

EtherCAT[®]

分布式时钟及其在 TwinCAT中的应用

ETG
叶儒峰
r.ye@ethercat.org.cn

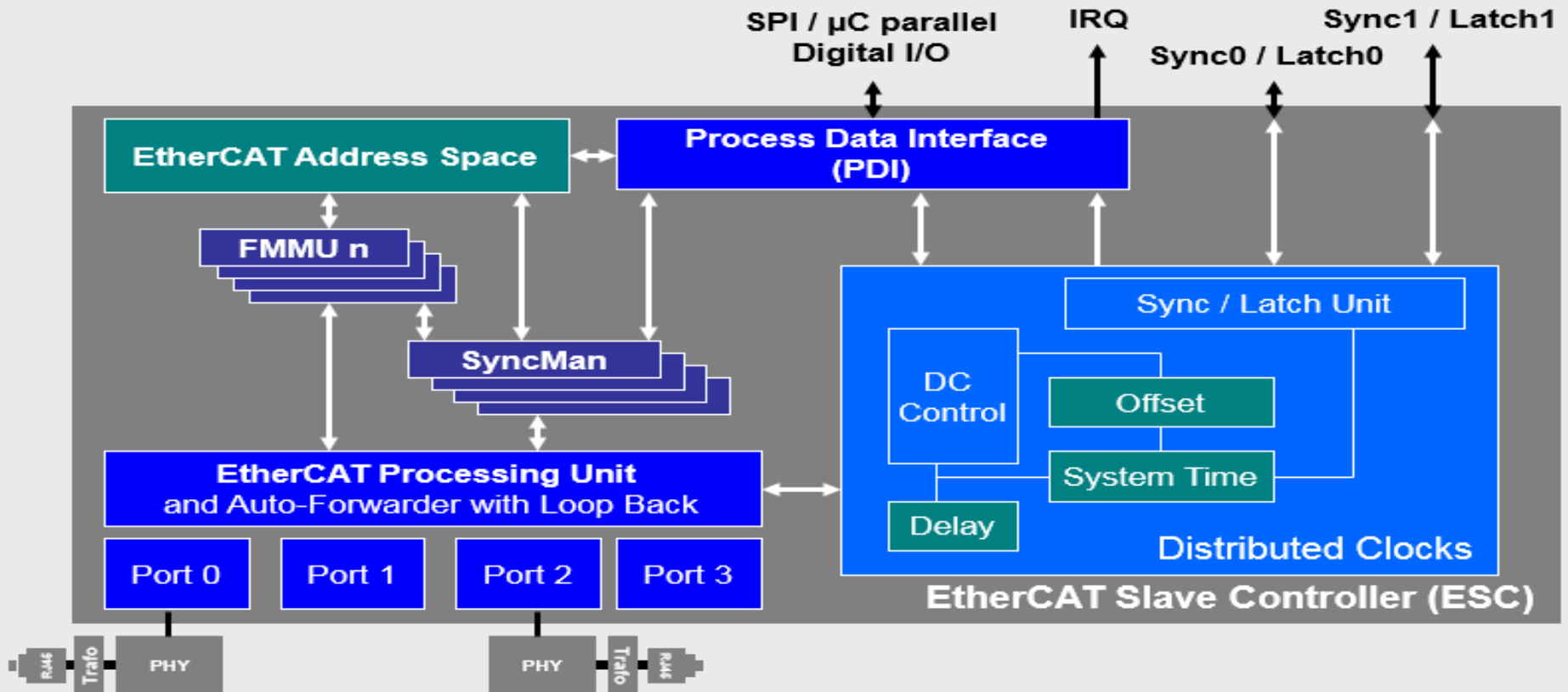
1.DC原理介绍

2.EtherCAT系统运行模式

3.DC所产生的中断信号及其应用

4.TwinCAT中有关DC部分的介绍

Distributed Clocks Unit



Definition of the System Time

- Beginning on January, 1st 2000 at 0:00h
- Base unit is 1 ns
- 64 bit value (enough for more than 500 years)
- Lower 32 bits span over 4.2 seconds (typically enough for communication and time stamping). Some ESCs only have 32 bit DCs, which are compatible with 64 bit DCs.

- 时间间隔为1纳秒，同步抖动在15纳秒以内
- 32位DC支持4.2秒，64位DC超过500年
- 这两种时钟的时间相适应

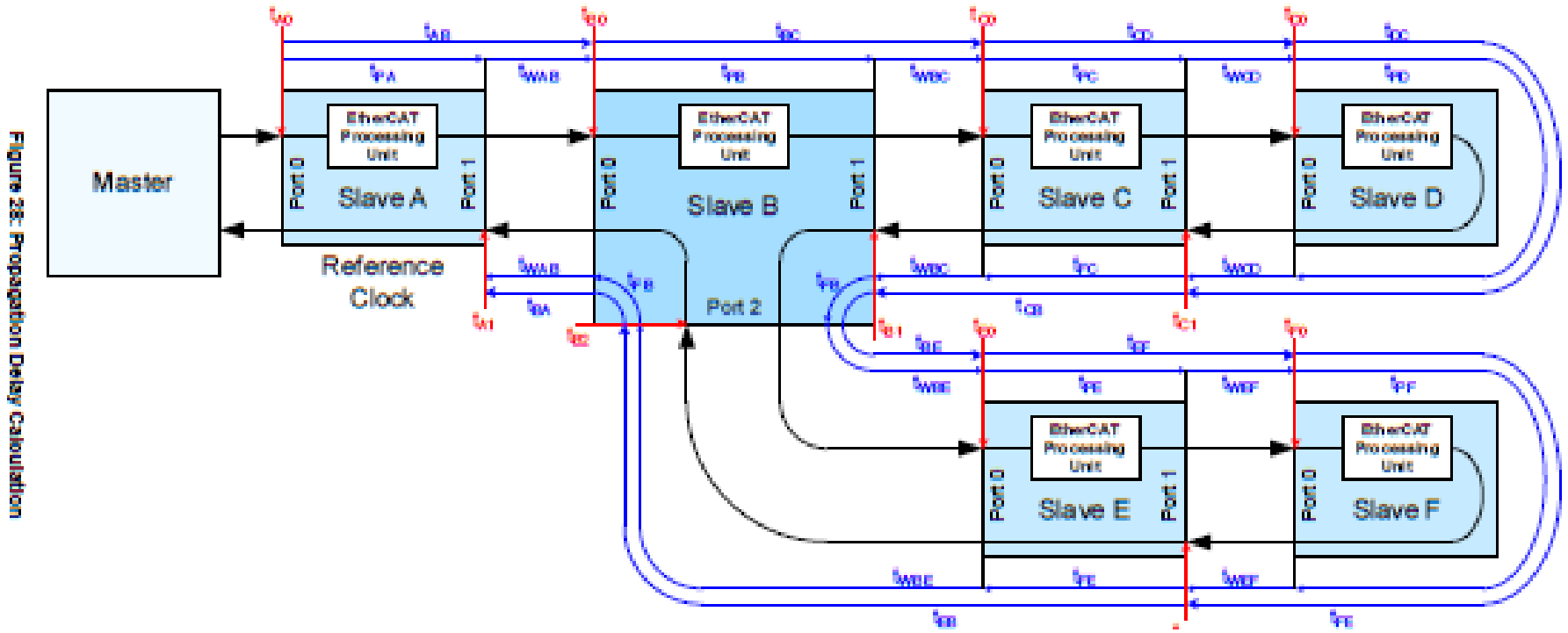
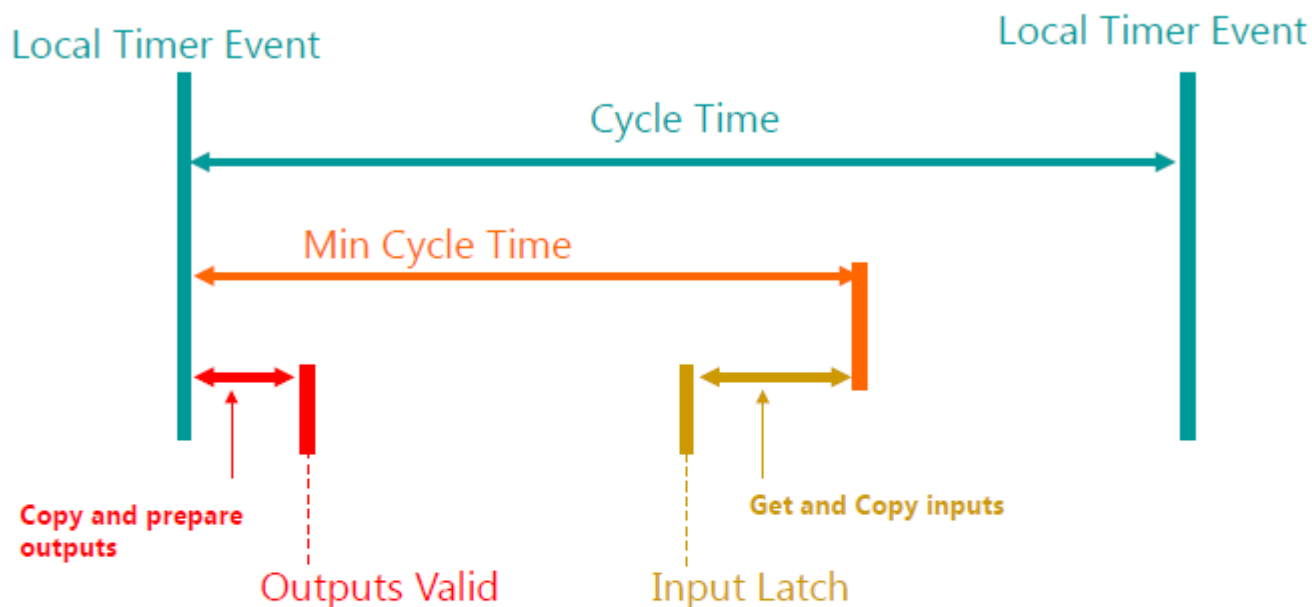


