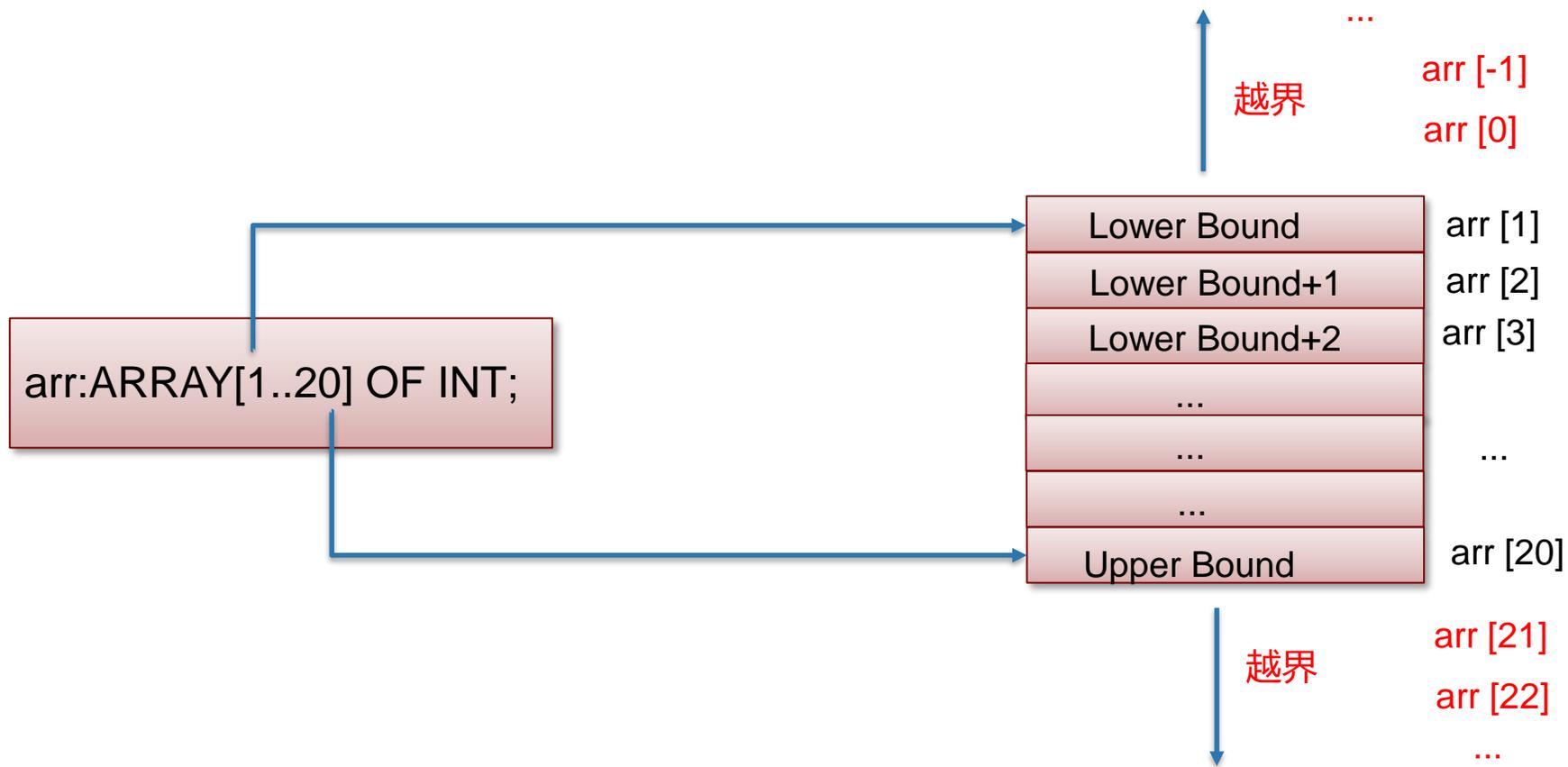


TC3数组跨界与Plc Exception

BECKHOFF



1 数组边界和越界



2 常见数组越界现象

BOOL变量在线监控时显示
<不能得到表达式的值>



g_Belt_Function1	INVALID: 16#47	
g_Belt_Function2	INVALID: 16#43	
InBuffer_Num_Pos		
arr3	ARRAY [1..2] OF BOOL	
arr3[1]	BOOL	<不能得到表达式的值。>
arr3[2]	BOOL	FALSE

