8.7 DO164

8.7.1 General Information

The screw-in module DO164 is equipped with four output channels. It is used to send firing pulses (triac coupler) for phase-angle control of power triacs.
The module is installed on the adapter module or on the CP interface.

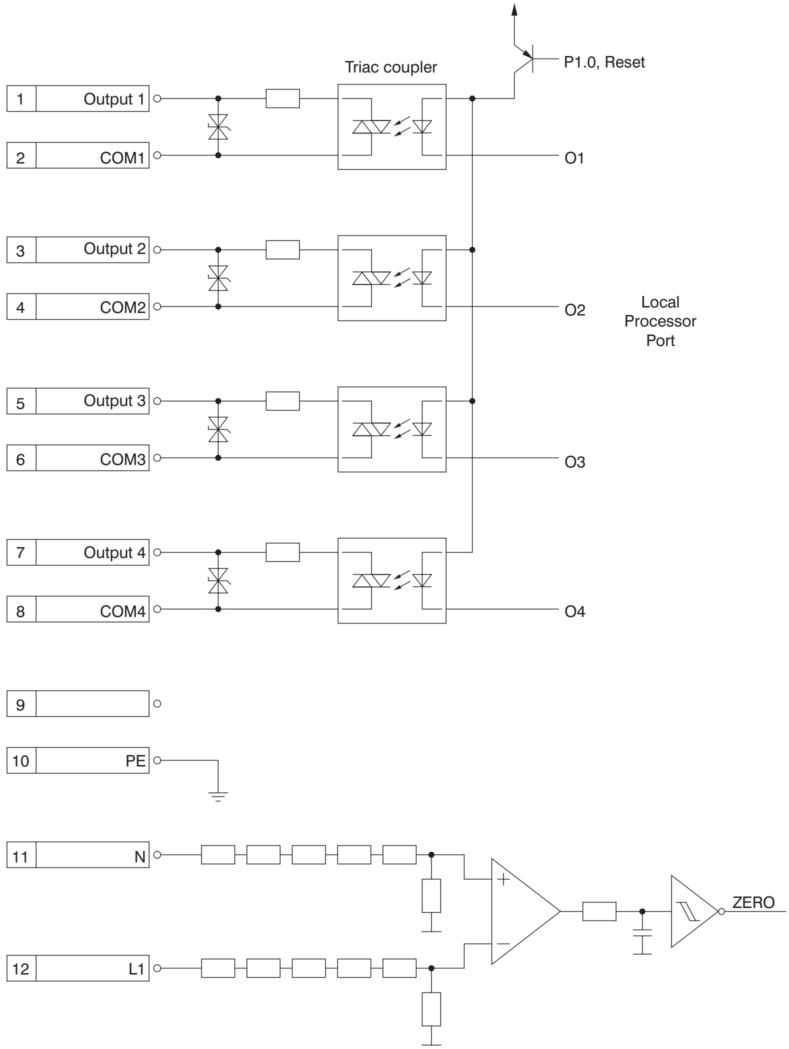
8.7.2 Technical Data

Module ID	DO164
General Information	
Model Number	7DO164.70
Short Description	2003 digital output module, 4 FET outputs 48 to 125 VAC, 0.05 A, zero cross detection, screw-in module, Order terminal block TB712 separately!
C-UL-US Listed	in preparation
B&R ID Code	$3C
Module Type	B&R 2003 screw-in module
Slot	AF101 adapter module, CP interface
Zero Cross Detection (connection pins 11 and 12)	
Number of Inputs	1
Rated Voltage	48 to 125 VAC
Rated Frequency	48 to 63 Hz
Input Impedance in Signal Range	1 MΩ symmetric 500 kΩ to GND
Switching Threshold Low Range High Range	 $<$-5 V $>$+5 V
Switching Hysteresis	0.2 V
Tolerance of the Zero Cross Signal at 48 to 125 VAC	0 to 100 μs
Electrical Isolation	No