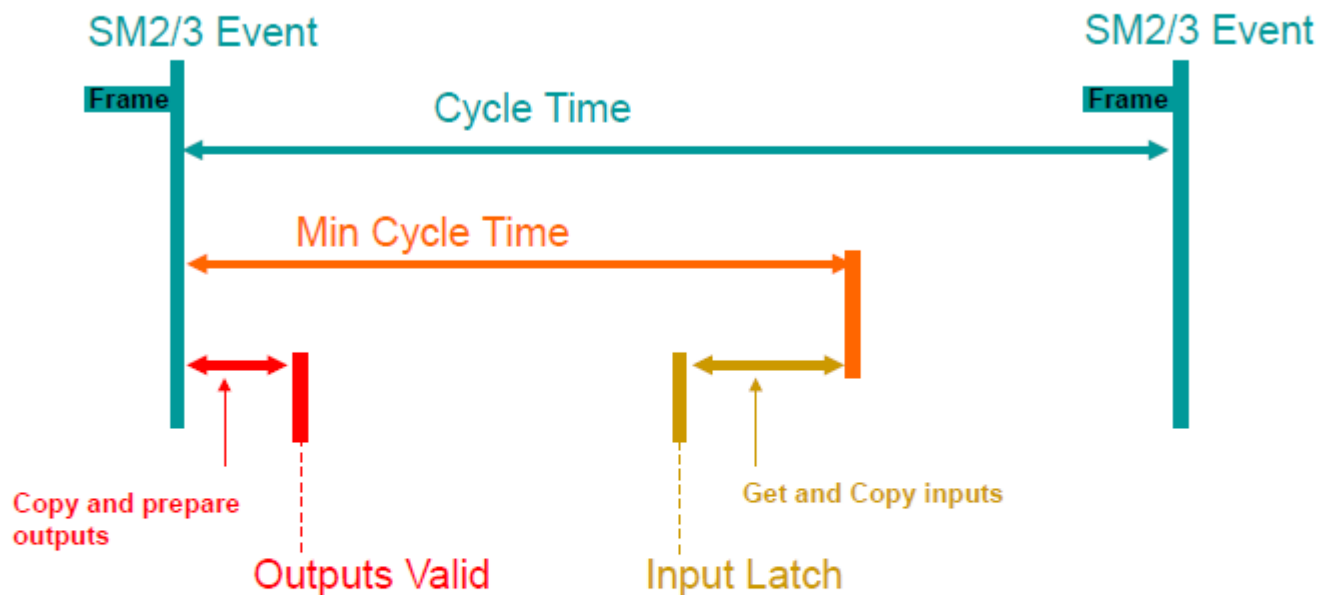
Figure 28: Propagation Delay Calculation

- 自由运行



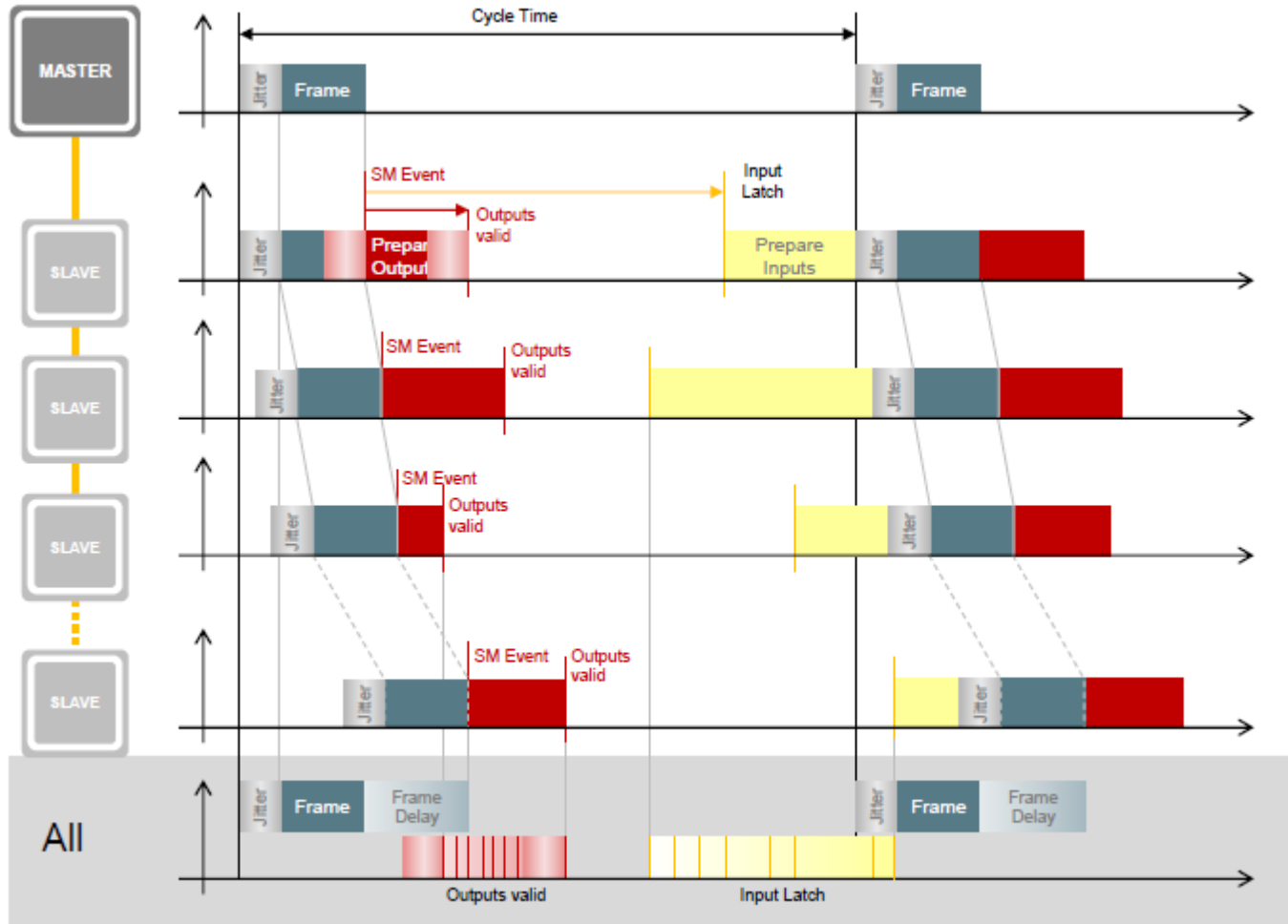
SyncManager Parameter Objects (if CoE is used):
 Cycle Time = OBJ0x1C32:02
 Min Cycle Time = OBJ0x1C32:05

