphen to product designation and all corresponding designation(s) as suffix. Example: G08-L04-PA

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Application Notes

T-58-11-31

1. Basic Requirement

The following basic requirements must be complied with to ensure correct operation of a PSR/NSR switching regulator:

The input voltage range specified on page 2 or page 3 must be strictly adhered to.

For options R and P, the minimum difference ΔU_{io} between input and output voltage specified on page 4 must be maintained.

The extreme values of any superimposed AC voltages must also be taken into consideration (e.g. line ripple, ripple caused by reactive currents).

The alternating voltage component developed by the switching regulator without option L, without external input capacitor and with a line inductance value L_L of at least 2 µH has a maximum value of 0.8 V_{pp} for $U_{i\ min}$ and $I_{o\ max}$ (measuring bandwidth 20 MHz). In the case of a short circuit, it must not exceed 2 V_{pp} at approx. 10 to 100 kHz.

Depending on the type of unit and the nature of the power supply source, various consequences result herefrom:

2. External Input Circuitry

2.1 Case A01

A switching regulator in case A01 can be operated with an input line length a + b of up 500 mm (sum of positive and negative input lines, see Fig. 20) without additional external circuitry. However the two input lines must be twisted if they are longer than 300 mm.
If the input line length exceeds 500 mm, an external (electrolytic) input capacitor C_e with a capacitance value of at least 100 µF must be connected across the switching regulator input terminals Vi and Gi (Fig. 21). However, the connection line lengths a + b together must not exceed 500 mm twisted or 300 mm untwisted.

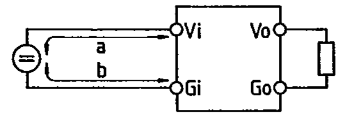

Fig. 20
Switching regulator without external input circuitry

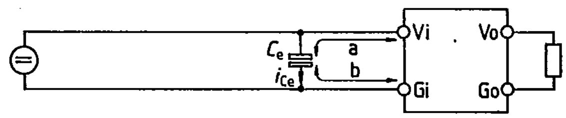

Fig. 21
Switching regulator with external input capacitor C_e

An alternating current thereby passes through the capacitor.
With a maximum length a + b = 150 mm, this current i_{Ce} can be up to 2.7 A_{rms} with a frequency of at least 10 kHz; with 500 mm (twisted) it is 3.2 A_{rms}.

The current loading is 2.7 $A_{rms} \cdot \sqrt{n}$ if the inputs of n switching regulators are connected in parallel. The data sheets of capacitor manufacturers state the maximum permissible rms ripple currents versus ambient temperature and frequency.

As shown in Fig. 22, a Melcher input filter can be wired into the input lines in place of capacitor C_e in Fig. 21.
Dimensions Fig. 15
Filter FP 38 is suitable for PSR 54 and PSA 55; filter FP 80 is suitable for all other PSRs. Filter FN 38 is suitable for NSR 54 and NSA 55; filter FN 80 is suitable for all other NSRs.

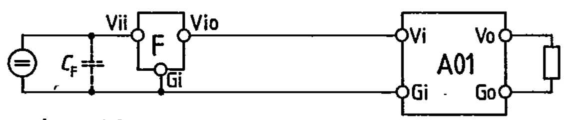

Fig. 22
Switching regulator in case A01 with external Melcher input filter.

The shortest possible connection between filter and switching regulator is recommended if the intention is to use the filter to reduce interference voltages and currents at the same time. Longer connection lines up to about 2 m will not affect the operation of the switching regulator. The filter increases the source impedance of the regulator interference voltage to about 25 Ω. In normal cases, this value is large compared to the impedance Z_s of the supply source and thus determines the interference current that flows. This current has a maximum value of 10 mA_{rms}. The frequency of the fundamental wave is about 150 kHz. The remaining interference voltage u_{is} at the supply source is calculated as u_{is} = 10 mA · Z_s. The addition of a capacitor C_F reduces the interference voltage still further.

If the inputs of a number of switching mode regulators are connected in parallel, each one must be provided with its own Melcher input filter, whereby the individual lines between Vio and Vi must not be interconnected.

A capacitor is required for rectifier operation in all cases. See "3.2 Dimensioning Capacitor C_L".

2.2 Cases B02, C03 and L04

Switching regulator in these cases can be operated with input line lengths a + b (Fig. 20) of about 5 m (or with connecting line induction values of less than about 5 µH) without the need for additional circuitry. Option L is recommended in the case of longer input lines. See page 12 "4.2 Long Input Lines".

However, if switching regulators are to be used without option L, an external capacitor C_e may be necessary (Fig. 21). See page 12 "4.2 Long Input Lines". If a capacitor is connected directly across input terminals Vi and Gi, a maximum current of 2.6 A_{rms} (about 150 kHz) will flow; in the case of an input line length a + b = 400 mm 1.5 A_{rms} at the most. The capacitor must be capable of handling this current.

3. Rectifier Operation

When operating in the rectifier mode, there must be no underride of the input voltage specified for the switching regulator at full load and at lowest line voltage nor an override in the no-load condition at the highest line voltage.
This requires an external charging capacitor C_L in all cases without option Q.
Figs. 23 and 24 show two examples of power supply systems with rectifier circuits.