程序中未对某变量赋值
但该变量显示有值



arr2	ARRAY [1..2] OF INT	
arr2[1]	INT	3
arr2[2]	INT	0

数组索引小于数组Lower
Bound导致PageFault



stArrayBounds	ST_ArrayBounds	
arr1	ARRAY [1..2] OF INT	
arr1[1]	INT	1
arr1[2]	INT	0
arr2	ARRAY [1..2] OF INT	
arr3	ARRAY [1..2] OF BOOL	
bool1	BOOL	FAL

1 stArrayBounds.arr1[1] := 1

2 RETURN

TwinCAT Port_851 Server

Exception (Exception Code: 0xc0000005, Page Fault) in PLC Application Untitled1 Instance, Task PlcTask (RBP: 0xffff800136f1ece0, RIP: 0xffff93898a46e17f, RSP: 0xffff800136f1ecd0)

确定

3 数组越界演示

Step1:
定义结构体

```
TYPE ST_ArrayBounds :  
STRUCT  
    arr1           :ARRAY[1..2] OF INT;  
    arr2           :ARRAY[1..2] OF INT;  
    arr3           :ARRAY[1..2] OF BOOL;  
END_STRUCT  
END_TYPE
```

说明：结构体中连续定义的变量的地址是连续的（忽略对齐造成的内存间隔），TC3程序或者全局变量中定义连续定义的变量的地址不一定是连续的，所以演示的时候以结构体举例

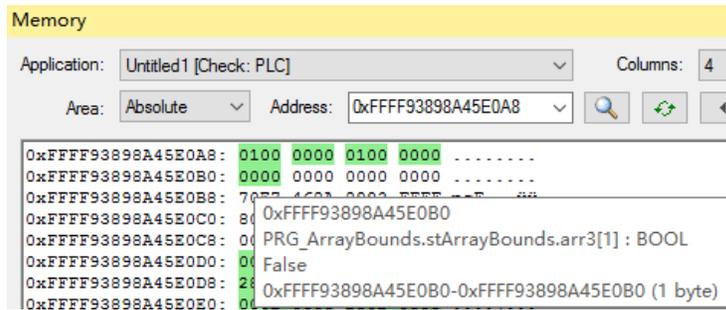
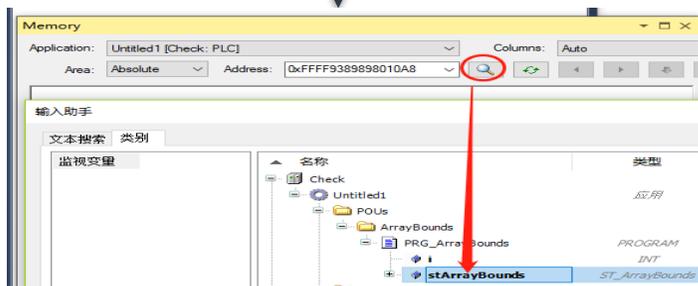
Step2:
程序编写

```
PROGRAM PRG_ArrayBounds  
VAR  
1 i :INT:=1;  
stArrayBounds :ST_ArrayBounds;  
END_VAR  
stArrayBounds.arr1[i]:=i;
```

说明：变量i的初始值为1（如果初值为0，PLC运行后就会报Page Fault）

3 数组越界演示

Step3:
打开内存监视界面



说明：
1. 鼠标放置在绿色地址区上，可以显示内存对应的PLC变量名称

2. 通过内存监控界面，可以确认结构中定义的两个数组变量的地址是连续，这样更方便演示数组越界

3 数组越界演示

Step4: 数组越界演示

表达式	类型	值
1	INT	1
stArrayBounds	ST_ArrayBounds	
arr1	ARRAY [1..2] OF INT	
arr1[1]	INT	1
arr1[2]	INT	0
arr2	ARRAY [1..2] OF INT	
arr2[1]	INT	0
arr2[2]	INT	0
arr3	ARRAY [1..2] OF BOOL	
arr3[1]	BOOL	FALSE
arr3[2]	BOOL	FALSE