- SM同步

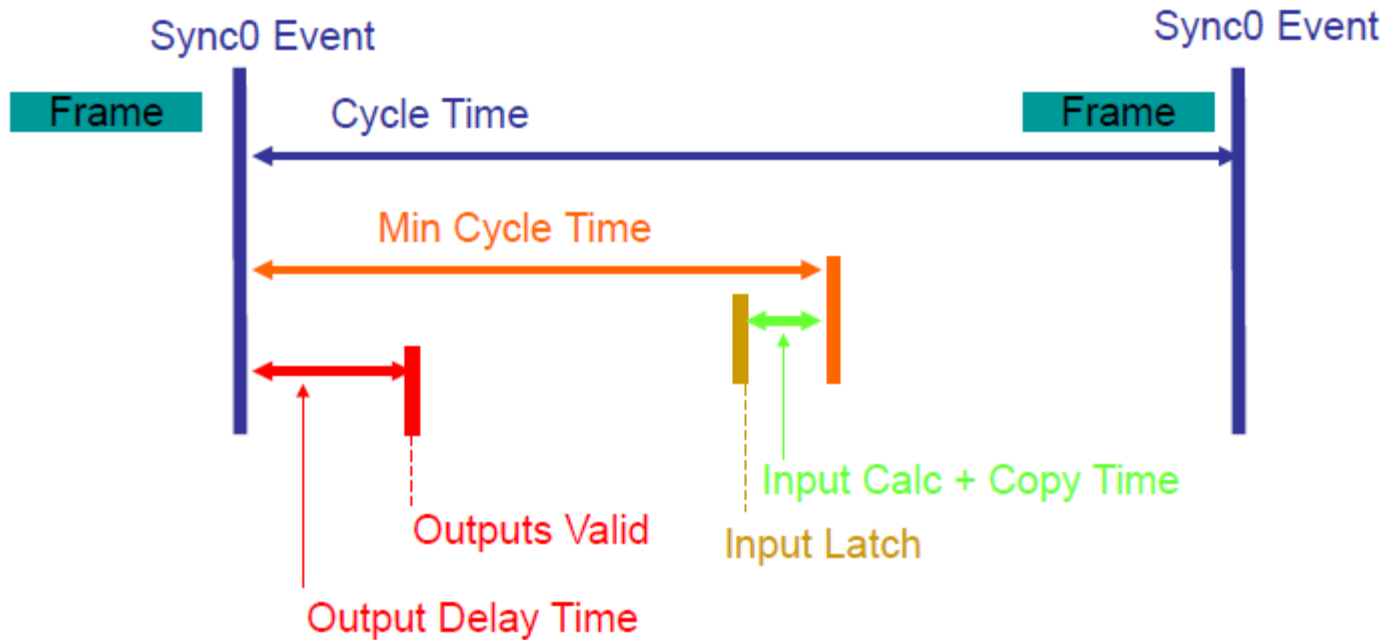


SyncManager Parameter Objects (if CoE is used):
 Cycle Time = OBJ0x1C32:02
 Min Cycle Time = OBJ0x1C32:05

● SM同步



● DC同步

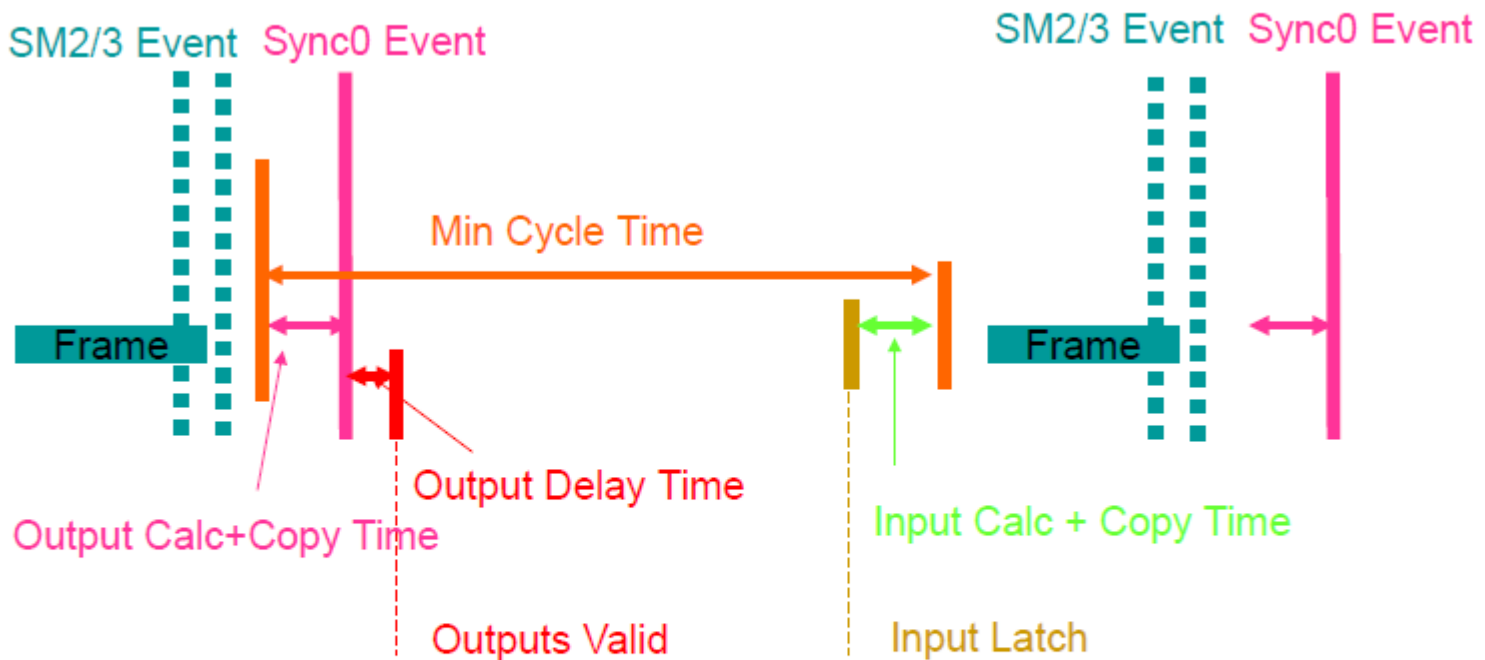


- Frame has to be received before Sync0 Event is generated
- Sync0 Cycle Time has to be greater than the value of `OBJ0x1C32:05`
- `OBJ0x1C32:01 = OBJ0x1C33:01 = 2, OBJ0x1C32:06 = 0, OBJ0x1C33:09 = 0`