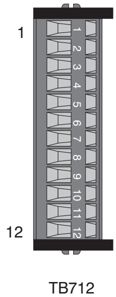
Module ID	DO164
Triac Outputs	
Number of Outputs	4
Type of Outputs [1]	Triac coupler, only to control power triacs or nonparallel thyristors
Rated Voltage	48 to 125 VAC
Rated Frequency	48 to 63 Hz
Output Current Continuous Current Ignition Pulse Current	 Max. 50 mA Max. 0.5 A
Residual Voltage	Max. 2.5 V at 50 mA
Holding Current	Max. 3.5 mA
Leakage Current (0 signal)	Max. 1 µA
Critical Rate of Rise of Commutating Voltage when Switched Off	>500 V/µs
Drive Pulse Duration T_{DP} (TPU outputs)	>250 µs
Power Consumption	Max. 0.6 W
Protection Characteristics	
Protection	No short circuit protection
Type of External Protective Circuit RC Combination Gate Resistance	 Reduced dV/dt Increased immunity
Dynamic Characteristics	
Delay 0 to 1	Max. 200 µs
Delay 1 to 0	Max. 200 µs
Operating Characteristics	
Electrical Isolation Input - Output Output - Output	 Yes Yes
Recommended Cable Types	Twisted pair cabling to the terminal pairs
Line Length to Power Triac	Max. 10 m
Mechanical Characteristics	
Dimensions	B&R 2003 screw-in module

[1] Because of the very low (dV/dt)c value of the triac coupler ("Critical Rate of Rise of Commutating Voltage"), the triac output is not suitable for use as SSR relay for direct switching of loads.

8.7.3 Output Circuit Diagram



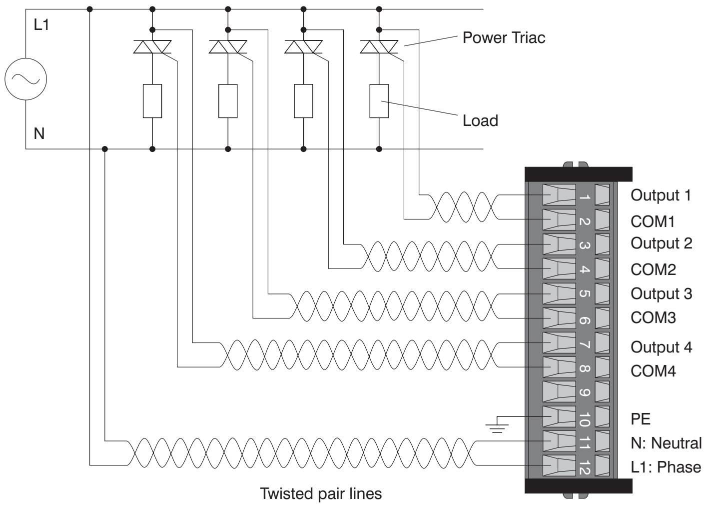
8.7.4 Connections



Pin	Assignment
1	Output 1
2	COM 1
3	Output 2
4	COM 2
5	Output 3
6	COM 3
7	Output 4
8	COM4
9	n. c.
10	PE: Ground potential
11	N: Neutral
12	L1: Phase

8.7.5 Connection Examples

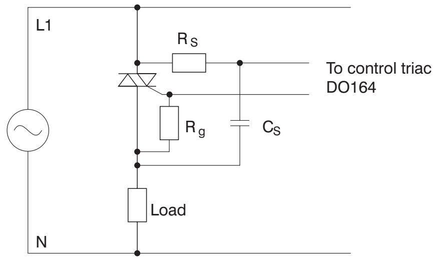
Standard Connection



Connection with RC combination and gate resistance

Connecting the power triac with an RC combination reduces the dV/dt.
The gate resistance increases immunity.