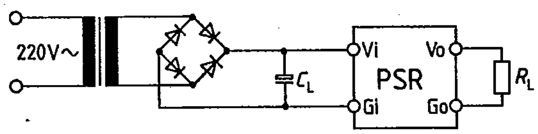

Fig. 23
Power supply system with bridge-type rectifier circuit

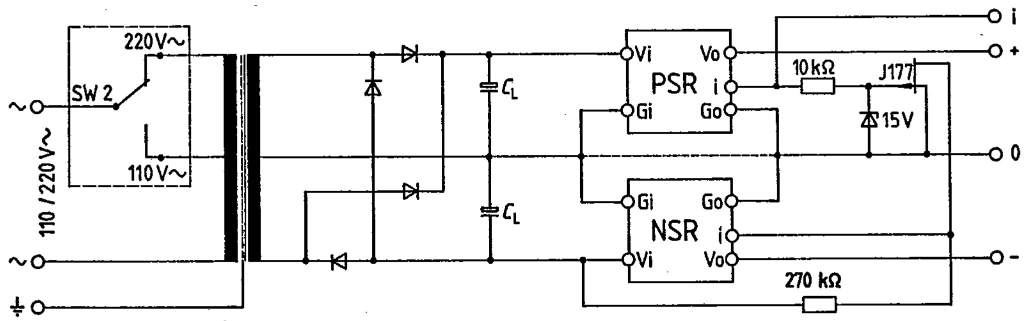

Fig. 24
Bipolar power supply system with dual center tap, level shift feature for inhibit and an SW 2 voltage selector at the input.

Systems with up to three switching regulators in case A01 including rectifier and charging capacitors or Melcher filters are available from us on standard Eurocards.

3.1 Dimensioning of Transformer (Single Phase)

When a transformer is operated with a rectifier and a charging capacitor, it does not have to supply current during the (long) non-conducting phase of the rectifier but is then exposed to a correspondingly larger load during the conducting phase. The root mean square value of this pulsating current is nearly twice as high as the average value. The rated power of the transformer must be at least twice the input rating of the regulator if a mains voltage tolerance of -15 %/ +10 % is assumed. The input power of the regulator can be calculated from the output power and from the operating efficiency value η specified on page 2 or 3. Example PSR 512-7: Output power = 5 V · 12 A = 60 W, efficiency = 82 %. Thus, the input power is 60 / 82 · 100 = 73 W and the transformer power 2 · 73 plus a reserve = 180 VA, for instance.
The power ratings of transformers are usually valid for a maximum ambient temperature of 40 °C. If higher temperatures are expected, thermal considerations must be taken into account when calculating the rating (consult transformer manufacturer).
Assuming a power supply line tolerance of -15 %/+10 %, a 22 V_{rms} nominal transformer secondary voltage is recommended for P/NSR 54, P/NSR 57 and P/NSR 512; for P/NSA 55: 20 V_{rms} and for all other switching regulators $U_{tr\ s\ rms}$ = 42 to 48 V_{rms}.

3.2 Dimensioning Capacitor C_L

In the cases of bridge or center-tapped circuits, a mains voltage tolerance of -15 %/+10 %, a mains frequency of 50 or 60 Hz and the above-recommended transformer voltage, the capacity C_L and the current load i_{CL} of the capacitor under the charging current can be calculated by the following rules of thumb:

For P/NSR 54, P/NSA 55, P/NSR 57 and P/NSR 512: $C_L \cong P_o \cdot 35\ \mu F/W$ (nominal voltage U_n = 40V) (1)

$i_{CL\ rms} \cong C_L \cdot 3\ mA/\mu F$ (at 100/120 Hz) (2)

For the other switching mode regulators: $C_L \cong \frac{P_o}{U_{tr\ s} - U_o} \cdot 200\ \mu F/A$ (nominal voltage U_n = 100 V) (3)

$i_{CL\ rms} \cong C_L\ (U_{tr\ s} - U_o) \cdot \frac{0.3\ mA}{\mu F \cdot V}$ (at 100/120 Hz) (4)

where P_o is the output power $U_o \cdot I_o$ of the regulator.

Example PSR 512-7: P_o = 60 W, $C_L \cong$ 60 W · 35 µF/W = 2100 µF.
Nominal value = 2200 µF, 40 V. $i_{CL\ rms} \cong$ 2200 µF · 3 mA/µF = 6600 mA = 6.6 A.

When the inputs of a number of switching regulators are connected in parallel, the sum of the output powers of these switching regulators must be used for P_o to calculate C_L with formulas (1) or (3) and the highest of the output voltages must be used for U_o.

In the case of devices without option L and without external input filter, an additional current will flow through the capacitor (see "2. External Input Circuitry"). This current must be taken into account when the capacitor rating is determined. In general, it is sufficient to rate the capacitor for the larger of the two currents.
If for case A01 the connection lines C_L to Vi and C_L to Gi cannot be made shorter than 500 mm (twisted) or 300 mm (untwisted), a second capacitor C_e must be connected with shorter lines or the Melcher input filter used.
For the other cases with option L, the critical line length lies in region above 5 meters. (See "4.2 Long Input Lines"). Line length is irrelevant for devices with option L. However, it must be ascertained that the maximum input voltage ripple quoted on page 5 above is not exceeded. This requirement is fulfilled by the capacity values calculated according to formulas (1) and (3).