SyncManager Parameter Objects (if CoE is used):

Cycle Time	= <code>OBJ0x1C32:02</code>
Min Cycle Time	= <code>OBJ0x1C32:05</code>
Input Shift Time	= <code>OBJ0x1C33:03</code>
Input Calc+Copy Time	= <code>OBJ0x1C33:06</code>
Output Delay Time	= <code>OBJ0x1C32:09</code>

● DC同步

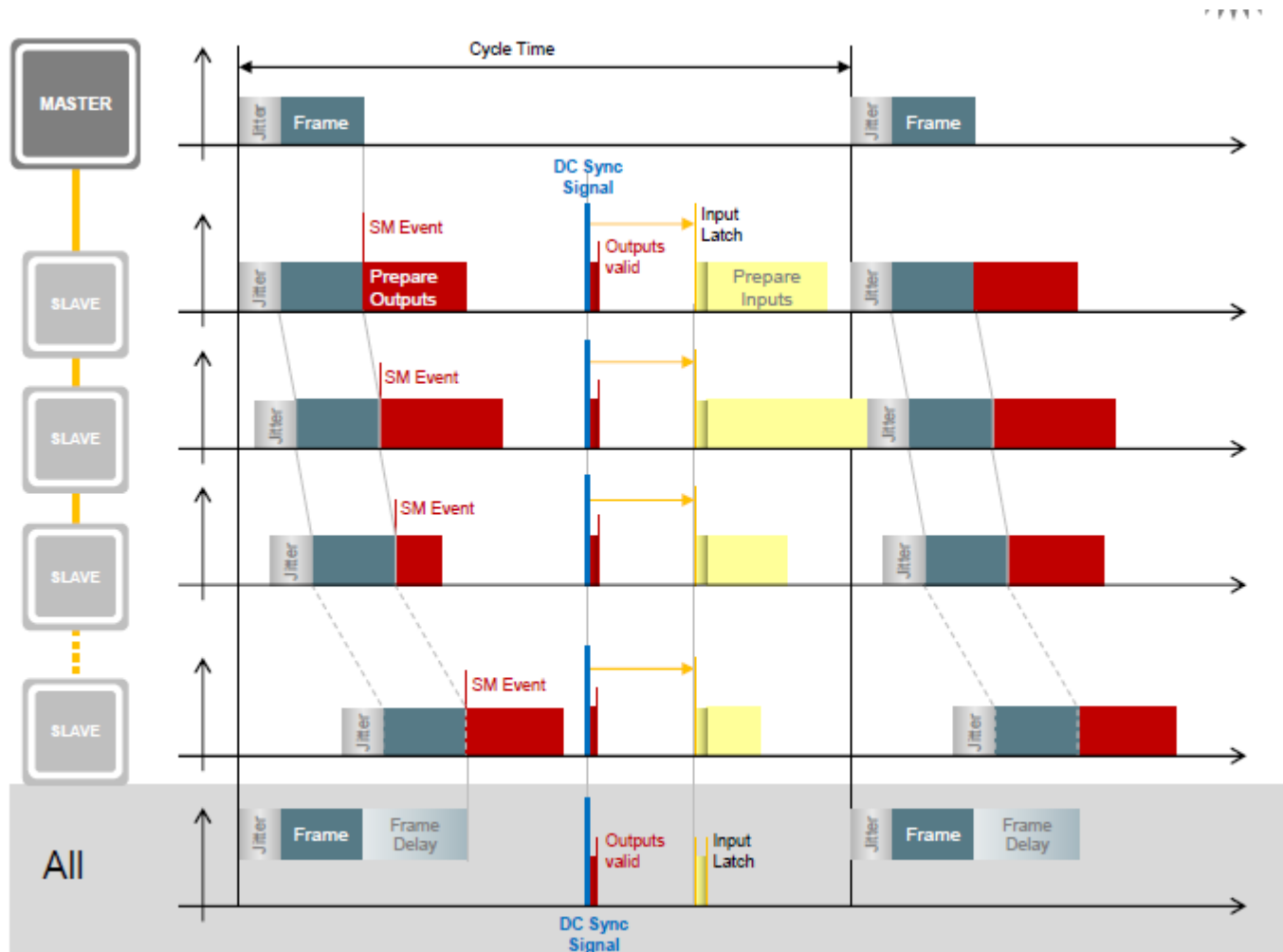


- Frame has to be received at least the value of $_{OBJ}0x1C32:06$ before Sync0 Event is generated
- Sync0 Cycle Time has to be greater than the value of $_{OBJ}0x1C32:05$
- $_{OBJ}0x1C32:01 = _{OBJ}0x1C33:01 = 2, _{OBJ}0x1C33:09 = 0$

SyncManager Parameter Objects (if CoE is used):

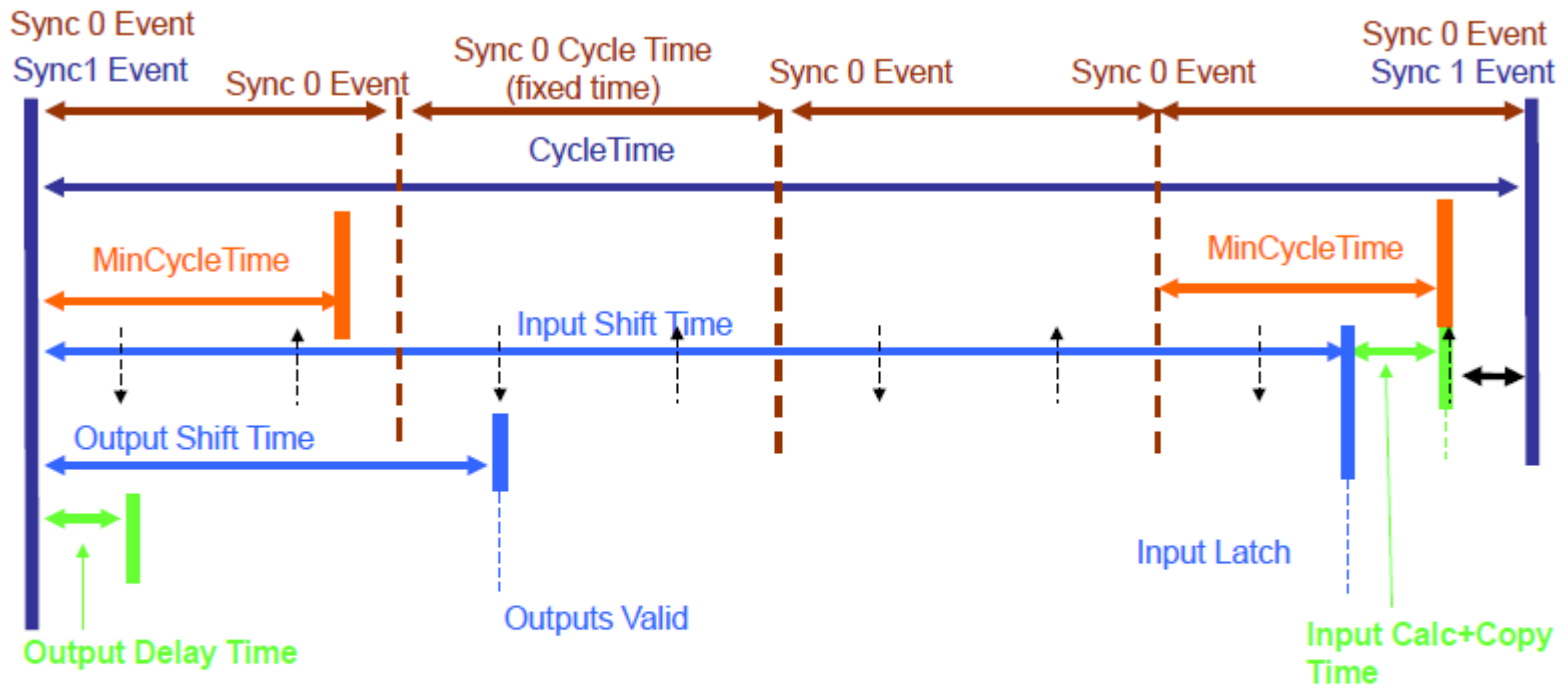
Cycle Time	= $_{OBJ}0x1C32:02$
Min Cycle Time	= $_{OBJ}0x1C32:05$
Output Calc+Copy Time	= $_{OBJ}0x1C32:06$
Input Calc+Copy Time	= $_{OBJ}0x1C33:06$
Output Delay Time	= $_{OBJ}0x1C32:09$
Input Delay Time	= $_{OBJ}0x1C33:09$

