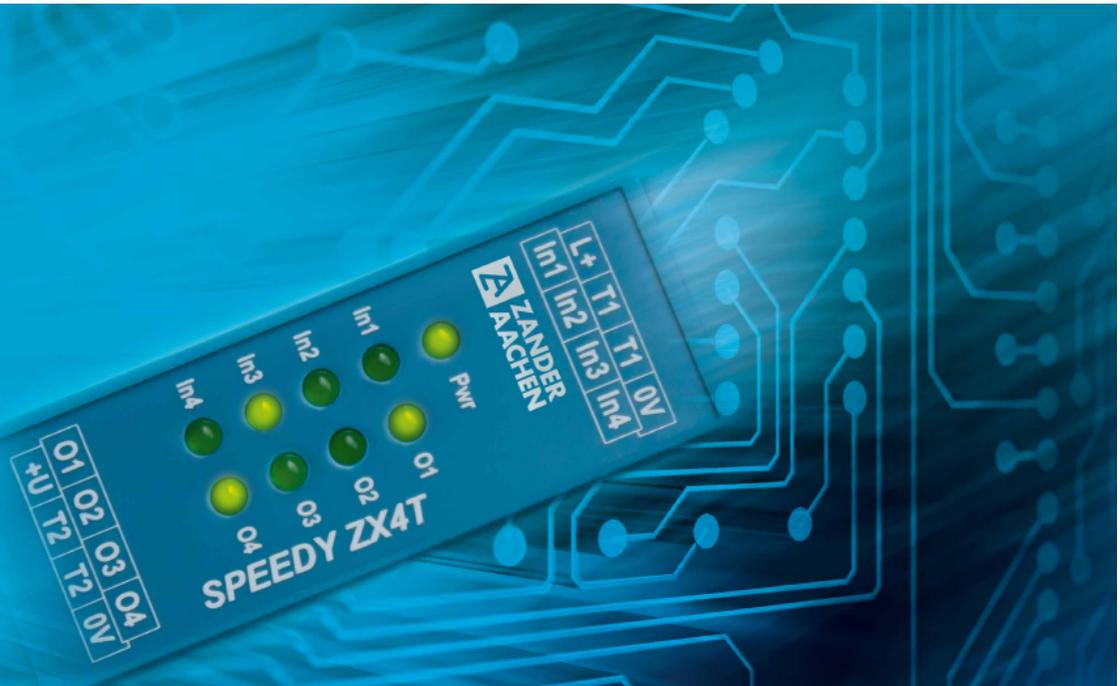


EX_PRESS 4 is so easy



Operating Instructions



A programming course for the PLC language
Structured Text according to IEC 61131-3

EX_PRESS 4 is so easy!

A programming course for the PLC language

Structured Text according to IEC 61131-3

By Dipl.-Ing. Alfons Austerhoff

This short programming guide provides a quick and easy entry to the programming of the ZANDER controllers EX16 and SPEEDY with the help of many practical and easy comprehensible examples. It teaches the essential knowledge of the PLC programming language „Structured Text“.

Further information provides the online help of the programming software EX_PRESS 4.

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This documentation is based on EX_PRESS 4 V4.4, February 2017.

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Subject to technical modifications; no responsibility is accepted for the accuracy of this information.

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1. Installation

EX_PRESS 4 is designed for the operating systems Windows XP, 7, 8.1,10 (32 or 64 bit).

For the EX_PRESS installation please connect the USB stick with your computer. Start the setup program (EX_PRESS_Setup_en2.exe - english language, EX_PRESS_Setup_de1.exe - german language) with the Windows Explorer or with the Function „Run“ in the start menu (Task Bar). Please follow the instructions.

Attention: A parallel installation of both languages (EX_PRESS_en2.exe, EX_PRESS_de1.exe) is possible. Uninstalling the first installed version will not affect the other, but uninstalling the latest version will prevent the remaining version from proper operation. Example: You are installing EX_PRESS_Setup_de1.exe (german language) first followed by the installation of EX_PRESS_Setup_en2.exe (english language). After the uninstalling of EX_PRESS 4e, the remaining version of EX_PRESS 4d will not work and must be reinstalled.

