iC-GE
PWM RELAY/SOLENOID DRIVER

preliminary

iC·Haus

FEATURES

- Current control for inductive actuators at 24 V (10 to 36 V)
- High efficient current control up to 1 A
- Power saving and power dissipation reduced switching
- Individual setting of energising and hold current
- Monitoring of coil current, supply voltage and temperature
- Status indication via LED or logic output
- Contact conserving switching of relays synchronous to the mains
- Shutdown with overtemperature and undervoltage
- Fast demagnetising due to 15 V countervoltage
- High PWM frequency mit frequency spreading for low EMI
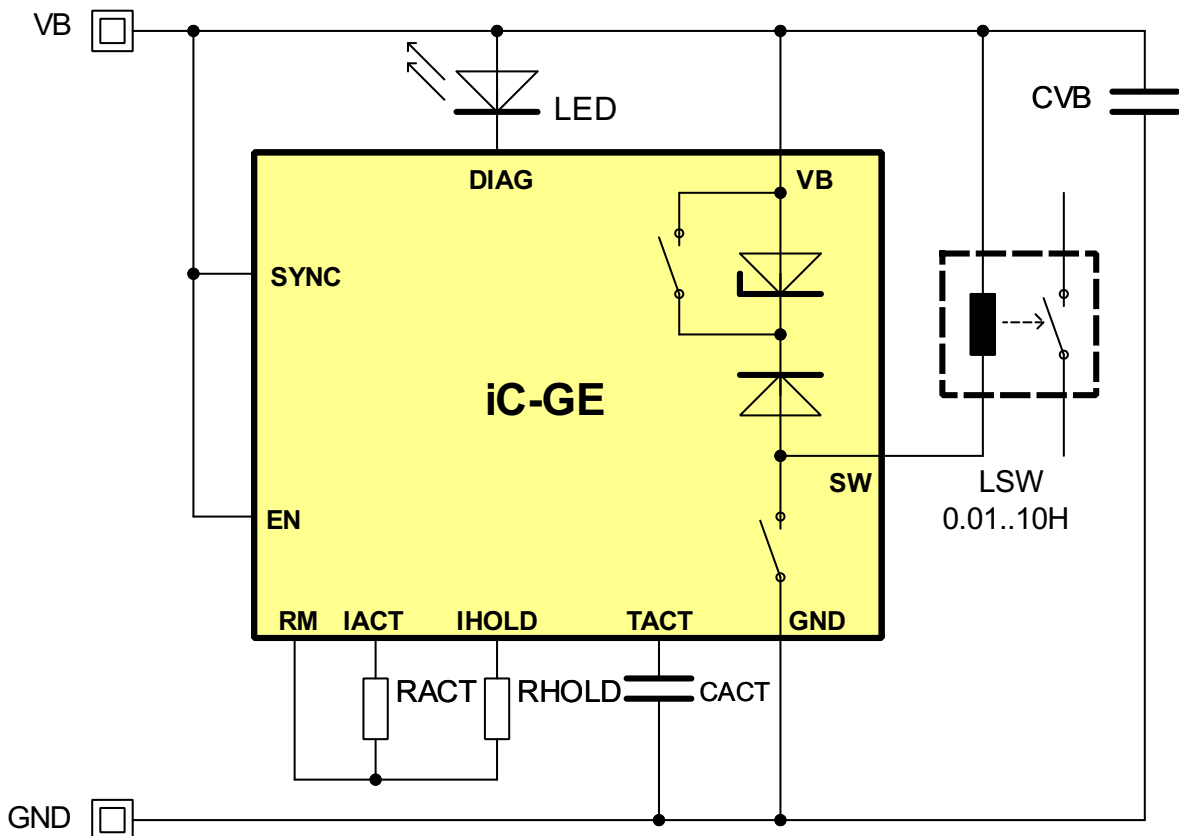- Energising time of 50 ms prolongable with external capacitor

APPLICATIONS

- PWM drive for inductive loads (e.g. 6/12 V relays, electrovalves) from 24 V
- Relay low-/high-side switch

PACKAGES
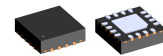
QFN16 4 x 4

BLOCK DIAGRAM

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DESCRIPTION

iC-GE is a PWM driver for inductive loads, such as relay coils, solenoid valves and other inductive loads.