● DC同步



- SYNC0 是最常用的同步信号，由DC产生，固定周期触发
- 在输出模块里，SYNC0常用于统一输出时间
- 在输入模块里，SYNC0常用于统一采样时间
- SYNC1信号不独立存在，通常是在SYNC0触发之后，延时一段时间触发
- SYNC1触发周期可以是SYNC0的整数倍
- 锁存信号（LATCH0/1）用于给外部信号打上时间戳（time stamp）

典型应用：超采样模块



↓ Possible Output Valid /
↓ Input Latch

SyncManager Parameter Objects (if CoE is used):
 Cycle Time = OBJ0x1C32:02
 Min Cycle Time = OBJ0x1C32:05
 Output Shift Time = OBJ0x1C32:03
 Input Shift Time = OBJ0x1C33:03
 Input Calc+Copy Time = OBJ0x1C33:06
 Output Delay Time = OBJ0x1C32:09

Advanced Settings

- State Machine
 - Master Settings
 - Slave Settings
- Cyclic Frames
 - Sync Tasks
 - Process Image
 - VLAN Tagging
- Distributed Clocks**
 - Diagnosis
 - Slave Diagnosis
- EoE Support
- Redundancy
- Emergency
 - Scan
- Diagnosis
 - Online View

Distributed Clocks

DC Mode

- Automatic DC Mode Selection
- DC in use

Reference Clock:

- Independent DC Time (Master Mode)
- DC Time controlled by TwinCAT Time (Slave Mode)
- DC Time controlled by External Sync Device (External Mode)

External Sync

Settings

- Continuous Run-Time Measuring
- Sync Window Monitoring
 - Sync Window (μ
- Show DC System Time (64 bit)
- Dc Sync

SYNC Shift Time (μs)

Percent of cycle

For +

For Inputs: +

确定 取消

● DC Mode

DC Mode

Automatic DC Mode Selection

DC in use

Reference Clock:

Independent DC Time (Master Mode)

DC Time controlled by TwinCAT Time (Slave Mode)

DC Time controlled by External Sync Device (External Mode)

External Sync

DC Mode

Automatic DC Mode Selection

DC in use

Reference Clock:

Independent DC Time (Master Mode)

DC Time controlled by TwinCAT Time (Slave Mode)

DC Time controlled by External Sync Device (External Mode)

External Sync

- 主要用于选择参考时钟
- 一般情况不建议修改
- 去掉自动选择选项后可以手动修改参考时钟

● DC Mode

Independent DC Time (Master Mode)

DC Time controlled by TwinCAT Time (Slave Mode)

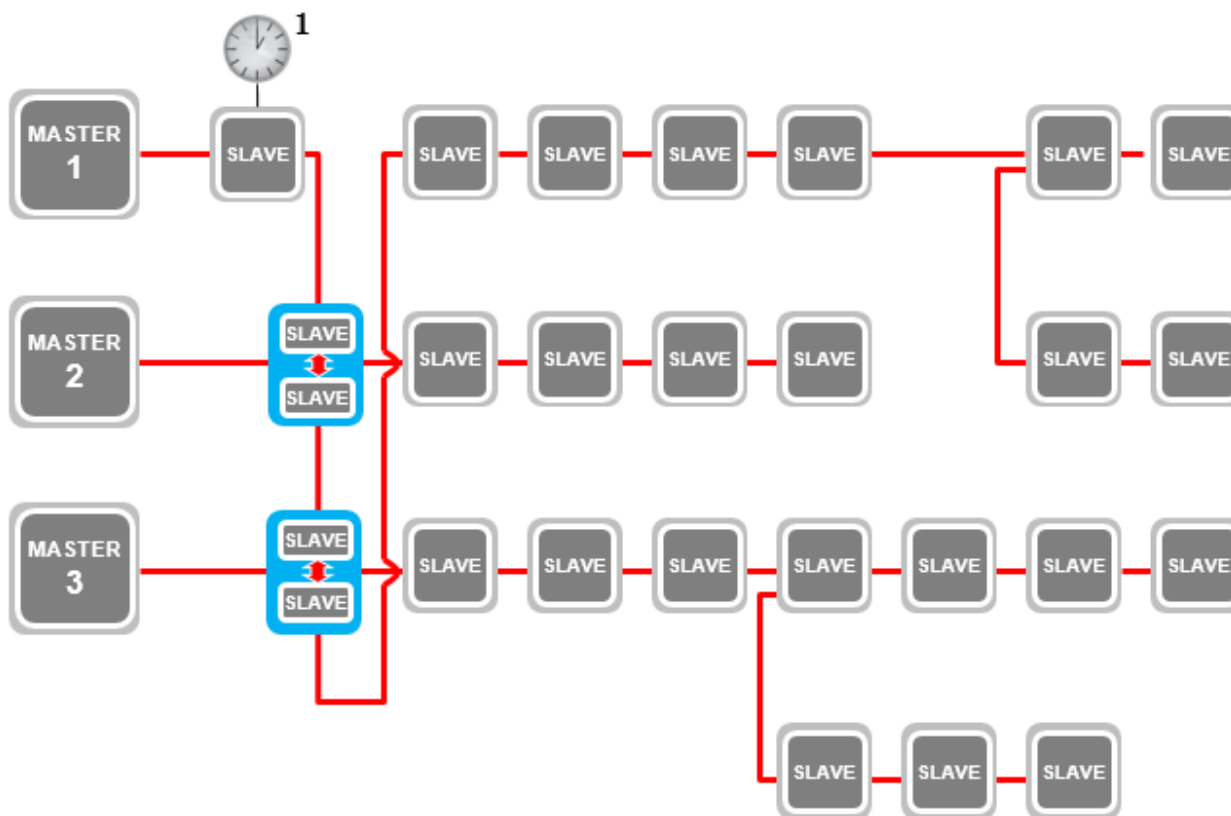
DC Time controlled by External Sync Device (External Mode)