2. Program Structure

Each EX_PRESS 4 program has the following general structure (see Fig. 1):

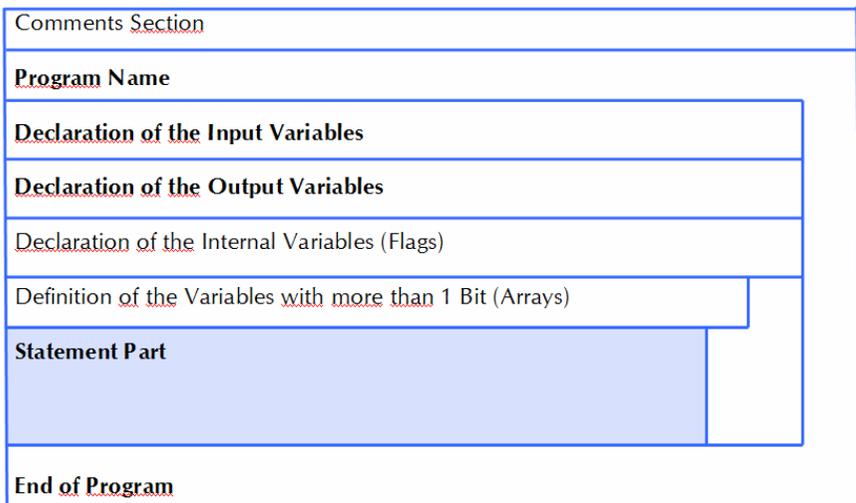


Fig. 1: Program Structure

The program parts printed in bold type are mandatory, the others are optional (depending on the project/application).

The bold marked parts of the program are necessary for each program. The other program parts are optionally depending on the individual application/project (optional).

The following „case study“ explains each program steps. We recommend to run each program step on your computer with your EX_PRESS 4 version.

As a first step open EX_PRESS 4 with the start menu/task bar. You see an empty text editor, in which you can realize your first program. Open the editor by using the menu “**File**”, „**New**“ (see Fig. 2).

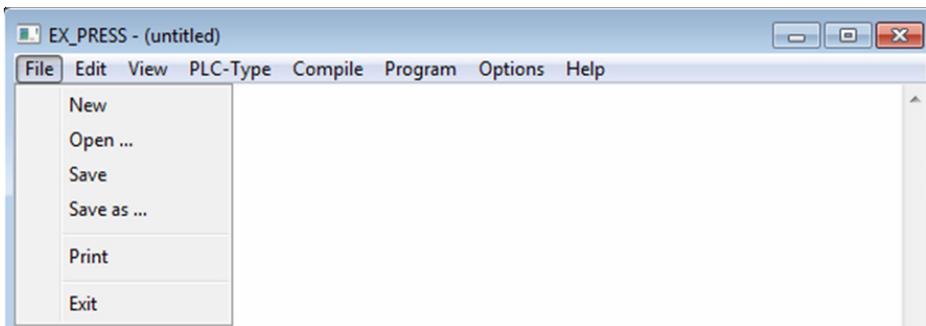


Fig. 2: New Program File

In this document the program code is visualized in italic!

3. The first Program with EX_PRESS 4

The first step is to describe the application. In this example a simple motor controller will be programmed. Three inputs and three outputs of the PLC are required for the application (Fig. 3):



Fig. 3: First Application

Description of the Application:

- 1) The motor has to run when the switch Start is closed
- 2) If the input signal (E2) is activated, the motor must stop.
- 3) If the output Alarm (A2) is getting a signal, the motor has to stop too.
- 4) The output Alarm (A2) should be inverted to the fault indication unit (E3).
→ Alarm should switch on when the fault indication signal falls to off state.
- 5) The warning light (A3) should be on when Alarm is on and also the start switch is closed.

Comments Section

This program part is optional, but highly recommended. Here you have the possibility to describe the function, document the version, document the date of preparation or any other hints are possible.

This is the first EX_PRESS-Programm. It contains everything to run a full functional control application for EX16 and all SPEEDY PLC's.

Last Change: 06.12.2016

Version: 2.16

Author: Dipl.-Ing. Alfons Austerhoff, H. ZANDER GmbH & Co. KG, Aachen

Program Name

Next step is to give the program a name. This is carried out with the command "PROGRAM". This is also the sign for the compiler that the comment section is finished and the „real“ source code starts. After a blank space you can choose your individual program name (maximum of 12 characters).

Please note: All EX_PRESS 4 commands and reserved keywords are capital letters ,e.g. the command "PROGRAM".

The freely selectable program and variable names can contain lower letters and from the second character also numbers.

After the key-word PROGRAM each comment has to be added in the following structure (* **Comment** *).

```
PROGRAM Example (* This program is called example *)
```

Declaration of the input variables

In order to use inputs, outputs and flags, the declaration of variables is necessary. This means variable names have to be declared. With these the logic level of the inputs will be queried or the outputs and flags will be set.