赋值3

arr2	ARRAY [1..2] OF INT	
arr2[1]	INT	3
arr2[2]	INT	0

赋值5

arr3	ARRAY [1..2] OF BOOL	
arr3[1]	BOOL	<不能得到表达式的值。>
arr3[2]	BOOL	FALSE

赋值0

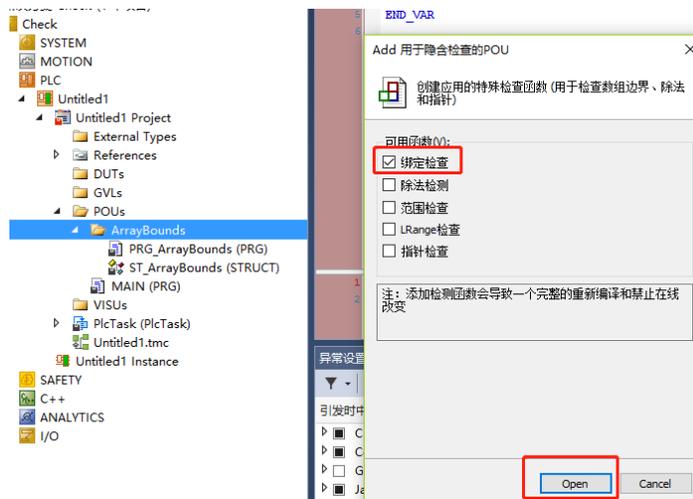
stArrayBounds	ST_ArrayBounds	
arr1	ARRAY [1..2] OF INT	
arr1[1]	INT	1
arr1[2]	INT	0
arr2	ARRAY [1..2] OF INT	
arr3	ARRAY [1..2] OF BOOL	
bool1	BOOL	FALSE

TwinCAT Port_851 Server

Exception (Exception Code: 0xc0000005, Page Fault) in PLC Application Untitled1 Instance, Task PlcTask (RBP: 0xffff800136f1ece0, RIP: 0xffff93898a46e17f, RSP: 0xffff800136f1ecd0)

确定

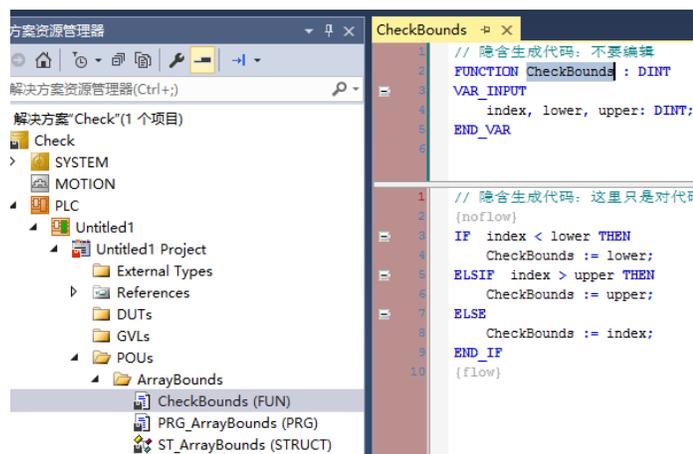
4 数组越界排查



说明:

添加CheckBounds函数后, 数组发生越界时PLC会自动调用CheckBounds函数, 不需要在PLC程序中手动调用。发生越界时, 如果数组索引小于LowerBound, PLC自动按照LowerBound处理; 如果数组索引大于UpperBound, PLC自动按照UpperBound处理。

Step1:
添加CheckBounds函数



4 数组越界排查

Step2:
CheckBounds函数中添加断点

Step3:
变量i赋值0, 触发越界

```
// 隐含生成代码: 这里只是对代码实现的建议
{noflow}
IF index[ ??? ] < lower[ ??? ] THEN
  CheckBounds[ ??? ] := lower[ ??? ];
ELSIF index[ ??? ] > upper[ ??? ] THEN
  CheckBounds[ ??? ] := upper[ ??? ];
ELSE
  CheckBounds[ ??? ] := index[ ??? ];
END_IF
```

The screenshot shows the Beckhoff development environment with a debugger window open. The code editor displays the same code as above, but with a breakpoint (red dot) at line 4: `CheckBounds[0] := lower[1];`. The variable `i` is set to 0, and the array `stArrayBounds` is shown with its first element at index 0. A red arrow points from the variable `i` in the variable window to the value 0 in the code editor.