External Sync

- 选择整个网络的DC模式
- Master Mode表示这个EtherCAT网络同步于本地参考时钟
- Slave Mode表示这个EtherCAT网络同步于其他网络
- External Mode表示这个EtherCAT网络同步于外部时钟源

- DC Mode

- 通过EtherCAT桥接端子模块耦合不同EtherCAT网络
- Bridge provides hardware synchronization of several networks



● Settings

Settings

Continuous Run-Time Measuring

Sync Window Monitoring

Sync Window (μs)

Show DC System Time (64 bit)

Dc Sync Highest Priority ▼

- **Continuous Run-Time Measuring** 周期性计算各从站设备之间的距离，此功能在 twincat2.11 之后不建议开启，会占用资源拖慢速度

- **Sync Window Monitoring**

周期性检查所有从站是否处于DC模式，激活后主站将在周期性数据帧中插入一个BRD命令，来读取各个从站的 0X92C 寄存器

检测原理是将寄存器中的数值与设定值相比较，若大于设定值，则判定此从站未同步

Register System Time Difference (0x092C:0x092F)

Bit	Description	ECAT	PDI
30:0	Mean difference between local copy of System Time and received System Time values	r/-	r/-
31	0: Local copy of System Time greater than or equal received System Time	r/-	r/-
	1: Local copy of System Time smaller than received System Time		

● Settings

勾选前:

Settings

Continuous Run-Time Measuring

Sync Window Monitoring

Sync Window (μs)

Show DC System Time (64 bit)

Dc Sync

Frame	Cmd	Addr	Len	WC	Sync Unit	Cycle...	Utilizatio...	Size / Durati...	Map
0	NOP	0x0000 0x0900	4			2.000			
0	ARMW	0x0000 0x0910	4			2.000			
0	LRD	0x09000000	1			2.000			
0	LRW	0x01000000	8	3	<default>	2.000			
0	LRD	0x01000800	16	2	<default>	2.000			
0	BRD	0x0000 0x0130	2	3		2.000	0.58	123 / 11.76	0
							0.59		

勾选后:

Settings

Continuous Run-Time Measuring

Sync Window Monitoring

Sync Window (μs)

Show DC System Time (64 bit)

Dc Sync

Frame	Cmd	Addr	Len	WC	Sync Unit	Cycle...	Utilizatio...	Size / Durati...	Map I
0	NOP	0x0000 0x0900	4			2.000			
0	ARMW	0x0000 0x0910	4			2.000			
0	LRD	0x09000000	1			2.000			
0	LRW	0x01000000	8	3	<default>	2.000			
0	LRD	0x01000800	16	2	<default>	2.000			
0	BRD	0x0000 0x092c	4			2.000			
0	BRD	0x0000 0x0130	2	3		2.000	0.65	139 / 13.04	0
							0.65		

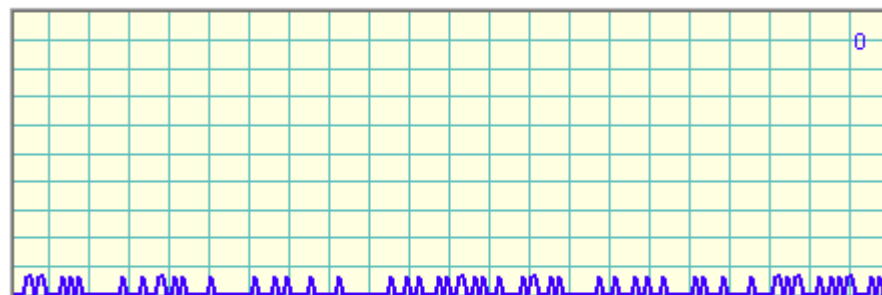
● Settings

勾选后（窗口10ns）：

Settings

- Continuous Run-Time Measuring
- Sync Window Monitoring
 - Sync Window (μ)
- Show DC System Time (64 bit)
- Dc Sync

Variable	Flags	Online
Value:	<input type="text" value="0"/>	
New Value:	<input type="button" value="Force..."/>	<input type="button" value="Release"/> <input type="button" value="Write..."/>
Comment:	<pre> 0x0080 = I/O reset active 0x0100 = At least one device in 'INIT' state 0x0200 = At least one device in 'PRE-OP' state 0x0400 = At least one device in 'SAFE-OP' state 0x0800 = At least one device indicates an error state 0x1000 = DC not in sync </pre>	



● Settings

Settings

Continuous Run-Time Measuring

Sync Window Monitoring

Sync Window (μs)

Show DC System Time (64 bit)

Dc Sync

- ▲ Inputs
 - ▲ DcSysTime
 - ▶ DcSysTime[0]
 - ▶ DcSysTime[1]
 - ▶ FrmOState
 - ▶ FrmOWcState
 - ▶ FrmOInputToggle
 - ▶ SlaveCount
 - ▶ DevState

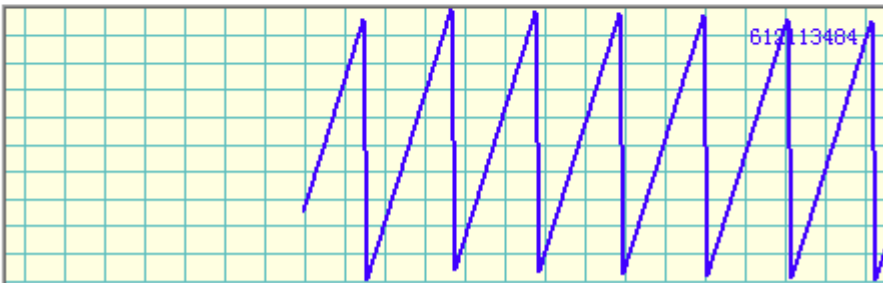
- Show DC System Time
激活后可以在Inputs中看到DC具体数值

Variable | Flags | Online

Value:

New Value:

Comment:



- Sync Shift Time

SYNC Shift Time (μs)

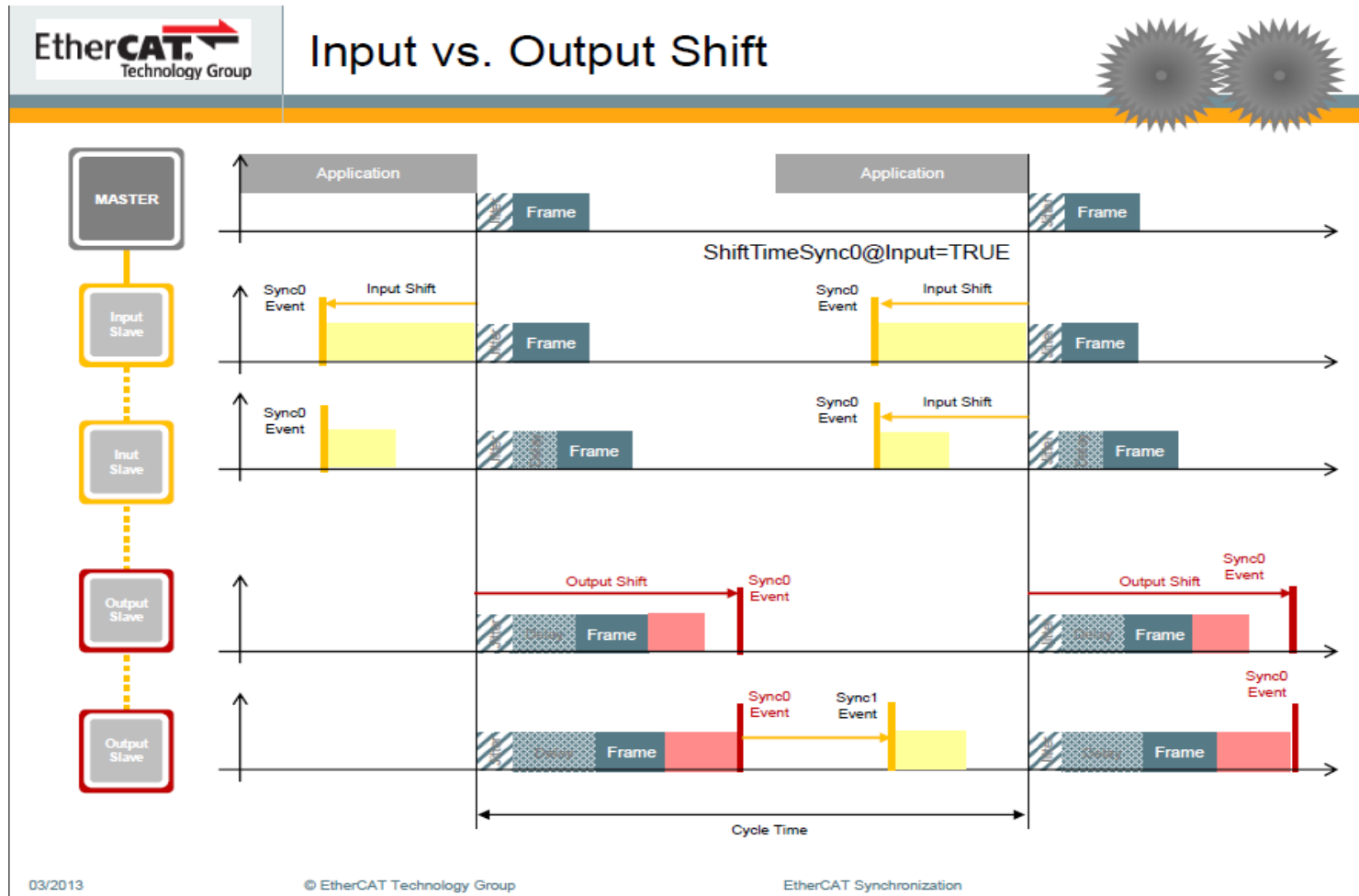
Percent of cycle

For +

For Inputs: +

- **Shift Time** 表示主站周期与所有从站sync信号触发之间的时间间隔
- 这个时间间隔由主站自动计算出，但是能够手动修改
- 第一个**shift time**一般表示主站与从站sync0信号之间的时间间隔，对于输出模块来说，就是主站周期和从站output valid之间的间隔
- **Input shift time**只对输入模块有效，表示输入有效信号（sync0信号延时或者sync1信号）提前主站周期多少时间

- Sync Shift Time



Advanced Settings

Distributed Clock

Distributed Clock

Cyclic Mode

Operation Mode: DC-Synchron

Enable Sync Unit Cycle (700

SYNC 0

Cycle Time (μs):

Sync Unit Cycle x 1

User Defined 700

Shift Time (μs):

User Defined 0

+ SYNCO Cycle x 0 0

Based on Input Reference

+ []

= 0

Enable SYNC 0

SYNC 1

Sync Unit Cycle []

SYNC 0 Cycle x 1

Cycle Time (μs): 700

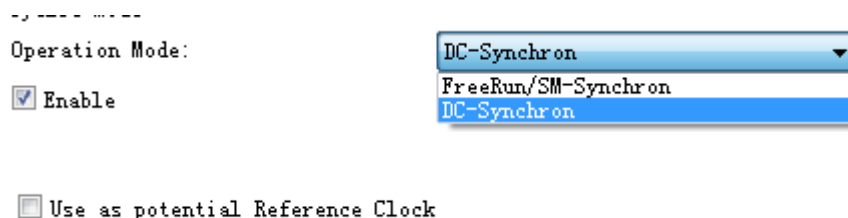
Shift Time (μs): 5

Enable SYNC 1

Use as potential Reference Clock

确定 取消

● Cyclic Mode



- Operation Mode 选择从站同步模式
- Enable 从站同步信号使能
- Use as potential Reference Clock 手动选择当前从站的同步时钟作为 Ref_Clk时需要激活此选项

● Sync 0

The image shows two side-by-side screenshots of the 'SYNC 0' configuration window in TWINCAT. Both windows have 'Enable SYNC 0' checked.

- Left Screenshot:**
 - Cycle Time (μs):** Radio button 'Sync Unit Cycle' is selected with a multiplier of 'x 1'. Radio button 'User Defined' is unselected. The value '2000' is entered in the text box.
 - Shift Time (μs):**
 - 'User Defined' is 0.
 - '+ SYNCO Cycle' is 'x 0' with a value of 0.
 - 'Based on Input Reference' is unchecked.
 - '+' is empty.
 - '=' is 0.
- Right Screenshot:**
 - Cycle Time (μs):** Radio button 'Sync Unit Cycle' is selected with a multiplier of 'x 1'. Radio button 'User Defined' is unselected. The value '2000' is entered in the text box.
 - Shift Time (μs):**
 - 'User Defined' is 100.
 - '+ SYNCO Cycle' is 'x 0' with a value of 0.
 - 'Based on Input Reference' is checked.
 - '+' is -818.800.
 - '=' is -718.800.

- Sync 0 信号的相关设置

• Cycle Time: Sync0信号的周期

• Enable SYNC0 : Sync0信号使能

• Shift Time: 本从站的sync0信号相对于主站循环周期的偏移时间

• Based on Input Reference: 相对于本地输入有效信号的偏移时间

● Sync 1

SYNC 1

<input type="radio"/> Sync Unit Cycle	<input type="text" value=""/>	Cycle Time (μs):	<input type="text" value="2000"/>
<input checked="" type="radio"/> SYNC 0 Cycle	<input type="text" value="x 1"/>	Shift Time (μs):	<input type="text" value="5"/>
<input checked="" type="checkbox"/> Enable SYNC 1			

- Sync 1 信号的相关设置

- Cycle Time:

Sync1信号的周期

由于Sync1信号不独立存在，twincat中可以选择其周期是sync0信号的倍数或者是同步单元周期的倍数

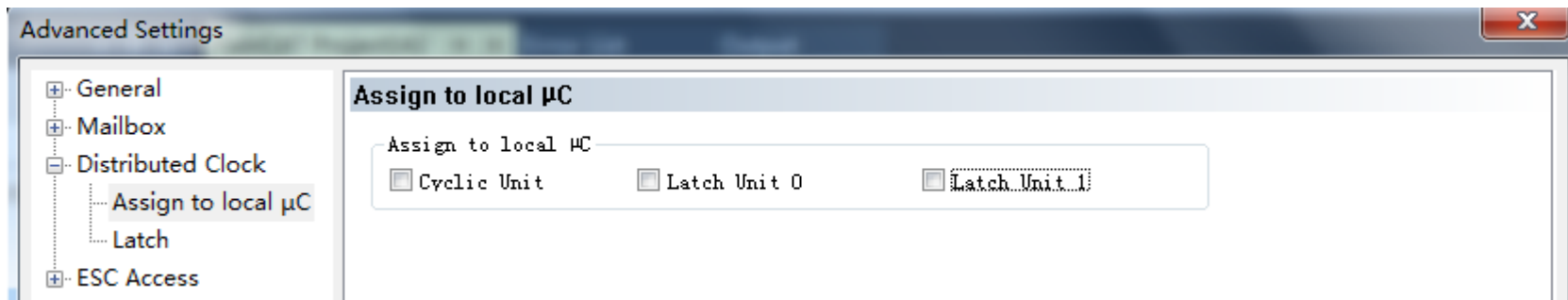
- Enable SYNC1 :

