## Fusion Temperature Control Overview

The DDI Fusion Temperature Controller controls a component's temperature through a heating or cooling element. Feedback is provided through an external sensor. Each loop can control a single element, and multiple loops may use the same sensor input. The maximum number of loops in the system is 64. For each loop one RxPDO (7nnE) and one TxPDO (6nnE) describe the default mapping. An additional SDO index (8nnE) is present for loop configuration. The number of loops is selected by setting the *Number of Control Loops* in the Device Information object (Index 0x2000, SubIndex 16).

## General Setup

1. While the Fusion is in Pre-Operational Mode set desired number of control loops (Index 0x2000, SubIndex 16). Note: Depending on your EtherCAT master configuration you may need to remove and re-add the Fusion to the EtherCAT network after this step.
2. For each controller perform the following minimum configuration of the 0x8nnE object:
    1. Set Input Index setting (subindex 1)
    2. Set Output Index setting (subindex 2)
    3. Set Sensor Type (subindex 3)
    4. Set Units of Measure (subindex 5)
    5. Set Safe State action (subindex 8)
        - If safe state action set to 2, then set Standby Setpoint (subindex 12)
    6. Set Process Scale high (subindex 9) in accordance with the Sensor Type and Units of Measure. Note: this step can be skipped if the sensor type is a TC or RTD.
    7. Set Process Scale low (subindex 10) in accordance with the Sensor Type and Units of Measure. Note: this step can be skipped if the sensor type is a TC or RTD.
    8. Set Output Mode (subindex 30)
        - If Output Mode is “PWM” then set Output Cycle Time (subindex 11)
    9. Set Proportional Band (subindex 19)
    10. Set Integrator Time (subindex 20)
    11. Set Derivative Time (subindex 21)
3. If Alarms are used set the relevant settings in each 0x8nnE object
4. If limits are required set the relevant limits in each 0x8nnE object
    - Use of Setpoint High Limit and Setpoint Low Limit is encouraged
5. Save controller configuration by sending "save" (0x73, 0x61, 0x76, 0x65, 0x00) to the *Store Parameters Object* (Index 0xFBF2, SubIndex 1) so that setup will be remembered on subsequent power cycles.

## Operation

After setup is complete the device is ready to be used. To activate the control loop the device must be placed into Operate Mode and the TxPDO (Ecat Main to Fusion) data is used to manage the controller. The device reports the operating status in the RxPDO (Fusion to Ecat Main) data. The PDO descriptions are below followed by the configuration SDO (0x8nnE).

## Temp Control TxPDO Object Description

Index: 0x6nnE

| SubIndex | Datatype | TempControl (inputs) | Temp Control Loop |
|---|---|---|---|
| 0x01 | BOOL | Control State | Indicates if the control loop is active.<br>0: Off 1: Running |
| 0x02 | BIT2 | Control Mode | Current mode of the control loop<br>0: Auto (PID Ctrl)<br>1: Manual<br>2: Auto (On-Off/Bang-Bang Ctrl)<br>3: Autotune is running |
| 0x03 | BIT3 | Tune State | Returns information about this loop's tuning progress<br>0: Not tuned since power-up<br>1: Tune in progress<br>2: Tune completed successfully<br>3: Tune failed and terminated<br>4-7: Reserved |
| 0x04 | pad_6 | | |
| 0x05 | BIT1 | New message in diagnosis history | **NOTE**: Unused. See Fusion object 0x10F3 for diagnostic data |
| 0x06 | BIT1 | TxPdoState | Indicates that this module is reporting correctly<br>0=OK 1=Module Fault |
| 0x07 | BIT2 | Input Cycle Counter | Passthrough of the Output Cycle Counter, can be used to determine if the slave is synchronous with the master |
| 0x08 | REAL | Process value | This is the measured value (PV) of the loop. If in error return +Infinity. |

| SubIndex | Datatype | TempControl (inputs) | Temp Control Loop |
|---|---|---|---|
| 0x09 | REAL | Manipulated Value | Total output control signal as a percentage of heating/cooling capacity –100.0 to +100.0%. Fusion does not directly support heaters so value will range from 0-100 |
| 0x0A | REAL | Heat Manipulated Value | **NOTE**: Not used. Reserved for future use.<br>Heat output control signal 0.0-100.0% |
| 0x0B | REAL | Controlling Set Point | Controller auto setpoint in use when Control Mode is set to Auto |
| 0x0C | UINT | Alarm Condition | 1 bit per alarm<br>Bit 0: Alarm 1 Condition Occurring<br>Bit 1: Alarm 2 Condition Occurring<br>Bit 2..15: Reserved for Future Use |

## Temp Control TxPDO Object Description

### Index: 0x7nnE

| SubIndex | Datatype | TempControl (outputs) | Temp Control Loop |
|---|---|---|---|
| 0x01 | BOOL | Control State | 0=Off: Set output off. 1=On: Activate controller. |
| 0x02 | BIT2 | Control Mode | Current mode of the control loop<br>0: Auto (PID Ctrl)<br>1: Manual<br>2: Auto (On-Off/Bang-Bang Ctrl)<br>3: Reserved. If a 3 is received the Fusion it will default to PID control. |
| 0x03 | pad_11 | | |
| 0x04 | BIT2 | Output Cycle Counter | **NOTE**: Unused by subdevice, passed back through to master<br>Incremented by the master with each cycle. The slave can determine if the master sends process data before the SyncSignal occurs |
| 0x05 | REAL | Target set point | Set point set by the user's system. Units match the Units of Measure setting in 8nnE subindex 5. |
| 0x06 | REAL | Forced Manipulated Value | User set output percent power in manual Mode. Range is 0.0 to 100.0 |

## Temp Control Module Configuration Object Description

### Index: 0x8nnE

| SubIndex | DataType | Access | Name | Default | Description |
|---|---|---|---|---|---|
| 0x01 | UINT | rw | Input Index Setting | 0 | Analog input index offset. Select which analog input to use as the PV input for the controller. The index can be obtained by looking at the 0x3nn1.06 module information channel low setting and using that as a channel offset for the module. For example, if you want to use the 3rd input channel on the 8th module you would read 0x3071.06. If the value read from 0x3071.06 was 48 the input index setting for the temperature controller would be 50: 48+3-1 (subtract off 1 because channels are 0-indexed). In **FW v1.15.3 and greater**: Invalid settings which do not map to a usable input channel will cause the temperature controller to report positive infinity to ensure the controller will not overdrive any heater output. |
| 0x02 | UINT | rw | Output Index Setting | 65535 | Digital output index offset that will be driven by the temperature controller output. The index can be obtained by looking at the 0x3nn1.06 module information channel low setting and using that as a channel offset for the module. For example, if you want to use the 2nd output channel on the 1st module you would read 0x3001.06. If the value read from 0x3001.06 was 8 the input index setting for the temperature controller would be 9: 8+2-1 (subtract off 1 because channels are 0-indexed) |

| SubIndex | DataType | Access | Name | Default | Description |
|---|---|---|---|---|---|
| 0x03 | USINT | rw | Sensor Type | 6 | Type of sensor being measured<br>0: TC<br>1: RTD100<br>2: RTD1000<br>3: 4-20mA<br>4: 0-20mA<br>5: 0-10V<br>6: -10-10V<br>7-255 Reserved. Behave as type 6 |
| 0x04 | USINT | rw | TC Type | 0 | **NOTE**: Not used. TC type is determined automatically based in the input index setting selected.<br>Thermocouple Type<br>0: K<br>1: J<br>2: T<br>3: E<br>5: R<br>6: S<br>7: B<br>8-255 reserved |
| 0x05 | USINT | rw | Units of Measure | 0 | Sets the units of measure for the PV value<br>0: Celsius<br>1: Fahrenheit<br>2: Process |
| 0x06 | USINT | rw | Alarm 1 Enable | 0 | 0=Off<br>1=Enabled<br>2-255=Future use |
| 0x07 | USINT | rw | Alarm 2 Enable | 0 | 0=Off<br>1=Enabled<br>2-255=Future use |

| SubIndex | DataType | Access | Name | Default | Description |
|---|---|---|---|---|---|
| 0x08 | USINT | rw | Safe State Action | 0 | The control behavior in the safe state<br>0: Control State = OFF<br>1: Control State = ON, Control Mode = AUTO, Controlling Set Point = Target Set Point<br>2: Control State = ON, Control Mode = AUTO, Controlling Set Point = Standby Set Point<br>3: Control State = ON, Control Mode = MANUAL, Manipulated Value = Forced MV<br>4: Operate as configured<br>5-255: Reserved. Will behave as action 4 |
| 0x09 | REAL | rw | Process Scale High | 0 | When the sensor type is set to a process input (0-20mA, 4-20mA, 0-10V, -10-10V) this is the Process Value that will correspond to the electrical signal input signal at its upper range. For example, if the sensor is -10-10V, the Process will take this reading when the input is +10V. The Process Value is scaled linearly between the upper and lower values. |
| 0x0A | REAL | rw | Process Scale Low | 0 | If the sensor type is set to a process input (0-20mA, 4-20mA, 0-10V, -10-10V) this is the Process Value that will correspond to the electrical signal input signal at its lower range. For example, if the sensor is -10-10V, the Process will take this reading when the input is -10V. The Process Value is scaled linearly between the upper and lower values. |
| 0x0B | REAL | rw | Output Cycle Time | 0 | The output cycling time in seconds. Must be set to allow partial power output in PWM mode (i.e. any power that is not 0 or 100) |

| SubIndex | DataType | Access | Name | Default | Description |
|---|---|---|---|---|---|
| 0x0C | REAL | rw | Standby Set Point | 0 | A set point used for standby situations. This is the standby setpoint used by safe state option 2. |
| 0x0D | REAL | rw | Setpoint High Limit | Infinity | Upper bound for the Target and Standby Set Points |
| 0x0E | REAL | rw | Setpoint Low Limit | -Infinity | The low bound for the Target and Standby Set Points |
| 0x0F | REAL | rw | PV Bias | 0 | An offset adjustment of the Process Value(PV). Units match the Units of Measure setting |
| 0x10 | REAL | rw | MV High Limit | Infinity | High bound of the Manipulated Value (MV) This will also limit the output MV in Auto/Closed Loop mode. Range +-100.0. |
| 0x11 | REAL | rw | MV Low Limit | -Infinity | Low bound of the Manipulated Value(MV) This will also limit the output MV in Auto/Closed Loop mode. Range: +-100.0 |
| 0x12 | REAL | rw | On-Off dead band | 0 | Hysteresis band for bang-bang control |
| 0x13 | REAL | rw | Proportional band | 0 | Proportional Band for the primary loop. When the error is outside this range the system will drive the output to the maximum duty cycle as limited by the MV High Limit setting. Units match Units of Measure setting. |
| 0x14 | REAL | rw | Integral | 0 | Integral Time in seconds for the primary loop |
| 0x15 | REAL | rw | Derivative | 0 | Derivative Time in seconds for the primary loop |
| 0x16 | REAL | rw | Alarm 1 SP High | 0 | High alarm trip point for the first alarm |
| 0x17 | REAL | rw | Alarm 1 SP Low | 0 | Low alarm trip point for the first alarm |

| SubIndex | DataType | Access | Name | Default | Description |
|---|---|---|---|---|---|
| 0x18 | REAL | rw | Alarm 1 SP Limit High | Infinity | Upper bound of Alarm 1 SP |
| 0x19 | REAL | rw | Alarm 1 SP Limit Low | -Infinity | Lower bound of Alarm 1 SP |
| 0x1A | REAL | rw | Alarm 2 SP High | 0 | High alarm trip point for the second alarm |
| 0x1B | REAL | rw | Alarm 2 SP Low | 0 | Low alarm trip point for the second alarm |
| 0x1C | REAL | rw | Alarm 2 SP Limit High | Infinity | Upper bound of Alarm 2 SP |
| 0x1D | REAL | rw | Alarm 2 SP Limit Low | -Infinity | Lower bound of Alarm 2 SP |
| 0x1E | USINT | rw | Output Mode | 0 | Type of output:<br>0: True PWM output<br>1: 50Hz Zero Cross mode. The output will be on or off in 20ms increments<br>2: 60Hz Zero Cross mode. The output will be on or off in 16.6ms increments<br>3: “Universal” Zero Cross mode. The output will be on or off in 100ms increments.<br>4-255: reserved. Will behave as PWM output. |