表达式	类型	值	准备值
i	INT	0	
stArrayBounds	ST_ArrayBounds		

stArrayBounds.arr [1] 0] ??? := 1 0]

说明:
添加CheckBounds函数后, 变量i赋值0, 此时PLC并没有报Page Fault, 而是运行至CheckBounds的lower处

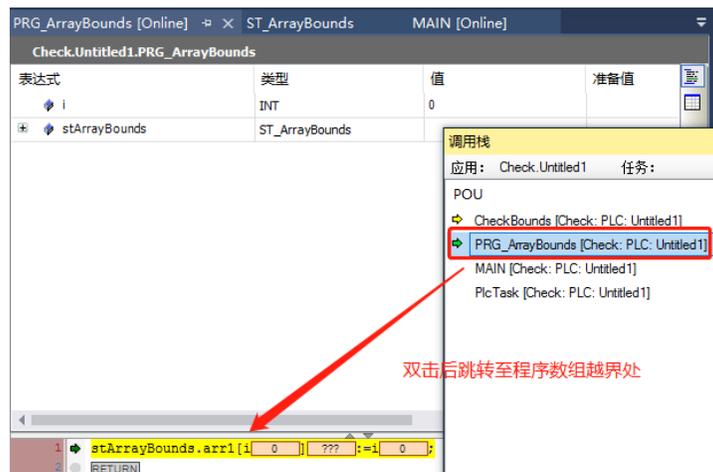
4 数组越界排查

Step4:
查看调用栈



调用栈				
应用:	Check.Untitled1	任务:		
POU	CheckBounds	下一行即为越界处	位置	实例路径
+	CheckBounds [Check: PLC: Untitled1]		4行, 2列 (Impl)	
	PRG_ArrayBounds [Check: PLC: Untitled1]		1行, 1列 (Impl)	
	MAIN [Check: PLC: Untitled1]		1行, 1列 (Impl)	
	PlcTask [Check: PLC: Untitled1]		???	PlcTask._fbTas...

Step5:
定位至程序越界



双击后跳转至程序数组越界处

1 Plc Exception (Plc 异常) 简介

Twincat内核为了保证用户程序的强壮和稳定，提供了异常处理，方便编程人员定位和处理异常。



```
1 int1 0 :=1/int1 0 ;  
2 RETURN
```

TwinCAT Port_851 Server



Exception (Exception Code: 0xc0000094, Integer divide by zero)
in PLC Application Untitled1 Instance, Task PlcTask (RBP:
0xfffffa100a622ece0, RIP: 0xfffffe78928c6242e, RSP:
0xfffffa100a622ecc0)

确定

2 Plc Exception参数说明

异常输出源:
TC3 Plc 中的异常一般显示为为Port_85x Server
TC3 C++中的异常一般显示为为CTcDebugger Server

异常所在任务: Task名称

异常所在实例: Instance名称

异常码:
可以在微软网站查询异常码的更详细说明
https://docs.microsoft.com/en-us/openspecs/windows_protocols/ms-erref/596a1078-e883-4972-9bbc-49e60bebca55

```
PROGRAM MAIN
VAR
  p1 : POINTER TO
  bDiveZero : BOOL;
END_VAR

// 数组越界
PRG_ArrayBounds ();

// 除零
IF bDiveZero THEN
  PRG_DiveZero ();
END_IF
```

2 Plc Exception参数说明

TwinCAT Port_851 Server

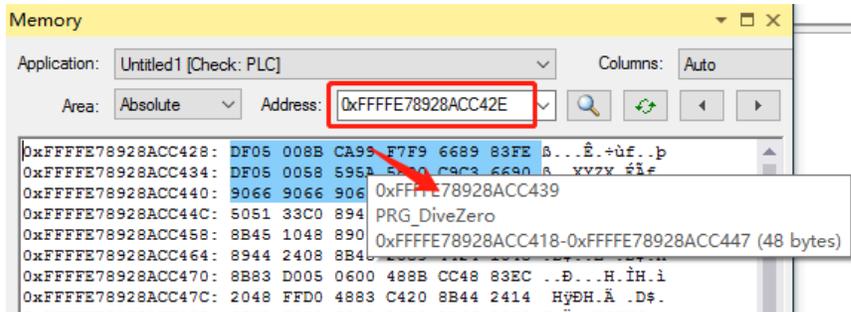
Exception (Exception Code: 0xc0000094, Integer divide by zero)
in PLC Application Untitled1 Instance, Task PlcTask (RBP: 0xfffffa100a529ece0, RIP: 0xffffe78928acc42e, RSP: 0xfffffa100a529ecc0)