The setpoints for the coil's energising and hold current are preset by means of external resistors RACT and RHOLD. These currents can be set in a range from 100 mA to 1 A. The iC-GE intrinsically switches from energising to hold mode after 50 ms provided that the set energising current has been reached. A capacitor at TACT prolongs the time before the switch to hold mode occurs.

The changeover between energising and hold modes is suitable for typical relay drives which require a powerful initial energising current which can then be reduced after closing the air gap in a magnetic circuit. The quadratic dependence on the current intensity means that cutting the current by halv reduces the power dissipation by ca. 75%.

Using PWM the output current is controlled to the values set at RACT and RHOLD. The internal flyback diode maintains the current during the switching pauses. The switching frequency of ca. 80 kHz is provided by the internal oscillator. Varying this frequency between 70 kHz and 90 kHz reduces the EMI.

The device is shutdown by a Low signal at input EN or the removal of the power supply; the current reduction in the coil is supported by the changeover of the free-wheeling circuit. The Zener diode now active permits higher free-wheeling voltages and thus a quicker demagnetising of the coil.

The status indicator LED is constantly ON when hold mode is functioning correctly and flashes with low voltage, excessive temperature or when the coil current in energise mode has not reached the setpoint. The driver output is shutdown with low voltage or excessive temperature. Alternatively to using an LED output DIAG signals the correct operating by outputting a high signal.

The input signal at EN can be synchronised with the zero crossing at input SYNC. Thus by using an external R/C network, the switching of the coil can be synchronised with the load current of e.g. the relay.

PACKAGES SO8, PDIP8 to JEDEC

PIN CONFIGURATION QFN16 4 mm x 4 mm
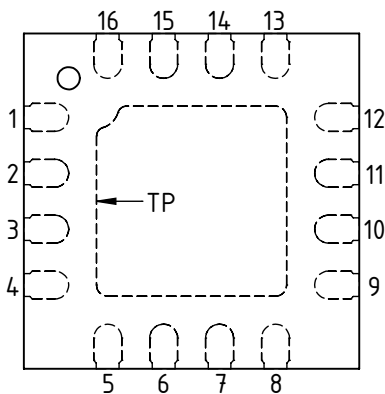
PIN FUNCTIONS

No.	Name	Function
1	EN	Enable Input
2	GND	Ground
3	GND	Ground
4	GND	Ground
5	SW	PWM Output
6	SW	PWM Output
7	SW	PWM Output
8	VB	+10...36 V Supply Voltage
9	VB	+10...36 V Supply Voltage
10	VB	+10...36 V Supply Voltage
11	DIAG	Status Output
12	SYNC	Sync Input
13	RM	Reference Ground for RACT and RHOLD
14	TACT	Energising Time Prolongation
15	IHOLD	Hold Current Setup
16	IACT	Energising Current Setup

ABSOLUTE MAXIMUM RATINGS

Beyond these values damage may occur; device operation is not guaranteed.

Item No.	Symbol	Parameter	Conditions	Min.	Max.	Unit
G001	V(VB)	Voltage at VB		-0.3	37	V
G002	I(VB)	Current in VB		-1100	6	mA
G003	V(SW)	Voltage at OUT		-0.3	53	V
G004	I(SW)	Output Current in OUT		-6	1100	mA
G005	V(DIAG)	Voltage at LED		-0.3	37	V
G006	I(DIAG)	Current in LED		-6	8	mA
G007	V(IACT)	Voltage at ISET		-0.3	7	V
G008	I(IACT)	Current in ISET		-6	6	mA
G009	V(IHOLD)	Voltage at IHOLD		-0.3	7	V
G010	I(IHOLD)	Current in IHOLD		-6	6	mA
G011	V(EN)	Voltage at IN		-0.3	37	V
G012	I(EN)	Current in IN		-6	6	mA
G013	V(SYNC)	Voltage at SYNC		-7	37	V
G014	I(SYNC)	Current in SYNC		-6	6	mA
G015	V(TACT)	Voltage at TACT		-0.3	7	V
G016	I(TACT)	Current in TACT		-6	6	mA
G017	V(RM)	Voltage at RM		-0.3	1	V
G018	I(RM)	Current in RM		-6	6	mA
G019	VD()	Susceptibility to ESD at all pins	HBM 100 pf discharged through 1.5 kΩ		2	kV
G020	Tj	Junction Temperature		-40	150	°C
G021	Ts	Storage Temperature		-40	150	°C