Sync1信号使能

- Shift Time:

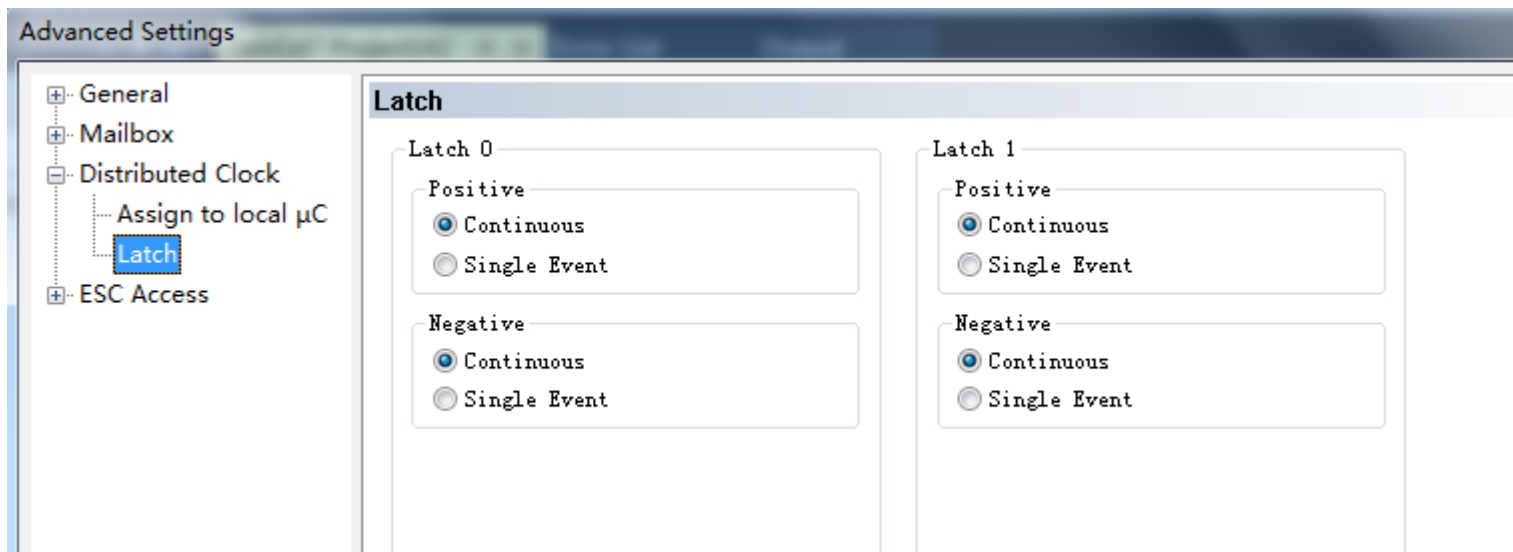
本从站的sync1信号相对于sync0信号的偏移时间

- Assign to local μ C



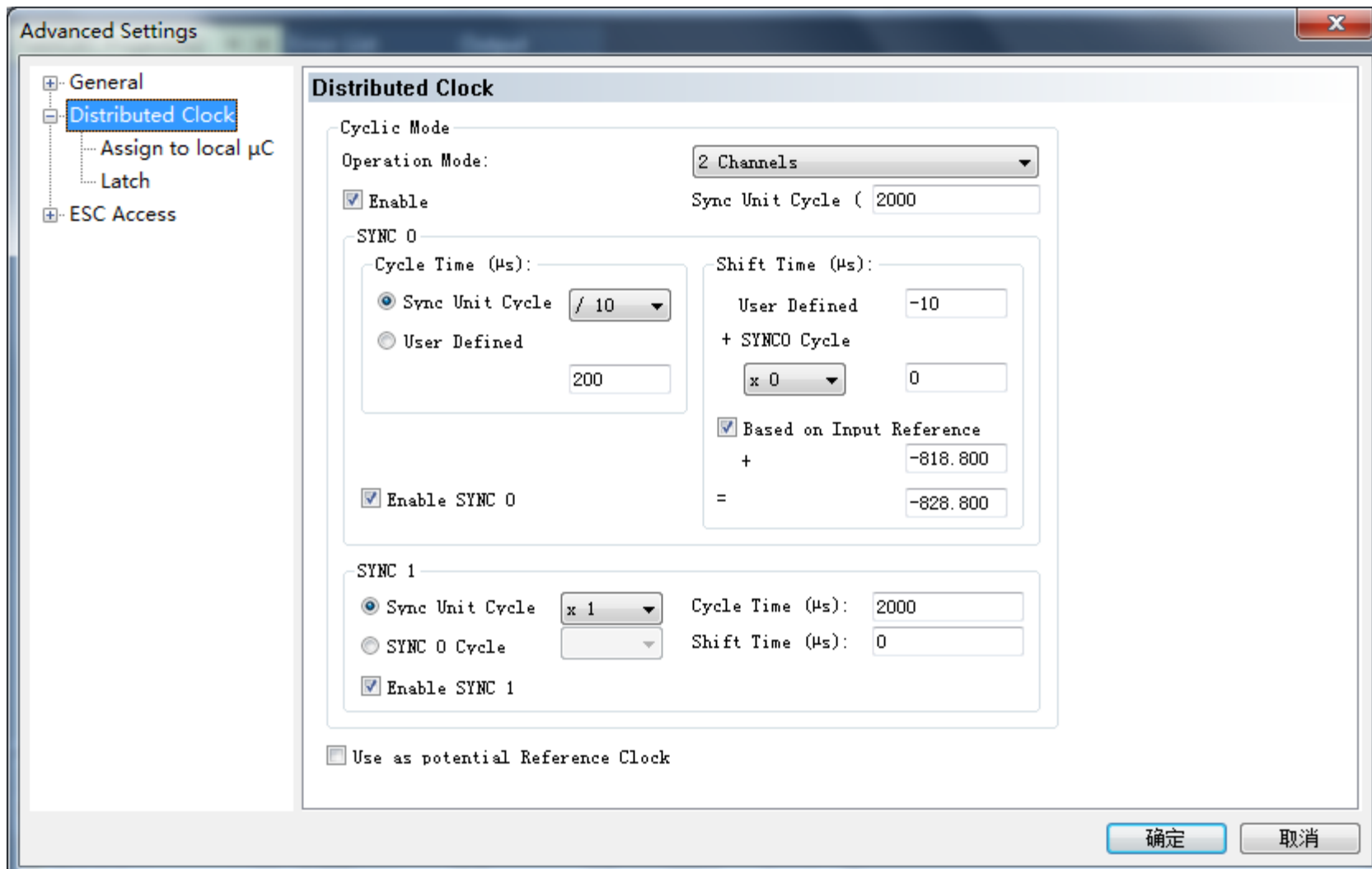
- Cyclic Unit 激活后DC主页面不可设置
- Latch Unit 0 激活后锁存信号Latch0不可设置
- Latch Unit 1 激活后锁存信号Latch1不可设置

● Latch



- 锁存信号工作模式分为单次模式和连续模式
- 单次模式只锁存在本周期内首次捕获上升沿和下降沿的时间
- 连续模式锁存本周期内最后一次捕获的上升沿和下降沿的时间
- 默认工作模式为连续模式

- 超采样模块演示



Thank You

ETG
叶儒峥
r.ye@ethercat.org.cn