RBP: 栈基址寄存器,指向栈底

RSP: 栈指针寄存器,指向栈顶

确定

RIP: 指令指针寄存器,用于保存下一条要执行的指令的地址



3 常规Plc Exception排查

Step1:
添加除零Check函数中添加断点

```
1 // 隐含生成代码: 这里只是对代码实现的建议
2 {noflow}
3 IF divisor = 0 THEN
4     CheckDivDInt := 1;
5 ELSE
6     CheckDivDInt := divisor;
7 END_IF;
8 {flow} RETURN
```

Step2:
查看调用栈

```
1 int1 := 1/int1;
2 RETURN
```

调用栈		
应用:	Check: Untitled1	任务:
POU	位置	实例路径
CheckDivDInt [Check: PLC: Untitled1]	4行, 2列 (Impl)	
PRG_DiveZero [Check: PLC: Untitled1]	1行, 1列 (Impl)	
MAIN [Check: PLC: Untitled1]	6行, 1列 (Impl)	
PlcTask [Check: PLC: Untitled1]	???	PlcTask.__fbTask.CycleUpdate

4 排查Check函数不能处理的Plc Exception

Check函数能规避大部分Plc Exception, 还有一些Plc Exception不能规避, 下面列出部分不能规避的情况 (更多的情况可以参考intel的FPU手册)

Table 31-20. Invalid Arithmetic Operations and the Masked Responses to Them

Condition	Masked Response
Any arithmetic operation on an operand that is in an unsupported format.	Return the real indefinite value to the destination operand.
Any arithmetic operation on a SNaN.	Return a QNaN to the destination operand (see "Operating on NaNs").
Compare and test operations: one or both operands are NaNs.	Set the condition code flags (C0, C2, and C3) in the FPU status word to 111B (not comparable).
Addition: operands are opposite-signed infinities. Subtraction: operands are like-signed infinities.	Return the real indefinite value to the destination operand.
Multiplication: ∞ by 0; 0 by ∞ .	Return the real indefinite value to the destination operand.
Division: ∞ by ∞ ; 0 by 0.	Return the real indefinite value to the destination operand.
Remainder instructions FPREM, FPREM1: modulus (divisor) is 0 or dividend is ∞ .	Return the real indefinite; clear condition code flag C2 to 0.
Trigonometric instructions FCOS, FPTAN, FSIN, FSINCOS: source operand is ∞ .	Return the real indefinite; clear condition code flag C2 to 0.
FSQRT: negative operand (except FSQRT (-0) = -0); FYL2X: negative operand (except FYL2X (-0) = - ∞); FYL2XP1: operand more negative than -1.	Return the real indefinite value to the destination operand.
FBSTP: source register is empty or it contains a NaN, ∞ , or a value that cannot be represented in 18 decimal digits.	Store BCD integer indefinite value in the destination operand.
FXCH: one or both registers are tagged empty.	Load empty registers with the real indefinite value, then perform the exchange.
FIST/FISTP instruction when input operand $\lt \gt$ MAXINT for destination operand size.	Return MAXNEG to destination operand.

4 排查Check函数不能处理的Plc Exception

1: SSE invalid operation

负数开平方操作 `fVar1[-1]:=SQRT(fVar1[-1]);`



2: floating point invalid operation

负数Ln的运算 `fVar1[-1]:=LN(fVar1[-1]);`



说明:

此类异常可以在运算前判断下被操作数的正负来规避

```
fVar1[-1]:=-1.0;  
IF fVar1[-1]>=0 THEN  
    fVar1[-1]:=SQRT(fVar1[-1]);  
END_IF
```


4 排查Check函数不能处理的Plc Exception

4: Other operation

The screenshot shows the TIA Portal interface. On the left, the 'References' tree is expanded to 'Tc2 Utilities'. The main window displays the 'FUNCTION LREAL_TO_INT64' definition. The description states: 'Converts LREAL to signed 64 bit integer. Conversion of numbers > 1.84467440737095E+019 (overflow) and negative numbers (underflow) generates FPU-Exception!'. Below the description is a table with the following data:

名称	类型	继承自	地址	初始化	注释
LREAL_TO_INT64	T_LARGE_INTEGER				
in	LREAL				

说明:

系统自带的函数，如果有关于FPU的提示，需要按照提示来使用。



The End