THERMAL DATA

Operating Conditions: VB = 10...36 V, LSW = 0.01...10 H, RACT = 5...50 kΩ, RHOLD = 5...50 kΩ

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
T01	Ta	Operating Ambient Temperature Range		-40		85	°C
T02	Rthja	Thermal Resistance Chip/Ambient	Mounted to a PCB, therm. PAD at ca. 2 cm² copper area		30	40	K/W

All voltages are referenced to ground unless otherwise stated.
All currents flowing into the device pins are positive; all currents flowing out of the device pins are negative.

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ELECTRICAL CHARACTERISTICS

Operating Conditions: VB = 10...36 V, LSW = 0.01...10 H, RACT = 5...50 kΩ, RHOLD = 5...50 kΩ, Tj = -40...125 °C.

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Total Device							
001	VB	Permissible Supply Voltage Range		10		36	V
002	I(VB)	Supply Current in VB	EN < 0.8 V			20	µA
003	I(VB)	Supply Current in VB	EN = hi	0.5		4	mA
004	Vc()lo	Clamp Voltage lo at all Pins except SYNC	I() = -4 mA, other Pins open	-1.4		-0.3	V
005	Vc()lo	Clamp Voltage lo an SYNC	I() = -4 mA, andere Pins offen			-7	V
006	Vc()hi	Clamp Voltage hi at VB, EN, DIAG, SYNC	I() = 4 mA, other Pins open	37			V
007	Vc()hi	Clamp-Voltage hi at IACT, IHOLD, TACT	I() = 4 mA, other pins open	7			V
008	Vc()hi			5			V
009	Vc()hi	Clamp-Spannung hi an SW	I(OUT) = 4 mA, other Pins open	10		17	V
Driver Output SW							
101	Vs()lo	Saturation Voltage lo	I(SW) = 1000 mA (see Figure 1)			600	mV
102	Vs()lo	Saturation Voltage lo	I(SW) = 100 mA (see Figure 1)			100	mV
103	I(SW)	PWM-Current Range		100		1000	mA
104	Isc()	Short-circuit Current	V(SW) = VB	1.1		4	A
105	Vc()hi	Clamp Voltage hi at PWM-Free-Wheeling	Vc()hi = V(SW) − VB; EN = hi, I(SW) = 1000 mA (see Figure 1)			600	mV
106	Vc()hi	Clamp Voltage hi at PWM-Free-Wheeling	Vc()hi = V(SW) − VB; EN = hi, I(SW) = 100 mA (see Figure 1)			100	mV
107	Vc()off	Clamp Voltage hi at Turn-off	Vc()hi = V(SW) − VB; EN: hi → lo, I(SW) = 1000 mA (see Figure 1)	12	15	17	V
108	IIK()	Leakage Current	EN = lo, V(SW) = 0...VB		1	10	µA
109	twon()min	Minimum PWM Turn-on Duration	EN = hi, I(SW) > I(SW)act resp. I(SW)hold (see Figure 1)	250		1000	ns
Input EN							
201	Vt()on	Threshold Voltage hi		1.1		1.4	V
202	Vt()off	Threshold Voltage lo		0.8		1.1	V
203	Vt()hys	Hysteresis	Vt()hys = Vt()on − Vt()off	200		400	mV
204	Ipd()	Pull-down Current	V(EN) = 0.8...36 V			20	µA
205	tp(VB-SW)	Turn-on Delay after power-up	EN = VB, VB = VBoff → VBon			40	µs
206	tp(EN-SW)	Turn-on Delay	EN: lo → hi until SW active	30			µs
207	tp(EN-SW)	Turn-off Delay	EN: hi → lo until SW inactive	10			µs
208	tp(EN-DIAG)	Delay Time from EN to DIAG = hi or LED permanently on	no error	20			µs
Status Monitor DIAG							
401	Ipd()	Pull-down Current	V(DIAG) = 6 V...VB, SW active, no error	3	5	8	mA
402	VBlo	Permissible Supply Voltage for LED operation at DIAG		6		36	V
403	V()hi	Hi-Level at DIAG	without LED	4.5		6.5	V
404	f()	Frequency on Error		1.8	2.4	3.6	Hz
405	Vs()lo	Saturation Voltage lo	I(DIAG) = 200 µA, without LED			0.4	V
406	Ipu()	Pull-up Current	V(DIAG) = 0 ...4 V	-120	-100	-80	µA
407	VBon	Turn-on Threshold at VB	V(DIAG): lo → hi	8	8.5	9	V
408	VBoff	Undervoltage Threshold at VB	Decreasing voltage VB, V(DIAG): hi → lo	7.5	8	8.5	V
409	VBhys	Hysteresis	VBhys = VBon − VBoff	200	500	800	mV
410	Toff	Thermal Shutdown Temperature		140		170	°C
411	Ton	Thermal Release Temperature	Decreasing temperature	120		150	°C
412	Thys	Thermal Shutdown Hysteresis	Thys = Toff − Ton	10	20	30	°C