3.3 Rectifier Rating

In bridge or center-tapped circuits, each diode conducts a pulsating direct current whose peak value corresponds to about four times that of the capacitor current i_{CL}. In the above example then, 4 · 6.6 A = 26.4 A.
The mean current flowing though each diode is about one half the current value obtained when the regulator input power is divided by the rated voltage of the transformer.

In the example, this is 73 W/22 V/2 ≅ 1.6 A (bridge circuit).

A transient peak current occurs when the system is switched on. This peak current can be about seven times the pulsating peak current in the case of a center-tapped circuit and up to 15 times this value in a bridge circuit. Thus, for a bridge circuit the maximum transient peak current in the example is 15 · 26.4 A ≅ 396 A. The blocking voltage of the diodes must be at least

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4. Negative Internal Resistance r_i:

The efficiency η of a switching regulator is almost constant over the entire input voltage range U_i. This results in a larger input current I_i for a low input voltage than for a high input voltage. This corresponds dynamically (in terms of alternating current) to a negative internal resistance r_i.

4.1 Operation with Current Limiting Device in the Input Circuit
(laboratory power supply unit, fuses)

Example: A PSR 55-7 switching regulator (5 V, 5 A, efficiency η = 79 %) is to be operated with an input voltage U_i = 48 V. The result of the calculation indicates that an input current I_i of about 650 mA will be required. When the input voltage rises from zero (power on transient or continuous voltage increase), the voltage will pass level U_i = 8 V at which the switching regulator (if it is not inhibited with option i, and if its output is fully loaded) requires an input current of 4 A.

If the current limitation value of the source is lower than 4 A, this will prevent the voltage from rising to the required value. It is possible to inhibit the switching regulator via terminal i (option i) and to reenable it after the required input voltage has been attained. Also, the load cannot be connected until after the source has been switched on.

This operating characteristic is not a problem when battery or rectifier operation is involved, since no current limiting takes place under normal circumstances. However, this characteristic must be taken into account when fuse ratings are being calculated.

4.2 Long Input Lines

If the input lines between the switching regulator and the supply source or the nearest capacitor (with a capacitance of at least 100 µF) are longer than about 5 meters, special measures may be necessary for devices in cases B02, C03 and L04 without option L. (When long input lines are involved, the switching regulators in case A01 always require an external capacitor or an external filter. See 2.1. "Case A01".)

The negative internal resistance r_i of the switching regulator together with the inductance L_L of its connecting lines and with the capacitor C_i (built into the switching regulator), naturally forms a parallel resonant circuit (Fig. 25). If the resonant frequency of this circuit is significantly lower than the switching frequency of the regulator (this is so in the case of a large L_L), the circuit may be excited by r_i. This can cause the input voltage of the switching regulator to leave the specified range. A resonant condition must be therefore be avoided by the adoption of suitable measures.

Now

$$r_i = -\frac{(U_{i\ min})^2}{P_{o\ max}} \cdot \frac{\eta}{100} \qquad (5)$$

where
$U_{i\ min}$ = minimum regulator input voltage occurring during normal operation.
$P_{o\ max}$ = maximum output power occurring during normal operation.
η = Percentage efficiency of switching regulator (specified on page 2 or page 3).

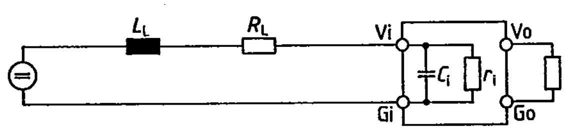

Fig. 25
Switching regulator without option L with long input lines

The circuit does not oscillate if

$$\frac{L_L}{R_L} < -C_i \cdot r_i \qquad (6)$$

where

L_L = inductance of input lines (a + b in accordance with Fig. 20) to the nearest voltage source. An inductance of about 1 nH/mm of input line length may be assumed for calculation purposes. A capacitor larger than about 100 µF may be treated as a voltage source.

R_L = Total resistance of input lines and source or input lines and series resistance of the capacitor.

C_i = 13.6 µF (case B02), 27.2 µF (cases C03 and L04).

If the calculation shows that inequality (6) is not satisfied, it will be necessary to adopt one of the measures listed below.

- Use devices with option L (built-in input filter, available in cases B02, C03 and L04).
- Reduce input line inductance L_L (twisting the two lines reduces the inductance to about 70%)
- Introduce an external capacitor C_e between Vi and Gi (Fig. 21) with a capacitance value of

  $$C_{e\ min} = -\frac{L_L}{R_L \cdot r_i} - C_i$$

  Also observe the contents of section "2. External input circuitry" when determining the characteristics of the capacitor.

- Increase resistance R_L in the input lines (smaller cross section). This step is usually not desirable because of the associated additional losses involved.

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