Wiring



Recommended Values

RC Combination	
R_S	Approx. 22 to 100 Ω / 1 W pulse resistant
C_S	Approx. 100 nF foil capacitor

Gate Resistance	
R_g	Approx. 22 to 100 Ω

Controllable Phase Angle

Because of the connection with an RC combination, the calculation for the minimum voltage when firing is started U_{FS1} and therefore the calculation of the controllable phase angle changes.

Formula with Gate Resistance
$U_{FS1} = (I_{GT}\ [A] + V_{GT}\ [V] / R_g\ [\Omega]) * (22\ \Omega + R_S\ [\Omega]) + V_{GT}\ [V] + 2\ V$

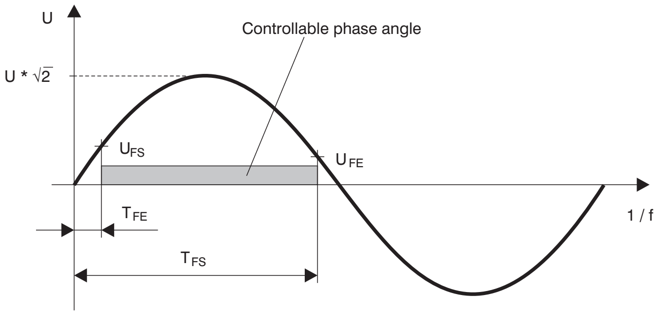
Formula without Gate Resistance
$U_{FS1} = I_{GT}\ [A] * (22\ \Omega + R_S\ [\Omega]) + V_{GT}\ [V] + 2\ V$

8.7.6 Controllable Phase Angle

Calculating the Phase Angle

With the following formula, the earliest switch-on angle and the latest switch-off angle can be calculated. The controllable phase angle is within this range.

Note: The switch-on delay for the power triacs must be shorter than 5 µs.



U	...	Effective value of the minimum operating voltage
U_{FS}	...	Minimum voltage when firing is started
U_{FE}	...	Minimum voltage when firing is ended
T_{FE}	...	Earliest switch-on time
T_{FS}	...	Latest switch-off time

<u>Minimum voltage when firing is started:</u> U_{FS1}

At the start of the firing pulse, the operating voltage must be high enough for the power triac to be fired securely.

$$U_{FS1} = I_{GT}\,[A] * 22\,\Omega + V_{GT}\,[V] + 2\,V$$

I_{GT} ...... Max. gate trigger current for the power triac

V_{GT} .... Max. gate voltage for the power triac

<u>Minimum voltage when firing is started:</u> U_{FS2}

When firing is started, the operating voltage must be high enough for the latch current of the power triac to be reached.

$$U_{FS2} = V_T\,[V] + I_L\,[A] * R_L\,[\Omega]$$

V_T ...... Max. voltage drop on the power triac when switched on

I_L .... Max. latch current for the power triac

R_L ...... Max. load resistance

Minimum voltage when firing is ended: U_{FE}

At the end of the firing pulse, the operating voltage must be high enough for the holding current of the power triac to be reached.

$$U_{FE} = V_T\ [V] + I_H\ [A] * R_L\ [\Omega]$$

V_T ...... Max. voltage drop on the power triac when switched on

I_H .... Max. holding current for the power triac

R_L ...... Max. load resistance

Earliest switch-on angle: φ_{FE}

The high of the two voltages U_{FS1} and U_{FS2} is selected. This voltage is used to calculate the earliest switch-on angle.

$$\varphi_{FE} = \arcsin\ (U_{FS}\ [V] / (U\ [V] * \sqrt{2}\ ))$$

U .... Effective value of the minimum operating voltage

Latest switch-off angle: φ_{FS}

The voltage U_{FE} is used to calculate the latest switch-off angle.