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ELECTRICAL CHARACTERISTICS

Operating Conditions: VB = 10...36 V, LSW = 0.01...10 H, RACT = 5...50 kΩ, RHOLD = 5...50 kΩ, Tj = -40...125 °C.

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Referenz IACT and IHOLD							
701	V()	Reference Voltage at IACT and IHOLD		1.21	1.27	1.33	V
702	Isc()	Short-Circuit Current in IACT and IHOLD	V(ISET) = 0 V or V(IHOLD) = 0 V	-4.5	-3.5	-2.5	mA
703	K1	Transfer Value for Energising Current RACT = K1 / I(SW)act	I(SW)act = 100...1000 mA	4500	5000	5500	ΩA
704	K2	Transfer Value for Hold Current RHOLD = K2 / I(SW)hold	I(SW)hold = 100...1000 mA	4500	5000	5500	ΩA
Energising Time Prolongation TACT							
C01	tpPWMlo	Propagation Delay from EN = hi to changeover from IACT to IHOLD	TACT not connected (ssee Figure 1)	40	50	60	ms
C02	K3	Energising Time Prolongation	tpPWM = tpPWMlo + K3 ∗ CACT	0.8	1	1.2	ms/nF
C03	Vth()tact	Threshold at TACT			1.27		V
C04	Ipu()	Pull-up Current at TACT	V(TACT) = 0.1...1.1 V		1.2		µA
C05	Ipd()	Pull-down Current at TACT	V(TACT) = 0.1...1.1 V, after crossing Threshold at TACT	0.3		3.5	mA
C06	Vs()	Saturation Voltage at TACT	I(TACT) = 10 µA		20		mV
Oscillator							
J01	fosc	Mean Oscillator Frequency	(fmax + fmin) / 2	60	80	120	kHz
J02	df	Frequency Variation	(fmax - fmin) / (2∗fosc)	12		15	%
Synchronisation SYNC							
S01	Vth()sync	Trigger Threshold at SYNC		-20		20	mV
S02	Ilk()	Leakage Current	V(SYNC) = -3 V ... 3 V	-100		100	nA