In our example three input variables will be required (Fig. 4):

```
VAR_INPUT
  Start AT E1;
  Stop AT E2;
  E3 AT E3;
END_VAR;
```

IDENTITY CARD



Fig. 4: Three Input Variables

All input variable definitions have the following form:

<Name> AT <Terminal>;

<Name> is freely selectable by the author. It is possible that the variables have the same name like the terminals (see example, E3).

<Terminal> always defines the connection of a variable to the input terminals **E1** up to **E16** (PLC type Speedy ZX8: E1 up to E9).

Attention: Each line has to be terminated by a semicolon. This also applies for the last line after the command **END_VAR**.

Declaration of the Output Variables

The declaration of the output variables is similar to the input variables.

<Name> AT <Terminal>;

The <Name> is freely selectable by the author. <Terminal> defines the connection to an output terminal **A1** to **A16** (Speedy A1 up to A8).

```
VAR_OUTPUT
    Motor AT A1;
    Alarm AT A2;
    A3 AT A3;
END_VAR;
```

The declaration of **internal variables** and **arrays** will be discussed later. These are only necessary for some special applications.

Statement Part

Regarding the first program. After all input and output variables have been declared the next step is the statement part of the program. In this part, the functions of the PLC will be realized. A logical state has to be assigned to each output variable. This is carried out by the following equation:

<Output variable> := <Logical expression>;

<Output variable> is a declared name in the program part *VAR_OUTPUT*, the symbol := is an assignment operator, <Logical expression> consists of a combination of declared variable names and logical operations *AND*, *OR*, *XOR* and *NOT*.

The sequence of the assignments is freely selectable due to a parallel processing of all signals. Therefore A3 is programmed first, followed by the

motor and at the end the alarm is programmed in this example.

Attention: Comparable to the variables, each assignment (each line) has to be finished by a semicolon.

```
A3 := Alarm AND Start;
```

```
Motor := Start AND NOT Stop AND NOT Alarm;
```

```
Alarm := NOT E3;
```

The first EX_PRESS 4 program is finished. Last step is the command that the program is finished.

```
END_PROGRAM;
```

For the next steps, your program has to be saved on a harddisk. Press the menu item “File” (Fig. 5) followed by “Save”. You will see a new window in which you can choose the program name. Our choice is “Example.s16”.

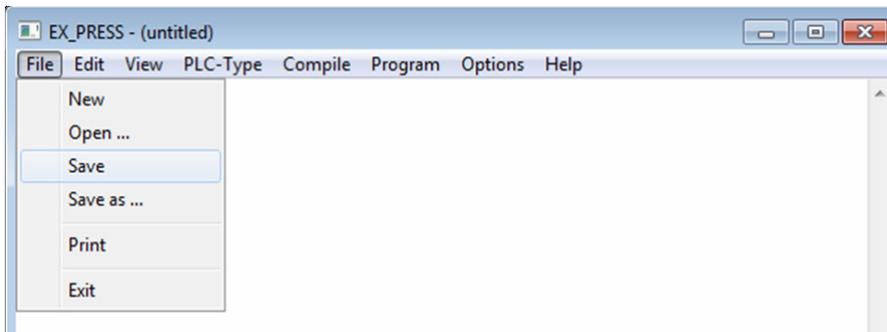


Fig. 5: Menu Item „File“

By pressing the menu „File“ followed by „Open ...“ you will find further application examples in Structured Text, which are sorted according to the Zander PLC types (EX16 / SPEEDY ZX4T, ZX4TE, ZX8T). The programs counter, conveyer, etc. are stored in the installation path. The default installation path is:

```
C:\Zander\EX_PRESS4\ExamplesEX_PRESS.
```

3.1 Select PLC Type

The PLC-Type Menu is included inside the Main Menu and contains the following items:

- EX16
- SPEEDY (ZX4T, ZX4TE, ZX8T)

EX_PRESS 4 supports these Programmable Logic Controls. You have to select one of these items in order to use the actual PLC you want to program; afterwards the actual selection is shown by a tick item (✓). See Fig. 6.

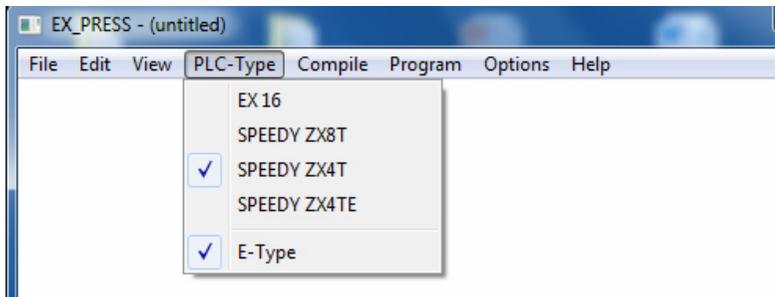


Fig. 6: Select PLC type

The so-called E-type distinguishes between different variants of the used CPLD. For EX16, and ZX8 relay type the tick should always be cleared, while for the SPEEDY-Family ZX8T and ZX4T/TE it should always be set.

