# Module – Motor Temperature Estimation

# High-Level Description

This module details out the estimation functions (first order lead lag filters) used to estimate the controller Silicon, motor magnet and the motor copper winding temperatures based on the measured substrate temperature and the variation in ambient temperature. The variation in ambient temperature is added as a correction term to the outputs of the lead lag filters and is separate for Si, Magnet and Cu. The correction term representing the variation of temperature above ambient is based off the measured motor current representing the Q-and D axes and uses a first order low pass filter structure.

# Figures

123.tif

## Diagram – Function Data Sharing

This diagram shows all data that is shared between functions within the module.

### Diagram – None

This diagram describes the functional characteristics and data flow of a given function.

# Variable Data Dictionary

For details on module input / output variable, refer to the Data Dictionary for the application. Input / output variable names are listed here for reference.

(Note: Full variable names required in table.)

(Note: All global variables including End Of Line data used should be shown here)

|  |  |
| --- | --- |
| Module Inputs (Global Variable Name) | Module Outputs (Global Variable Name) |
| CtrlTempFinal\_DegC\_f32 | CuTempEst\_DegC\_f32 |
| EstPkCurr\_AmpSq\_f32 | MagTempEst\_DegC\_f32 |
| EngTemp\_DegC\_f32 | SiTempEst\_DegC\_f32 |
| AmbTemp\_DegC\_f32 | AssistMechTempEst\_DegC\_f32 |
| HwVel\_HwRadpS\_f32 |  |
| ScomTempDataRcvd\_Cnt\_lgc |  |
| AMTempEstDisable\_Cnt\_lgc |  |

## Module Internal Variables

This section identifies the name, range and resolutions for module specific data created by this module. If there are no range restrictions on the variable, the term “FULL” is placed into the table for legal range.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable Name | Resolution | Legal Range  (min) | Legal Range  (max) | Software Segment |
| CuCorr\_DegC\_D\_f32 | Single Precision Floating Point | -100.0 | 100.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| CuLLFiltSV\_DegC\_M\_f32 | Single Precision Floating Point | -50 | 150 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| CuAmbLPFiltSV\_Watts\_M\_str | N/A | N/A | N/A | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_UNSPECIFIED |
| CuAmbLPFiltSV\_Watts\_M\_str .K\_Uls\_f32 | Single Precision Floating Point | 6.28e-05 | 0.0609 |  |
| CuAmbLPFiltSV\_Watts\_M\_str .SV\_Uls\_f32 | Single Precision Floating Point | 0 | 25.0 |  |
| MagCorr\_DegC\_D\_f32 | Single Precision Floating Point | -100.0 | 100.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| MagLLFiltSV\_DegC\_M\_f32 | Single Precision Floating Point | -50 | 150 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| MagAmbLPFiltSV\_Watts\_M\_ str | N/A | N/A | N/A | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_UNSPECIFIED |
| MagAmbLPFiltSV\_Watts\_M\_ str .K\_Uls\_f32 | Single Precision Floating Point | 6.28e-05 | 0.0609 |  |
| CuAmbLPFiltSV\_Watts\_M\_str .SV\_Uls\_f32 | Single Precision Floating Point | 0 | 25.0 |  |
| SiCorr\_DegC\_D\_f32 | Single Precision Floating Point | -100.0 | 100.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| SiLLFiltSV\_DegC\_M\_f32 | Single Precision Floating Point | -50 | 150 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| SiAmbLPFiltSV\_Watts\_M\_ str | N/A | N/A | N/A | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_UNSPECIFIED |
| SiAmbLPFiltSV\_Watts\_M\_ str .K\_Uls\_f32 | Single Precision Floating Point | 6.28e-05 | 0.0609 |  |
| SiAmbLPFiltSV\_Watts\_M\_ str .SV\_Uls\_f32 | Single Precision Floating Point | 0 | 25.0 |  |
| AsstMechLPFiltSV\_Watts\_M\_str. | N/A | N/A | N/A | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_UNSPECIFIED |
| AsstMechLPFiltSV\_Watts\_M\_str.K\_Uls\_f32 | Single Precision Floating Point | 6.28e-05 | 0.0609 |  |
| AsstMechLPFiltSV\_Watts\_M\_str.SV\_Uls\_f32 | Single Precision Floating Point | 0 | 2048.0 |  |
| AmCorr\_DegC\_D\_f32 | Single Precision Floating Point | -100.0 | 100.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| AMTempEst\_DegC\_M\_f32 | Single Precision Floating Point | -50.0 | 150.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| AssMechFiltSV\_DegC\_M\_f32 | Single Precision Floating Point | -50 | 150 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| AmbPwr\_Watts\_D\_f32 | Single Precision Floating Point | 0.0 | 6250 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| ScaledAmbTemp\_DegC\_D\_f32 | Single Precision Floating Point | -40.0 | 87.5 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| ScaledEngTemp\_DegC\_D\_f32 | Single Precision Floating Point | -40.0 | 215.0 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| EstMech\_Watts\_D\_f32 | Single Precision Floating Point | 0.0 | 250 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| AssMechInitComp\_Cnt\_M\_lgc | 1 | FALSE | TRUE | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_BOOLEAN |
| PrevScomTempDataRcvd\_Cnt\_M\_lgc | 1 | FALSE | TRUE | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_BOOLEAN |
| AssistMechSlew\_DegC\_M\_f32 | Single Precision Floating Point | 0.1 | 10 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |
| AssistMechFilt\_DegC\_D\_f32 | Single Precision Floating Point | -50 | 150 | MTRTEMPEST\_START\_SEC\_VAR\_CLEARED\_32 |

### User defined typedef definition/declaration

This section documents any user types uniquely used for the module.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Typedef Name | Element Name | User Defined Type | Legal Range  (min) | Legal Range  (max) |
| None |  |  |  |  |

# Constant Data Dictionary

## Calibration Constants

This section lists the calibrations used by the module. For details on calibration constants, refer to the Data Dictionary for the application.

|  |
| --- |
| Constant Name |
| k\_SiAmbLPFKn\_Hz\_f32 |
| k\_SiAmbMult\_DegCpWatt\_f32 |
| k\_SiLLFiltKB0\_Uls\_f32 |
| k\_SiLLFiltKB1\_Uls\_f32 |
| k\_SiLLFiltKA1\_Uls\_f32 |
| k\_MagAmbLPFKn\_Hz\_f32 |
| k\_MagAmbMult\_DegCpWatt\_f32 |
| k\_MagLLFiltKB0\_Uls\_f32 |
| k\_MagLLFiltKB1\_Uls\_f32 |
| k\_MagLLFiltKA1\_Uls\_f32 |
| k\_CuAmbLPFKn\_Hz\_f32 |
| k\_CuLLFiltKB0\_Uls\_f32 |
| k\_CuLLFiltKB1\_Uls\_f32 |
| k\_CuLLFiltKA1\_Uls\_f32 |
| k\_AmbPwrMult\_WtspAmpSq\_f32 |
| k\_CuAmbMult\_DegCpWatt\_f32 |
| k\_TrimTempSi\_DegC\_f32 |
| k\_TrimTempCu\_DegC\_f32 |
| k\_TrimTempMag\_DegC\_f32 |
| k\_TrimTempAM\_DegC\_f32 |
| k\_EngTempScl\_Uls\_f32 |
| k\_AmbTempScl\_Uls\_f32 |
| k\_AMLLFiltCoefB0\_Uls\_f32 |
| k\_AMLLFiltCoefB1\_Uls\_f32 |
| k\_AMLLFiltPoleA1\_Uls\_f32 |
| k\_AMAmbLPFKn\_Hz\_f32 |
| k\_AMAmbMult\_DegCpWatt\_f32 |
| k\_AMDampScl\_NmpRadpS\_f32 |
| k\_TempAMEstCorrLmt\_DegC\_f32 |
| k\_AssistMechSlew\_DegCpS\_f32 |
| k\_SiCorrLmt\_DegC\_f32 |
| k\_MagCorrLmt\_DegC\_f32 |
| k\_CuCorrLmt\_DegC\_f32 |
| k\_AMDfltOutoutTemp\_DegC\_f32 |
| k\_WtAvgTempDFt\_Cnt\_lgc |

## Program(fixed) Constants

### Embedded Constants

All embedded constants whose values are provided in Eng units will be evaluated to the equivalent counts by using the FPM\_InitFixedPoint\_m() macro within the #define statement.

#### Local

|  |  |  |
| --- | --- | --- |
| Constant Name | Resolution | Value |
| D\_TEMPESTLOLMT\_DEGC\_F32 | Single Precision Floating Point | -50.0 |
| D\_TEMPESTHILMT\_DEGC\_F32 | Single Precision Floating Point | 150.0 |
| D\_AMTEMPESTLOLMT\_DEGC\_F32 | Single Precision Floating Point | -50.0 |
| D\_AMTEMPESTHILMT\_DEGC\_F32 | Single Precision Floating Point | 150.0 |
| D\_LOOPSPERSEC\_CNT\_F32 | Single Precision Floating Point | 10.0 |

#### Global

This section lists the global constants used by the module. For details on global constants, refer to the Data Dictionary for the application.

|  |
| --- |
| Constant Name |
| None |

### Module specific Lookup Tables Constants

(This is for lookup tables (arrays) with fixed values, same name as other tables)

|  |  |  |  |
| --- | --- | --- | --- |
| Constant Name | Resolution | Value | Software Segment |
| None |  |  |  |

# Functions/Macros used by the Sub-Modules

## Library Functions / Macros

The library functions / Macros that are called by the various sub modules are identified below,

1. FPM\_FloatToFixed\_m()
2. FPM\_FixedToFloat\_m()
3. LPF\_KUpdate\_f32\_m ()
4. LPF\_OpUpdate\_f32\_m ()
5. Limit\_m()
6. Min\_m()

## Data Hiding Functions

The data hiding functions / macros used in this module are identified below,

1. None

## Local Functions/Macros Used by this MDD only

(Note if they are defined in another source file, then reference the appropriate header file)

The local functions/macros in this module are identified below,

1. LeadLagFilt()
2. LeadLagFiltInit (CtrlTempFinal\_DegC\_T\_f32, AmbTemp\_DegC\_T\_f32, EngTemp\_DegC\_T\_f32)
3. AssMechFiltInit(AmbTemp\_DegC\_T\_f32, EngTemp\_DegC\_T\_f32)

# Software Module Implementation

## Initialization Functions

### Init: MtrTempEst\_Init1

#### Design Rationale

Initialization of Lead Lag Filter State Variables and Temperature Estimate outputs.

LPF\_KUpdate\_f32 is used to initialize the LPF filter instead of the full LPF\_Init\_f32 macro as an optimization since the required initial state of the filter is 0, which is the initialized value of the RAM, so there is no need to explicitly initialize the state variables in this init function.

#### Module Outputs

CtrlTempFinal\_DegC\_T\_f32 = Rte\_IRead\_MtrTempEst\_Init1\_CtrlTempFinal\_DegC\_f32()

AmbTemp \_DegC\_T\_f32 = Rte\_IRead\_MtrTempEst\_Init1\_ AmbTemp\_DegC\_f32()

EngTemp \_DegC\_T\_f32 = Rte\_IRead\_MtrTempEst\_Init1\_ EngTemp\_DegC\_f32()

ScaledEngTemp\_DegC\_T\_f32 = EngTemp\_DegC\_T\_f32 \* k\_EngTempScl\_Uls\_f32

ScaledAmbTemp\_DegC\_T\_f32 = AmbTemp\_DegC\_T\_f32 \* k\_AmbTempScl\_Uls\_f32

AMTempEst\_DegC\_T\_f32 = ScaledAmbTemp\_DegC\_T\_f32 + ScaledEngTemp\_DegC\_T\_f32

Rte\_Iwrite\_MtrTempEst\_Init1\_ AMTempEst\_DegC\_f32(AMTempEst\_DegC\_T\_f32)

Rte\_Iwrite\_MtrTempEst\_Init1\_SiTempEst\_DegC\_f32(CtrlTempFinal\_DegC\_T\_f32)

Rte\_Iwrite\_MtrTempEst\_Init1\_MagTempEst\_DegC\_f32(CtrlTempFinal\_DegC\_T\_f32)

Rte\_Iwrite\_MtrTempEst\_Init1\_CuTempEst\_DegC\_f32(CtrlTempFinal\_DegC\_T\_f32)

LPF\_KUpdate\_f32\_m(k\_SiAmbLPFKn\_Hz\_f32, D\_100MS\_SEC\_F32, &SiAmbLPFiltSV\_Watts\_M\_str);

LPF\_KUpdate\_f32\_m(k\_MagAmbLPFKn\_Hz\_f32, D\_100MS\_SEC\_F32, &MagAmbLPFiltSV\_Watts\_M\_str);

LPF\_KUpdate\_f32\_m(k\_CuAmbLPFKn\_Hz\_f32, D\_100MS\_SEC\_F32, &CuAmbLPFiltSV\_Watts\_M\_str);

LPF\_KUpdate\_f32\_m(k\_AMAmbLPFKn\_Hz\_f32, D\_100MS\_SEC\_F32, &AsstMechLPFiltSV\_Watts\_M\_str);

#### Module Internal

LeadLagFiltInit (CtrlTempFinal\_DegC\_T\_f32, AmbTemp\_DegC\_T\_f32, EngTemp\_DegC\_T\_f32)

AssMechInitComp\_Cnt\_M\_lgc = False

AssistMechSlew\_DegC\_M\_f32 = (k\_AssistMechSlew\_DegCpS\_f32 / D\_LOOPSPERSEC\_CNT\_F32);

## Periodic Functions

### Per: MtrTempEst\_Per1

#### Design Rationale

#### Program Flow Start

#### Rte\_Call\_MtrTempEst\_Per1\_CP0\_CheckpointReached()Store Module Inputs to Local copies

CtrlTempFinal\_DegC\_T\_f32 = Rte\_Iread\_MtrTempEst\_Per1\_CtrlTempFinal\_DegC\_f32()

EngTemp\_DegC\_T\_f32 = Rte\_IRead\_MtrTempEst\_Per1\_EngTemp\_DegC\_f32()

AmbTemp\_DegC\_T\_f32 = Rte\_IRead\_MtrTempEst\_Per1\_AmbTemp\_DegC\_f32()

HwVel\_HwRadpS\_T\_f32 = Rte\_IRead\_MtrTempEst\_Per1\_HwVel\_HwRadpS\_f32()

ScomTempDataRcvd\_Cnt\_T\_lgc = Rte\_IRead\_MtrTempEst\_Per1\_ScomTempDataRcvd\_Cnt\_lgc ()

EstPkCurr\_AmpSq\_T\_f32 = Rte\_IRead\_MtrTempEst\_Per2\_EstPkCurr\_AmpSq\_f32()

AMTempEstDisable\_Cnt\_T\_lgc = Rte\_IRead\_MtrTempEst\_Per1\_AMTempEstDisable\_Cnt\_lgc()

#### Calculate Ambient Power in Watts



#### Silicon, Magnet, and Copper Ambient Low Pass Filter



#### Generate Ambient Correction Terms and Limit



#### Calculate Temperature Estimation



##### Reset Filter



##### Assist Mech Temperature Estimation



#### Store Local copy of outputs into Module Outputs

PrevScomTempDataRcvd\_Cnt\_M\_lgc = ScomTempDataRcvd\_Cnt\_T\_lgc

Rte\_Iwrite\_MtrTempEst\_Per1\_ AssistMechTempEst\_DegC\_f32 (AMTempEst\_DegC\_M\_f32)

Rte\_Iwrite\_MtrTempEst\_Per1\_SiTempEst\_DegC\_f32(SiTempEst\_DegC\_T\_f32)

Rte\_Iwrite\_MtrTempEst\_Per1\_MagTempEst\_DegC\_f32(MagTempEst\_DegC\_T\_f32)

Rte\_Iwrite\_MtrTempEst\_Per1\_CuTempEst\_DegC\_f32(CuTempEst\_DegC\_T\_f32)

#### Program Flow End

Rte\_Call\_MtrTempEst\_Per1\_CP1\_CheckpointReached()

## Fault Recovery Functions

None

## Shutdown Functions

None

## Interrupt Functions

None

## Serial Communication Functions

None

## Local Function/Macro Definitions

If these are numerous and defined in a separate source file then reference the source file only.

### LeadLagFiltInit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Function Name** | LeadLagFiltInit | Type | Min | Max |
| **Arguments Passed** | CtrlTempFinal\_DegC\_T\_f32 | Single Precision Floating Point | -50 | 150 |
|  | AmbTemp\_DegC\_T\_f32 | Single Precision Floating Point | -40 | 87.5 |
|  | EngTemp\_DegC\_T\_f32 | Single Precision Floating Point | -40 | 215 |
| **Return Value** |  |  |  |  |

#### Description



### AssMechFiltInit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Function Name** | AssMechFiltInit | Type | Min | Max |
| **Arguments Passed** | AmbTemp\_DegC\_T\_f32 | Single Precision Floating Point | -40 | 87.5 |
|  | EngTemp\_DegC\_T\_f32 | Single Precision Floating Point | -40 | 215 |
|  |  |  |  |  |
| **Return Value** |  |  |  |  |

#### Description



### Lead Lag Filter

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Function Name** | LeadLagFilt | Type | Min | Max |
| **Arguments Passed** | InputTemp\_DegC\_T\_f32 | Single Precision Floating Point | -70.0 | 170.0 |
|  | FiltSVPtr\_DegC\_T\_f32 | Single Precision Floating Point\* | Address | Address |
|  | LLFiltKB0\_Uls\_T\_f32 | Single Precision Floating Point | 0.00003 | 0.002 |
|  | LLFiltKB1\_Uls\_T\_f32 | Single Precision Floating Point | 0.00003 | 0.002 |
|  | LLFiltKA1\_Uls\_T\_f32 | Single Precision Floating Point | 0.00003 | 0.002 |
| **Return Value** | FiltOutput\_DegC\_T\_f32 | Single Precision Floating Point | -70.0 | 170.0 |

#### Lead Lag Filter Structure 1GP1-B (For Reference Only)



#### Description



# Execution Requirements

## Execution Sequence of the Module

(Describe in words relevant details about the execution sequence of the different sub modules.)

## Execution Rates for sub-modules called by the Scheduler

This table serves as reference for the Scheduler design

|  |  |  |  |
| --- | --- | --- | --- |
| Function Name | Task List | Calling Frequency | System State(s) in which the function is called |
| MtrTempEst\_Init1() |  | Once | START UP |
| MtrTempEst\_Per1() |  | 100ms | WARM INIT, OPERATE, DISABLE |

## Execution Requirements for Serial Communication Functions

|  |  |
| --- | --- |
| Function Name | Sub-Module called by (Serial Comm Function Name) |
| N/A |  |

# Memory Map Definition Requirements

## Sub Modules (Functions)

This table identifies the software segments for functions identified in this module.

|  |  |
| --- | --- |
| Name of Sub Module | Software Segment |
| MtrTempEst\_Init1 () |  |
| MtrTempEst\_Per1() |  |

## Local Functions

This table identifies the software segments for local functions identified in this module.

|  |  |
| --- | --- |
| Name of Sub Module | Software Segment |
| LeadLagFilt() |  |
| LeadLagFiltInit() |  |
| AssMechFiltInit() |  |

# 

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# Known Issues / Limitations With Design

1. Config option 2 from the FDD is not implemented in this module. This is due to the fact that this option is still under development and has not been verified as a valid option.

# Revision Control Log

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item #** | **Rev #** | **Change Description** | **Date** | **Author Initials** |
| 1 | 1.0 | Initial AutoSAR version. | 17Feb11 | L.N. |
| 2 | 2.0 | Update to FDD #FS6 001 | 03Dec11 | M. Story |
| 3 | 3.0 | Corrected periodic timings and removed incorrect input | 03Jan12 | M. Story |
| 4 | 4.0 | Corrected issues found in UTP. | 04Jan12 | M. Story |
| 5 | 5.0 | Corrected the initialization of SumCurr\_AmpSq\_M\_f32 | 11Jan12 | M. Story |
| 6 | 6.0 | Anomaly 4920 changed input to use EstPkCurr\_AmpSq\_f32 | 20Feb12 | M. Story |
| 7 | 7.0 | FDD changes to version 003 | 24Feb12 | M. Story |
| 8 | 8.0 | Added AssistMechFilt\_DegC\_D\_f32 display variable | 09MAR12 | M. Story |
| 9 | 9.0 | Updated component to SF-6 Revision 4 | 16MAY12 | KJS |
| 10 | 10 | Corrected filter K init to specify 100ms execution rate  Removed unused FPM Filter constants | 22MAY12 | JJW |
| 11 | 11 | Updated floating-point filter structures to include range and resolution | 12Jun12 | KJS |
| 12 | 12 | Check points flow updated | 23- Sep -12 | Selva |
| 13 | 13 | Updated to SF06 Ver 005 | 22-Oct-12 | NRAR |
| 14 | 14 | Updated to SF06 Ver 006 | 12-Apr-13 | Selva |