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ELECTRICAL CHARACTERISTICS: Diagrams
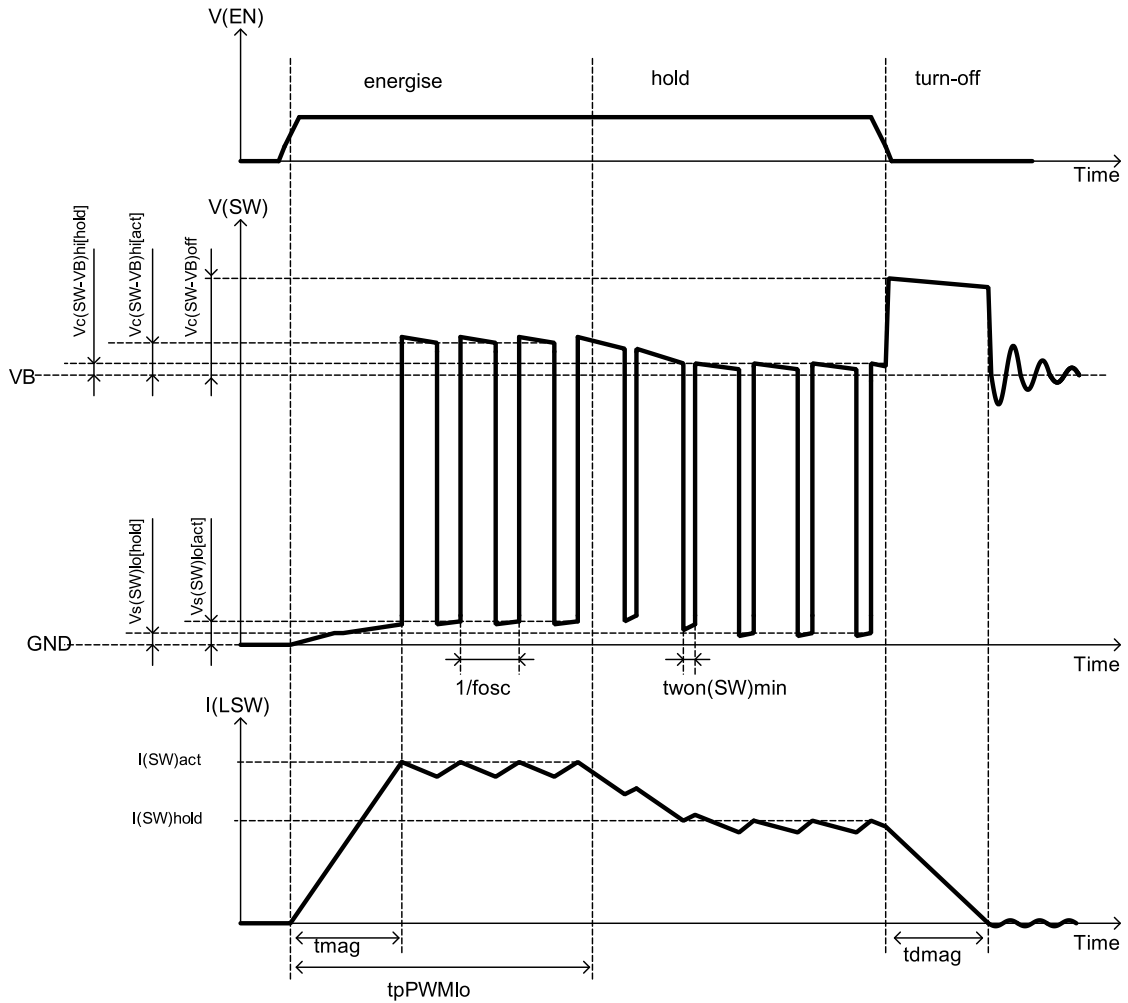
Figure 1: Operation modes *energise*, *hold*, *turn-off*

$$t_{mag} \approx \frac{I(SW)_{act} \times LSW}{VB} \tag{1}$$

$$t_{dmag} \approx \frac{I(SW)_{hold} \times LSW}{V_c(SW - VB)_{off}} \tag{2}$$

APPLICATIONS INFORMATION

Setting the coil current

The following equations can be given for the energise and hold modes of the PWM control using Electrical Characteristics Nos. 703 resp. 704:

$$RACT = \frac{K1}{I(SW)_{act}} \qquad (3)$$

$$RHOLD = \frac{K2}{I(SW)_{hold}} \qquad (4)$$

Example

For a relay with a starting current of 200 mA and 100 mA hold current the following applies:

$$RACT = \frac{5\,k\Omega A}{0.2\,A} = 25\,k\Omega \qquad (5)$$

$$RHOLD = \frac{5\,k\Omega A}{0.1\,A} = 50\,k\Omega \qquad (6)$$

Application circuits
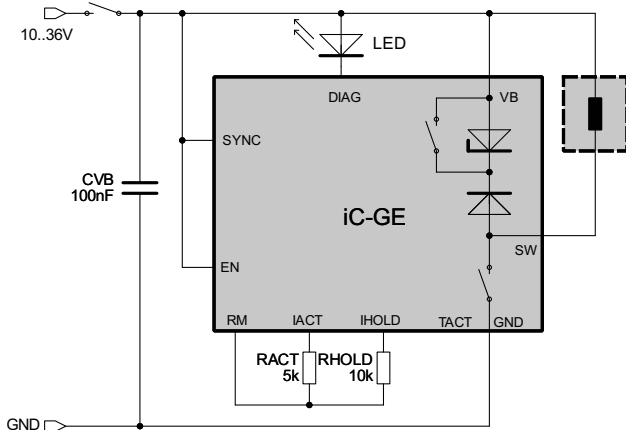
Figure 2: Activation by switching VB
RACT = 5 kΩ for 1 A energising current and
RHOLD = 10 kΩ for 500 mA hold current
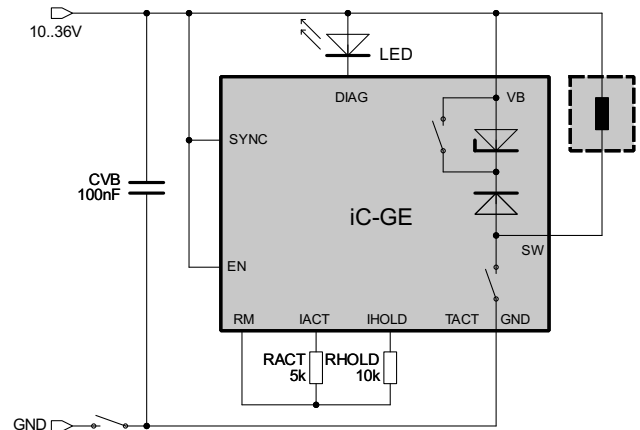
Figure 3: Activation by switching GND
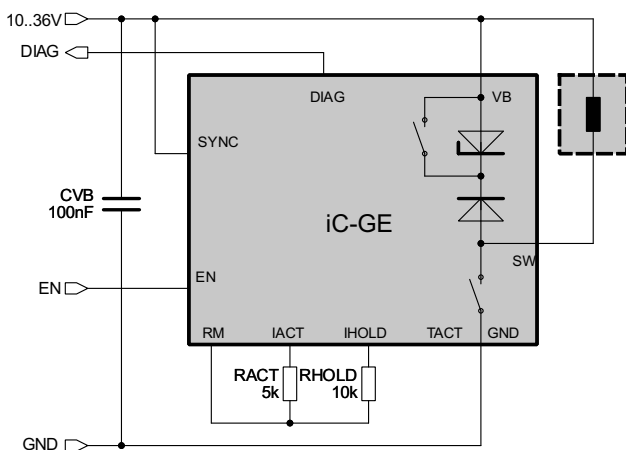
Figure 4: Activation via EN
feedback from DIAG with 5 V logic levels
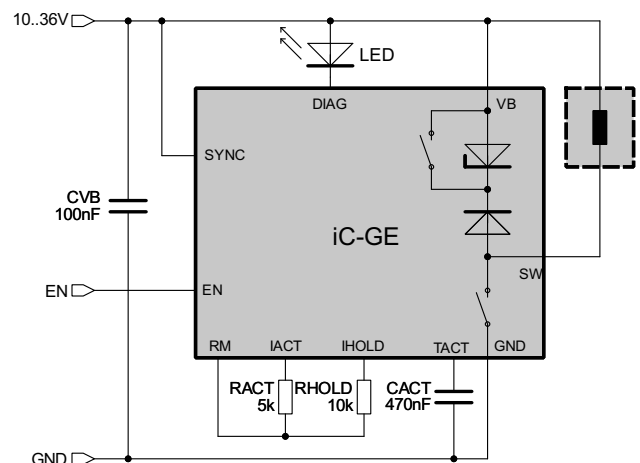
Figure 5: 470 nF for 470 ms energising time prolongation
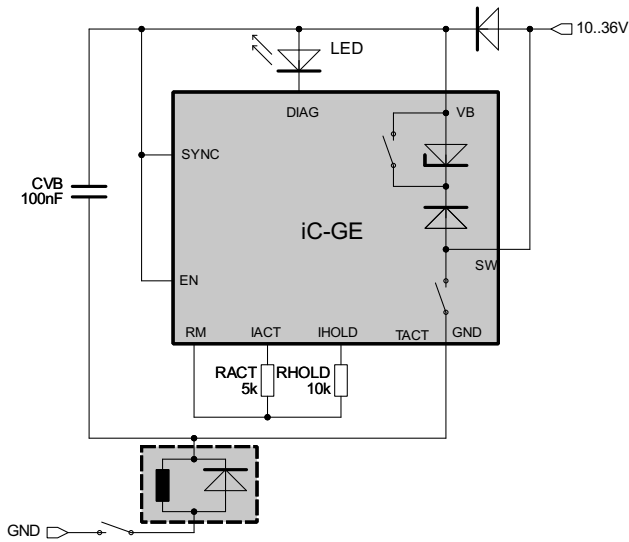
Figure 6: High-side driver for relays with free-wheeling diode
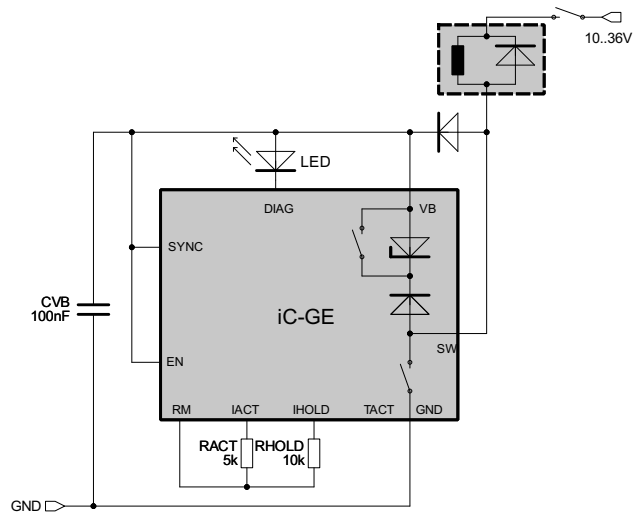
Figure 7: Low-side driver for relays with free-wheeling diode
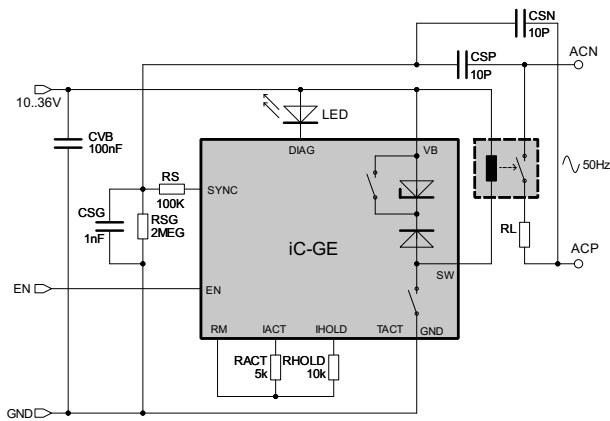
Figure 8: Utilising the SYNC input