The PLC type affects both compiling and programming. If programming fails, please toggle the tick for the E-Type and re-compile and re-program the code into the PLC. This should fix the problem.

3.2 Compilation and Fitting

The program has to be transferred into a structure, which is compatible to the programmable logic parts of the PLC. This is realized in two steps.

In a first step the compiler translates the Structured Text (ST) program into a boolean code. The result is a logical intermediate code. Following this, the fitter can be started. This process generates the so called „Jedec-Code“. This code can be transferred into your PLC (Speedy, EX16).

These two steps are carried out by choosing „Compile“ in the menu bar and after that “Compile and Fit“ (see Fig. 7).

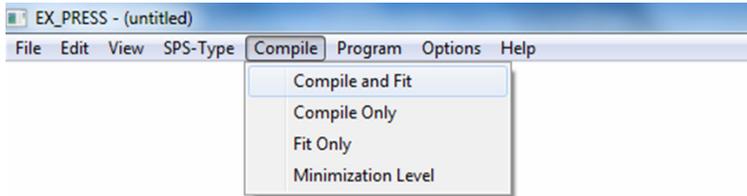


Fig. 7: Compilation and Fitting

After the successful operation, the newly opened "LOG"-window shows the message „Compiler finished, Error: 0, Warnings 0. Fitter successful“.

If the compiler detects any errors (see Fig. 8), detailed information about the errors can be found in the menu “View“ and „Error Messages“ (see Fig. 9). Typically after the first „Error“ EX_PRESS will detect some subsequent errors.

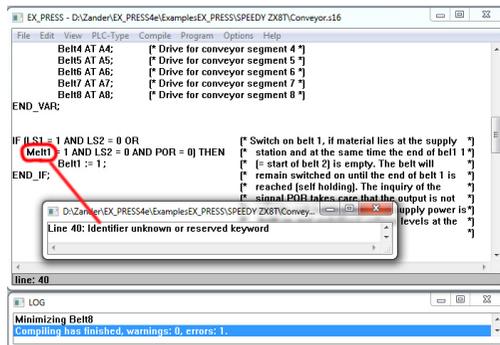


Fig. 8: Error detected

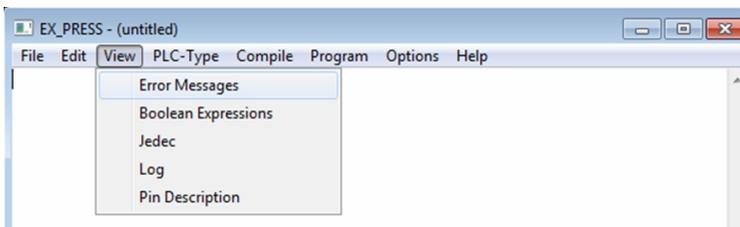


Fig. 9: View Error Messages

The user should correct the first error in the list. After that the whole program should be compiled and fitted again.

3.3 Download the Program into the PLC

For a program test, the data have to be transferred into the PLC. Connect the programming cable with the USB port of your PC. After connecting the cable start the EX_PRESS 4 program (not before). (The previously delivered parallel port cable is also supported by EX_PRESS 4). On the other side the cable is connected with the PLC.

In the menu "Options" the "Interface configuration" can be selected (Fig. 10).

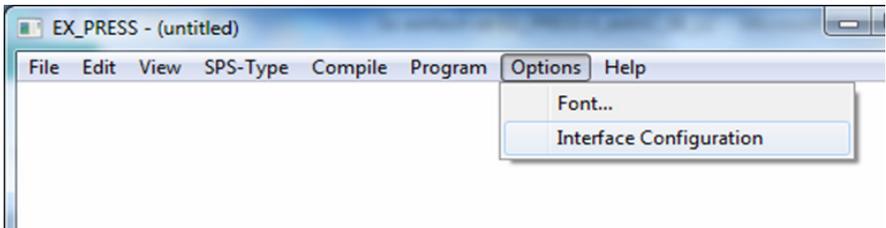


Fig. 10: Menu Interface Configuration

Please check the Log Window if the USB cable has been detected. This might take a few seconds (see Fig. 11).



Fig. 11: Log Window

After applying the supply voltage the program can be transmitted by choosing “Download to...” in the menu „Program“ (see Fig. 12).