$$\varphi_{FS} = 180 - \arcsin\ (U_{FE}\ [V] / (U\ [V] * \sqrt{2}\ ))$$

U .... Effective value of the minimum operating voltage

Earliest switch-on time: T_{FE}

$$T_{FE} = \varphi_{FE}\ / (f * 360)$$

Latest switch-off time: T_{FS}

$$T_{FS} = (\varphi_{FS}\ / (f * 360)) * 10^6\ [\mu s] - (100 + 200)\ \mu s$$

f .... Frequency of the operating voltage

100 µs ...... Max. tolerance of the zero cross signal

200 µs ...... Max. switching delay for triac coupler

Earlier switch-on time with small loads

To achieve an earlier switch-on time, especially for small loads, only use the voltage U_{FS1} for the calculation. In this case however, U_{FS2} must be greater than U_{FS1} and the drive pulse must be available until the voltage U_{FS2} is reached.
This drive pulse duration is calculated from the time difference for these two voltages T_{FS2} - T_{FS1}. The drive pulse duration always has to be larger than the specified minimum pulse duration T_{DP}.

Calculation Example

	Entry
Operating Voltage Voltage Frequency	 48 VAC ±15 % 50 Hz
Load Load resistance R_L	1 kW heating element 20Ω
Power Triac (SKKT92 SEMIKRON) Max. Gate Trigger Current I_{GT} Max. Gate Voltage V_{GT} Max. Latch Current I_L Max. Holding Current I_H Max. Voltage Drop V_T Min. Gate Trigger Current I_{GD}	 200 mA (T_j = 0 °C) 3.5 V (T_j = 0 °C) 600 mA 250 mA 1.6 V 6 mA (T_j = 125 °C)
RC Combination R_S C_S	 22Ω 100 nF
Gate Resistance	Not required because I_{GD} >> leakage current

<u>Minimum voltage when firing is started:</u> U_{FS1}

$$U_{FS1} = I_{GT}\ [A] * (22\ \Omega + R_S\ [\Omega]) + V_{GT}\ [V] + 2\ V$$
$$U_{FS1} = 0.2 * 44 + 3.5 + 2 = 14.3\ V$$

<u>Minimum voltage when firing is started:</u> U_{FS2}

$$U_{FS2} = V_T\ [V] + I_L\ [A] * R_L\ [\Omega]$$
$$U_{FS2} = 1.6 + 0.6 * 20 = 13.6\ V$$

<u>Minimum voltage when firing is ended:</u> U_{FE}

$$U_{FE} = V_T\ [V] + I_H\ [A] * R_L\ [\Omega]$$
$$U_{FE} = 1.6 + 0.25 * 20 = 6.6\ V$$

Earliest switch-on angle: φ_{FE}

φ_{FE} = arc sin (U_{FS} [V] / (U [V] * $\sqrt{2}$))

$U_{FS1} > U_{FS2} => U_{FS} = U_{FS1}$ = 14.3 V

U ... Effective value of the minimum operating voltage

U = 48 VAC * 0.85 = 40.8 VAC

φ_{FE} = arc sin (14.3 / (40.8 * 1.41)) = 14.39°

Latest switch-off angle: φ_{FS}

φ_{FS} = 180 - arc sin (U_{FE} [V] / (U [V] * $\sqrt{2}$))

φ_{FS} = 180 - arc sin (6.6 / (40.8 * 1.41)) = 173.41°

Earliest switch-on time: T_{FE}

$T_{FE} = \varphi_{FE}$ / (f * 360)

T_{FE} = 14.39 / (50 * 360) = 799.5 µs

Latest switch-off time: T_{FS}

T_{FS} = (φ_{FS} / (f * 360)) * 10^6 [µs] - (100 + 200) µs

T_{FS} = (173.41 / (50 * 360)) * 10^6 - 300 = 9333.5 µs

Controllable Phase Angle:

The controllable phase angle in this example is 14.39° to 173.41° or 0.8 to 9.3 ms with reference to the zero cross signal.

8.7.7 Variable Declaration

The variable declaration is valid for the following controllers:

- 2003 PCC CPU
- Remote I/O Bus Controller
- CAN Bus Controller

The variable declaration is made in PG2000. The variable declaration is described in Chapter 4, "Module Addressing".

Automation Studio™ Support: See Automation Studio™ Help starting with V 1.40

Accessing screw-in modules is also explained in the sections "AF101" and "CPU".

Data access takes place using data and configuration words. The following table provides an overview of which data and configuration words are used for this module.

Data Access	VD Data Type	VD Module Type	VD Chan.	R	W	Description
Data word 0	WORD	Analog In	1	●		Module status
	INT16	Analog Out	1		●	Output state of output 1
Data word 1	INT16	Analog Out	2		●	Output state of output 2
Data word 2	INT16	Analog Out	3		●	Output state of output 3
Data word 3	INT16	Analog Out	4		●	Output state of output 4
Configuration word 14	WORD	Transp. In	28	●		Module type
	WORD	Transp. Out	28		●	Module configuration

8.7.8 Access Using CAN IDs

Access via CAN Identifiers is used if the slave is being controlled by a device from another manufacturer. Access via CAN Identifiers is described in an example in Chapter 4, "Module Addressing".
The transfer modes are explained in Chapter 5, "CAN Bus Controller Functions".

Input Data (module status)

The input data can be transferred packed or unpacked.

CAN objects can only be returned in packed mode.

CAN ID [1]	Slot 1		Slot 2		Slot 3		Slot 4	
542	ScrM 1L	ScrM 1H	ScrM 2L	ScrM 2H	ScrM 3L	ScrM 3H	ScrM 4L	ScrM 4H
543	free							
544	free							
545	free							

[1] CAN ID = 542 + (nd - 1) x 16 + (ma - 1) x 4
nd ..... Node number of the CAN slave = 1
ma .... Module address of the AF101 = 1

Four CAN objects can be sent back in unpacked mode.

Slot	CAN ID [1]	Word 1		Word 2	Word 3	Word 4
1	542	ScrM 1L	ScrM 1H	Not used (2 byte objects)		
2	543	ScrM 2L	ScrM 2H	Not used (2 byte objects)		
3	544	ScrM 3L	ScrM 3H	Not used (2 byte objects)		
4	545	ScrM 4L	ScrM 4H	Not used (2 byte objects)		

[1] CAN ID = 542 + (nd - 1) x 16 + (ma - 1) x 4 + (sl - 1)

nd ..... Node number of the CAN slave = 1

ma .... Module address of the AF101 = 1

sl .... Slot number of the screw-in module on the AF101 (1 - 4)

Output Data

It is not possible to pack output data with the DO164. Therefore one CAN object is transferred per screw-in module. If an adapter module AF101 is equipped with a four DO164 modules, the CAN object has the following structure:

Slot	CAN ID [1]	Word 1		Word 2		Word 3		Word 4	
1	1054	Chan. 1L	Chan. 1H	Chan. 2L	Chan. 2H	Chan. 3L	Chan. 3H	Chan. 4L	Chan. 4H
2	1055	Chan. 1L	Chan. 1H	Chan. 2L	Chan. 2H	Chan. 3L	Chan. 3H	Chan. 4L	Chan. 4H
3	1056	Chan. 1L	Chan. 1H	Chan. 2L	Chan. 2H	Chan. 3L	Chan. 3H	Chan. 4L	Chan. 4H
4	1057	Chan. 1L	Chan. 1H	Chan. 2L	Chan. 2H	Chan. 3L	Chan. 3H	Chan. 4L	Chan. 4H

[1] CAN ID = 1054 + (nd - 1) x 16 + (ma - 1) x 4 + (sl - 1)

nd ..... Node number of the CAN slave = 1

ma .... Module address of the AF101 = 1

sl .... Slot number of the screw-in module on the AF101 (1 - 4)

B&R 2000 users have to exchange the data so that the high data is first (Motorola format)!

For more information on ID allocation, see Chapter 5, "CAN Bus Controller Functions".

8.7.9 Description of Data and Configuration Words

Data Word 0 (read)

Data word 0 contains the module status.

Bit	Description
6 - 15	x .... Not defined, masked out
5	0 .... Frequency of the input voltage is in valid range during normal operation 1 .... Frequency of the input voltage exceeds the valid range of 30 to 80 Hz during normal operation (outputs are switched off)
4	0 .... Outputs are synchronized to the frequency of the input voltage 1 .... Outputs are being synchronized to the frequency of the input voltage (outputs are switched off)
0 - 3	x .... Not defined, masked out

15							8	7							0
x	x	x	x	x	x	x	x	x	x			x	x	x	x

Data words 0, 1, 2, 3 (write)

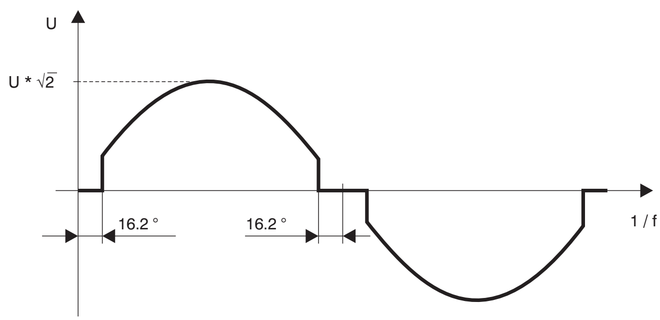
If a channel is configured as inactive, it is tristate. During normal operation, bit 0 corresponds to the output status.

<u>Example for Output 1</u>

Output 1 = 0 .... Data word 0 = $0000
Output 1 = 1 .... Data word 0 = $0001

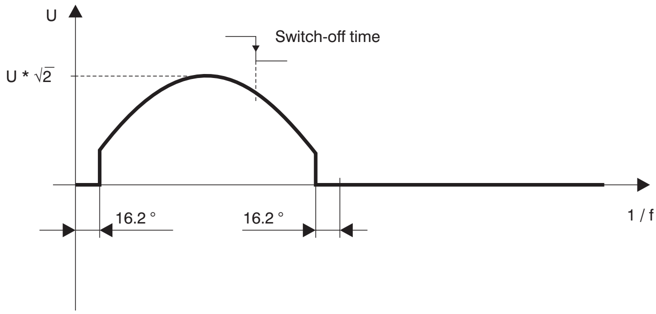
<u>Controllable Phase Angle</u>

The controllable phase angle is 16.2° to 163.8°. During normal operation, the outputs are always set within this range. This results in the following voltage curve:



Switching Output Off

If an output is switched off during normal operation, the output remains set during the current half-wave. The output is switched off the next time the voltage crosses zero.



Phase-angle Control

The DO164 module must be installed on the CP interface. Software operation takes place using TPU function blocks.

Configuration word 14 (read)

The High Byte of configuration word 14 defines the module code.

Bit	Description
8 - 15	Module code = $3C
0 - 7	x .... Not defined, masked out

15							8	7							0
0	0	1	1	1	1	0	0	x	x	x	x	x	x	x	x

Configuration word 14 (write)

The module is configured using configuration word 14.

Bit	Description
9 - 15	0
8	0 .... Zero cross-over of the input voltage is not evaluated 1 .... Zero cross-over of the input voltage is evaluated. Channel 4 is operated as an input.
6 - 7	Definition of the operating mode for channel 4 0 .... Channel is not active (tristate) 1 .... Normal operation
4 - 5	Definition of the operating mode for channel 3 0 .... Channel is not active (tristate) 1 .... Normal operation
2 - 3	Definition of the operating mode for channel 2 0 .... Channel is not active (tristate) 1 .... Normal operation
0 - 1	Definition of the operating mode for channel 1 0 .... Channel is not active (tristate) 1 .... Normal operation

15							8	7							0
0	0	0	0	0	0	0									