By means of resistors RS* and capacitors CS* a phase shifted signal at SYNC is derived from the 50 Hz load supply.

Thus the relay is activated resp. deactivated with zero crossing of the load supply after sworking EN.

The phase shift is used to compensate the switching delay of the relay so that the load can be switched at zero current.

The benefit from synchronous switching may be utilised, if the switching times are short and reproducible.
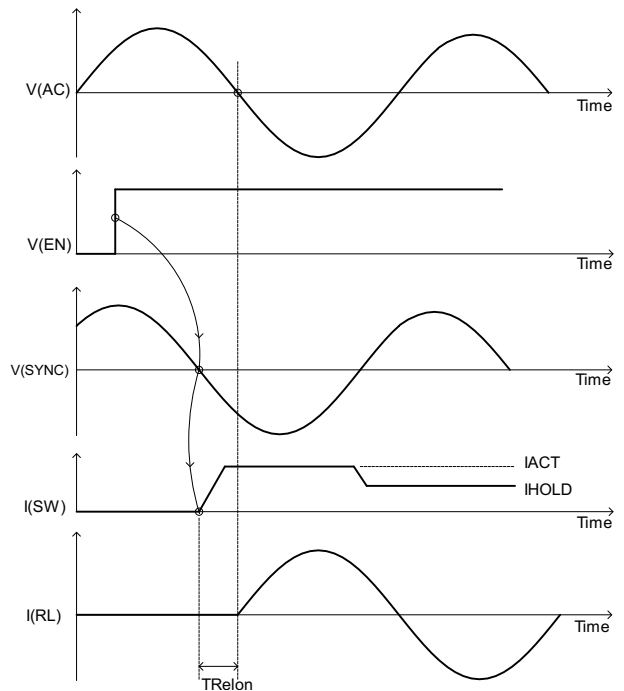
Figure 9: Utilising the SYNC input