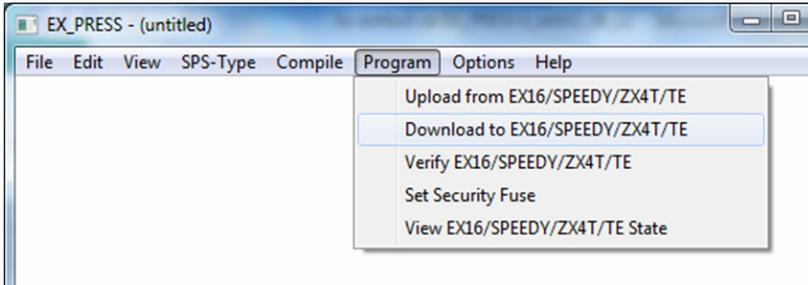


Fig. 12: Download the program into the PLC

The first EX_PRESS 4 program is finished. We can now check the functionality of the program by the input and output LED of the PLC.

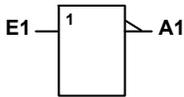
Comparable to these example you can realize a lot of applications.

The next chapters contain further logic operations and if- and case-assignments.

4. Logical Operators NOT, AND, OR, XOR

All logical control tasks can be achieved with the logical operators NOT, AND, OR und XOR. The following diagrams show for each operator type a graphical function block, the truth table and the syntax in Structured Text.

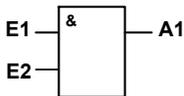
NOT



E1	A1
0	1
1	0

`A1 := NOT E1;`

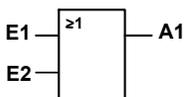
AND



E1	E2	A1
0	0	0
0	1	0
1	0	0
1	1	1

`A1 := E1 AND E2`

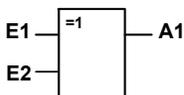
OR



E1	E2	A1
0	0	0
0	1	1
1	0	1
1	1	1

`A1 := E1 OR E2;`

XOR

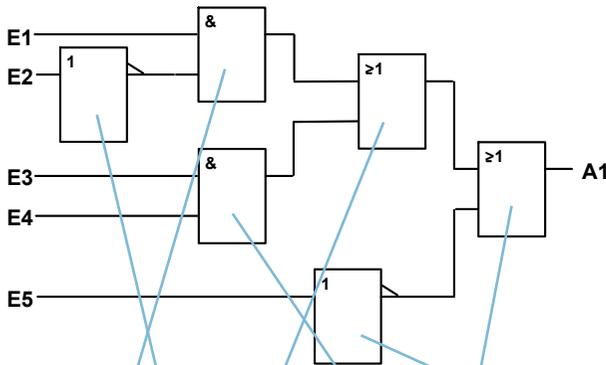


E1	E2	A1
0	0	0
0	1	1
1	0	1
1	1	0

`A1 := E1 XOR E2;`

Fig. 13: Logical Operators

If a drawing in the form of logical symbols exists, then it is easy to convert it into Structured Text . Care must be taken that all input signals belonging to a logical symbol are grouped by using brackets to preserve the sequence of operations and the priorities. (see Fig. 14).



```
A1 := ((E1 AND NOT E2) OR (E3 AND E4)) OR NOT E5;
```

Fig. 14: Input signals grouped together

5. Self-retaining

In the example program a motor was switched on by activating the input „Start“. As soon as the signal is no longer present, the motor switches off. It would be more convenient to switch on the motor by pressing a button „Start“, and to switch it off by pressing a button „Stop“. To achieve this, the following changes are necessary in the example program:

The input variable POR (=Power-On-Reset) is added to the declaration:

```
VAR_INPUT
    ...
    POR AT POR;
END_VAR;
```

The signal POR is a power-on / reset signal by a specific on-board hardware circuit, which will be active for approx. 200 ms after the supply voltage has been switched on.

This is required to assure that the output „Motor“ does not inadvertently goes into self-retaining, because the signal level is briefly undefined during the power-on.

For obtaining the self-retaining, the assignment for „Motor“ has to be extended with the following program line:

```
Motor := Start AND NOT Stop AND NOT Alarm  
      OR Motor AND NOT Stop AND NOT Alarm AND NOT POR;
```

If the start button is switched on, the part before the OR is true, so the motor switches on. As soon as this happens, the part behind the OR will become true too, so that the motor continues to run, even if the start button is released. Only pressing the Stop button or the activation of the output „Alarm“ cause the part behind the OR to become logically 0 and the motor switches off. The self-retaining can only be activated by inserting „AND NOT POR“ if the power-on reset signal falls to 0.

6. Register

In addition to the described AND-, OR- and XOR-gates the programmable logic module of the EX16 or SPEEDY has additional registers, which can store logical conditions. This function is easily recognized in the following diagram (Fig. 15):

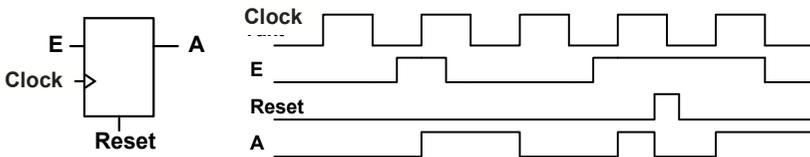


Fig. 15: Register

Using registers with EX_PRESS 4 is performed by the command

```
<Variable>.CLK := <clock signal>;
```

The logic value at the input of the register is then stored at the output at any positive edge (transition from 0 to 1) of the clock signal. If required, registers can be reset asynchronously by a signal connected to the reset input. Asynchronously means that the reset to 0 is spontaneously done without any edge at the clock signal.

<Variable>.RE := <reset signal>;

The following example generates exactly the output signal which is shown in the diagramm:

Program for the explanation of the registers
PROGRAM Register

```

VAR_INPUT
    E AT E1;
    Clock AT T1;
    Reset AT E2;
END_VAR;

VAR_OUTPUT
    A AT A1;
END_VAR;

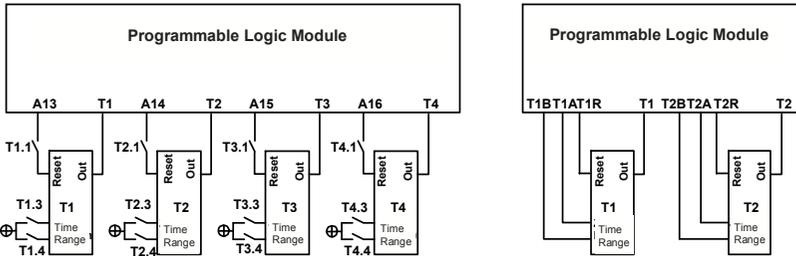
A.CLK := Clock;      (* With this line, the output becomes
                      a register *)
A.RE := Reset;      (* Assignment of the asynchron Reset *)
A := E;              (* logic input of the registers *)
END_PROGRAM;

```

7. Timer

In the program "Register" the timer T1 was used as a clock generator. Unless otherwise specified, the time laps begin when the operating voltage is applied, however there is also the possibility to start and stop it by the program: Via the reset inputs (see picture) the timer can be started (Low) or stopped (High).

For the EX16 the DIL-switches are used for selection of the time ranges whereas for the SPEEDY the time ranges can be changed by reserved outputs of the logic module (see schematic below - Fig. 16).



EX16: Controlling of the Timer

SPEEDY: Controlling of the Timer

Fig. 16: Configuration and Controlling of the Timer

A chart of the time ranges and the associated switch position or conditions of the reserved outputs are shown in the online help under the heading of „Timer“.

This means that the function „on-delayed output“ will be added to the program „Register“ as follows. Output A switches on after a defined time T1. The following example was written for the PLC SPEEDY, for EX16 see the inserted comments.

PROGRAM Register

```

VAR_INPUT
    E AT E1;
    Clock AT T1;
    Reset AT E2;
END_VAR;

VAR_OUTPUT
    A AT A1;
    T1Reset AT T1R;
    (* EX16: T1Reset AT A13; *)
    T1A AT T1A;          (* time range, not for EX16 *)
    T1B AT T1B;          (* time range, not for EX16 *)
END_VAR;
    
```

```

A.CLK := Clock; (* With this line the output becomes a
                 register *)
A.RE := Reset;  (* Assignment of the asynchronical reset *)

A := 1;        (* A switches on after time T1 (=clock),
                 because the logic signal 1 is always at
                 the logic input of the register. The
                 switching off is performed by Reset *)
T1Reset := NOT E; (* T1Reset changes to 0, if E becomes
                  active, and therefore Timer T1 runs*)

END_PROGRAM;

```

8. Internal Variables

The programmable logic modules of the PLC's EX16 and SPEEDY have 44 1-bit registers, which are not connected to any input or output. This can be used to buffer logical status signals, e.g. if a short pulse is present at an input.

Internal variables are defined in the declaration part "VAR_INTERN" and contain just a name, not a location. They behave like output variables, so they can be defined asynchronously (output of a logical gate) or with the .CLK-extension as a register.

In the above shown example an internal variable can be used to bridge the gap between applying the input signal „E“ and the output „A“ switches, so that only a short impulse at the input „E“ is necessary. Since a self-retaining should be programmed the input variable „POR“ (Power-On-Reset) must be defined.

```

VAR_INPUT
    ...
    POR AT POR;
END_VAR;

VAR_INTERN
    M;
END_VAR;

M := E                (* switch-on condition *)
OR M AND NOT A AND NOT POR; (* self-retaining with
                             Switch-off condition *)

```

The assignment equation "T1Reset := NOT E;" is replaced by:

```
T1Reset := NOT M;
```

9. IF Instruction

The program language "Structured Text" features some program constructs which provides a good program oversight and makes it easier to read the program.

One of them ist the IF instruction which separates visually logical conditions and instructions and which has a greater functionality than the before introduced logical equations. The form of the IF instruction is as follows:

```
IF      ( <condition> ) THEN  
          <assignment(s);>  
ELSIF ( <condition> ) THEN  
          <assignment(s);>  
ELSE  
          <assignment(s);>  
ENDIF;
```

The assignment "ELSIF" and "ELSE" are optional and therefore not printed in bold characters.

Example:

```
PROGRAM IF_Anw  
  
VAR_INPUT  
    E1 AT E1;  
    E2 AT E2;  
    E3 AT E3;  
    E4 AT E4;  
END_VAR;
```

```
VAR_OUTPUT
  A1 AT A1;
  A2 AT A2;
  A3 AT A3;
  A4 AT A4;
  A5 AT A5;
  A6 AT A6;
END_VAR;

IF (E1 AND (E2 XOR E3) OR NOT E4) THEN
  A1 := 1;
  A3 := 1;
ELSIF (NOT (E2 XOR E3)) THEN
  A2 := 1;
  A5 := 1;
ELSE
  A4 := 1;
  A6 := 1;
END_IF;

END_PROGRAM;
```

10. Arrays

EX_PRESS 4 offers the possibility to combine several 1-bit variables into one multi-bit (max. 8 Bit). This is done in the declaration part by:

```
VAR_ARRAY
  <NAME> [<Var1>, <Var2, ... >];
END_VAR;
```

<Var1>, <Var2> etc. must be previously declared as variables. <VAR1> is the most significant bit.

11. Rational Operators

With the rational operators =, >, <, >=, <= and <> it is possible to carry out logical comparisons of an array with a fixed value, but also of 1-bit variables with 0 or 1.

12. CASE Instruction

The CASE instruction offers the possibility to perform different assignments depending on the variable value in the following form:

```

CASE <Variable> of
    <Value1>: <assignment(s)>;
    <Value2>: <assignment(s)>;
    ...
ELSE
    <assignment(s)>;
END_CASE;

```

Example for arrays, rational operators and CASE instructions:

```

PROGRAM CASE_Anw

VAR_INPUT
    E1 AT E1;
    E2 AT E2;
END_VAR;

VAR_OUTPUT
    A1 AT A1;
    A2 AT A2;
    A3 AT A3;
    A4 AT A4;
    A5 AT A5;
    A6 AT A6;
END_VAR;

VAR_ARRAY          (* Declaration of an array *)
    E [E2, E1];
END_VAR;

IF (E >= 2) THEN  (* Usage of a relational operator *)
    A1 := 1;
END_IF;

```

```
CASE E OF                (* CASE instruction*)
  0:  A2 := 1;

     1:  A3 := 1;
        A4 := 1;

     2:  A2 := 1;
        A5 := 1;

     3:  A6 := 1;
END_CASE;

END_PROGRAM;
```

13. Online Help, Program Examples

This document contains a first introduction into the language ST-16 and the use of the features of PLCs for applications.

For more detailed information, please use the online help, which is provided with the Software EX-PRESS 4.

Also you will find more program examples in ST (see page 9).

Annex 1 – Commands and keywords of EX_PRESS

Keyword	Function, Meaning	Chapter of the online help (Menu "Help", Function "Content", "Introduction into the language ST-16")
AND, & _____	Logical AND operation _____	Allocation and logical operators
CASE...OF..._____	Multiple branching, -case distinction _____	Program constructs
ELSE _____	Alternative for CASE or IF _____	Program constructs
ELSIF...THEN _____	Alternative condition for IF _____	Program constructs
ENDIF _____	End of IF-query _____	Program constructs
END_CASE _____	End of CASE-branching _____	Program constructs
END_PROGRAM _____	End of programm source code _____	General Structured Text
END_VAR _____	End of variable declaration _____	Variables– and name conventions
IF...THEN..._____	Branching, case distinction _____	Program constructs
NOT, - _____	Logical negation _____	Allocations and logical operators
OR _____	Logical OR-combination _____	Allocations and logical operators
PROGRAM _____	Start of the programm source code _____	General Structured Text
VAR_ARRAY _____	Declaration of multibit-variables _____	Variables– and name conventions
VAR_INPUT...AT..._	Declaration of input variables _____	Variables– and name conventions
VAR_INTERN _____	Declaration of registers and flags _____	Variables– and name conventions
VAR_OUTPUT...AT..._	Declaration of output variables _____	Variables– and name conventions
XOR _____	Logical anticoincidence-linking _____	Allocations and logical operators
.CLK _____	Definition of a register variable _____	Properties of variables
.CRIT _____	Definition of a time sensitive Signal _____	Properties of variables
.OE _____	Deactivating of a output variable _____	Properties of variables
.RE _____	Reset input for register variable _____	Properties of variables
:= _____	Assignment operator _____	Allocations and logical operators
= _____	Relational operator: equal _____	Allocations and logical operators
<> _____	Relational operator: different _____	Allocations and logical operators
< _____	Relational operator: less than _____	Allocations and logical operators
<= _____	Relational operator: less than or equal _____	Allocations and logical operators
> _____	Relational operator: more than _____	Allocations and logical operators
>= _____	Relational operator: more than or equal _____	Allocations and logical operators
(...)	Change of evaluation prioritisation _____	Allocations and logical operators
(*...*) _____	Comment _____	General Structured Text

Annex 2 – Program Capacity of the CPLD

The programmable logic device of the PLC EX16 or SPEEDY possesses a total of 96 registers, 36 of those are directly assigned to the inputs and outputs. From the remaining 60 registers, always one is required for each defined output. The rest can be used in the program as registers, flags, counting variables etc.

Within the CPLD 300 OR and 5000 AND gates are available. Each signal can individually be inverted. These variables are arranged as logic blocks in and can be connected by a connection matrix.

Practice shows that the limiting factor of the program capacity is not the amount of available logic modules but the amount of inputs and outputs per logic block. The fitter software takes care of the assignment of the logic function to the logic modules as well as the wiring of the modules to each other or the inputs and outputs and optimises as far as possible.

To estimate the required resources within the CPLD for a particular program it is noted that besides the directly programmed logic and registry functions additional logic might be required as linking help; so there will be some “ glue logic - waste “. Thereby: The more complex the equations are, the higher the waste; 20% can be assumed as an average value.

Annex 3 – Frequently Asked Questions

How large is the program memory of the EX16/Speedy?

You cannot measure the storage capacity in kByte as with a microcontroller, because the programming is converted into hard-wired logic.

Therefore a statement can only be issued about the numbers of logical gates and the number of the available electrical wires within the programmable logic module (see Annex 2).

How many times can the EX16/Speedy be reprogrammed?

The manufacturer of the programmable logic device ensures a minimum of 1000 write cycles.

Which operating system is necessary for EX_PRESS 4?

Windows XP, 7, 8.1, 10 (32 or 64 Bit)

Can times be programmed by software?

The logic device does not have internal timers, therefore one of the timer signals T1 - T4. SPEEDY provides a calibrated time base of 100 ms at the left stop of the potentiometer.

By programming of a counter a clock can be scaled down. By using one clock signal several timing intervals can be generated.

An example for the programming of a timer can be found in the online help under the menu item „Introducing the Structured Test Syntax“, subitem „one example explained in detail“. With the variables Z1 to Z4 a 4-Bit-timer was programmed.

How many flags are available?

There is a minimum of 44 1-Bit-registers available.

See also Annex 2 - *Program Capacity of the CPLD*.

Annex 4: EX_PRESS Troubleshooting for EX_PRESS 4, from version 4.0 and later

1. Long File Names

Pathnames can be as long as required for EX_PRESS 4, version V4.0, so that also subdirectories can be created in the folder „\User\

2. Fitter does not start (Windows XP)

If the installation of the EX_PRESS was completed without error, but the fitter does not activate (a window with white background and black writing should be opened), please check the following:

In the start menu at “Settings“ open the “Control Panel“, double click on „Region and language options“. Select Languages tab and check if the option “Install files for East Asian languages“ is active. If yes, please deactivate this and restart your computer.

3. USB cable is not detected after inserting (Windows XP)

It can happen, that during the setup of EX_PRESS 4 the driver for the USB cable has not been installed correctly. Execute the program “FTDI_USB.exe“ from the folder “USB“ in your installation path.

4. Problem with POR_signal

To ensure that the POR_Signal works properly, the programming plug must be removed from the PLC after the download of the program.



- Safety
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