Application example with four relays of equal acceleration

REL#	Relay type	REL1	REL2	REL3	REL4	
N	No. of turns	6000	3000	1500	3000	
d	Wire diameter	0.2	0.28	0.4	0.4	mm
VBLn	Nominal coil supply voltage	24	12	6	6	V
VBLmin	Minimum required supply voltage 75% of VBLn	18	9	4.5	4.5	V
VBLmax	Maximum allowed supply voltage VBLn + 25%	30	15	7.5	7.5	V
ISWn	Nominal coil current	208	416	832	416	mA
Ri	Coil resistance at room temperature	115.4	28.8	7.2	14.4	Ω
Rimax	Elevated coil resistance at 80 °C	155	38.8	9.7	19.4	Ω
PvLn	Power dissipation in the coil VBLn^2 / Ri	5	5	5	2.5	W

Table 4: Manufacturer data

Imin	Energising current VBLmin / RImax, for sure switching of the realy at high temperature and low power supply	116	232	464	232	mA
RACT	Calculation: RACT = K1min / Imin = 4500 / Imin, the selected resistor must be smaller then the calculated value	38.8	19.4	9.7	19.4	kΩ
ISWmax	Maximum current is ISWmax = K1max / RACT = 5500 / RACT	142	284	567	284	mA
VBLact	Maximum voltage at coil Rimax * ISWmax	22.0	11.0	5.5	5.5	V
Vs	Saturation voltage Characteristics No. 101 and No. 102 interpolated, Vs()lo * ISWmax / 1000 mA	0.1	0.2	0.4	0.2	V
VBmin	Minimum supply voltage at iC-GE VBLact + Vs	22.1	11.2	10	10	V
VBmax	Maximum supply voltage at iC-GE	36	36	36	36	V
Pv	Power dissipation at PWM Vs / VBLact	0.5	1.8	7.3	3.6	%
IVB	Average current in VB for PWM at 24 V VB ISWmax * VBLact / 24 V * (1 + Pv)	131	133	139	68	mA
PvL	Power dissipation in the coil Rimax * ISWmax^2	3.12	3.12	3.12	1.56	W
PvLhold	Power dissipation at reduced hold current IHOLD of e.g. 2/3 * IACT	1.39	1.39	1.39	0.7	W

Table 5: iC-GE application

REL1 would be a standard 24 V relay. It could only be used with iC-GE, if operation at 22.1 V can be guaranteed.

REL2 and REL3 are 6/12 V standard relays and thus optimal usable with iC-GE at a 24 V supply voltage.

REL4 is optimised for low power dissipation, since the coils has twice the number of turns than REL3 and a $\sqrt{2}$ wider diameter than REL2. Thus the power dissipation in the coil is halved.

By means of the optimised power control e.g. with a permanently-on 24 V mains-insulation relay of photovoltaic or heating systems up to

$(5\,W - 0.7\,W) * 24\,h * 365\,days = 37.7\,kWh$
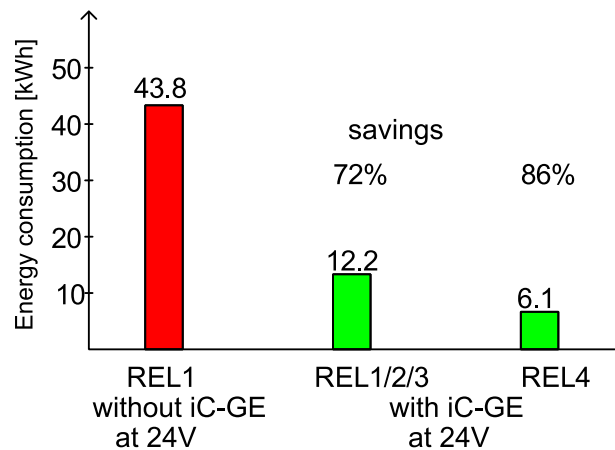
may be saved per year.

Figure 10: Energy savings

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ORDERING INFORMATION

Type	Package	Order Designation
iC-GE	QFN16 4 mm x 4 mm	iC-GE QFN16 4x4

For technical support, information about prices and terms of delivery please contact: