e-Tech Racing's Inverter Firmware

v0

Generated by Doxygen 1.10.0

Chapter 1

Data Structure Index

1.1 Data Structures

Here are the data structures with brief descriptions:

Chapter 2

File Index

2.1 File List

Here is a list of all files with brief descriptions:

Chapter 3

Data Structure Documentation

3.1 Analog Struct Reference

Structure for ADC measurements in units.

`#include <MEASUREMENTS.h>`

Data Fields

- float ia
- float ib
- float ic
- float vDC
- float currentOffsets [3]

3.1.1 Detailed Description

Structure for ADC measurements in units.

3.1.2 Field Documentation

3.1.2.1 currentOffsets

`float currentOffsets[3]`

Offsets for the current measurements

3.1.2.2 ia

`float ia`

Phase A current in A

3.1.2.3 ib

```
float ib
```

Phase B current in A

3.1.2.4 ic

```
float ic
```

Phase C current in A

3.1.2.5 vDC

```
float vDC
```

DC link voltage in V

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h

3.2 CANMessageInfo Struct Reference

```
#include <CAN_e-Tech.h>
```

Data Fields

- const uint32_t ID
- const uint8_t IDE
- const uint8_t DLC
- const signal_positioned * getSig

3.2.1 Field Documentation

3.2.1.1 DLC

```
const uint8_t DLC
```

3.2.1.2 getSig

```
const signal_positioned* getSig
```

3.2.1.3 ID

```
const uint32_t ID
```

3.2.1.4 IDE

```
const uint8_t IDE
```

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CAN_e-Tech.h

3.3 Duties Struct Reference

Structure to hold PWM configuration parameters.

```
#include <PWM.h>
```

Data Fields

- float Da
- float Db
- float Dc

3.3.1 Detailed Description

Structure to hold PWM configuration parameters.

3.3.2 Field Documentation

3.3.2.1 Da

```
float Da
```

Duty cycle for channel 1

3.3.2.2 Db

```
float Db
```

Duty cycle for channel 2

3.3.2.3 Dc

```
float Dc
```

Duty cycle for channel 3

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PWM.h

3.4 Encoder Struct Reference

Structure for encoder reading.

```
#include <MEASUREMENTS.h>
```

Data Fields

- uint16_t A
- uint16_t B
- uint16_t Z
- float we
- float theta_e
- float sinTheta_e
- float cosTheta_e
- uint8_t directionMeas

3.4.1 Detailed Description

Structure for encoder reading.

3.4.2 Field Documentation

3.4.2.1 A

```
uint16_t A
```

Encoder channel A value

3.4.2.2 B

```
uint16_t B
```

Encoder channel B value

3.4.2.3 cosTheta_e

```
float cosTheta_e
```

Electrical rotor position cosine

3.4.2.4 directionMeas

```
uint8_t directionMeas
```

Measured direction

3.4.2.5 sinTheta_e

```
float sinTheta_e
```

Electrical rotor position sine

3.4.2.6 theta_e

```
float theta_e
```

Electrical rotor position

3.4.2.7 we

```
float we
```

Electrical angular velocity

3.4.2.8 Z

```
uint16_t Z
```

Encoder channel Z value

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h

3.5 Feedback Struct Reference

Structure for feedback values.

```
#include <MEASUREMENTS.h>
```

Data Fields

- float idMeas
- float iqMeas
- float torqueCalc
- float speedMeas

3.5.1 Detailed Description

Structure for feedback values.

3.5.2 Field Documentation

3.5.2.1 idMeas

```
float idMeas
```

Measured d-axis current in A

3.5.2.2 iqMeas

```
float iqMeas
```

Measured q-axis current in A

3.5.2.3 speedMeas

```
float speedMeas
```

Measured speed in RPM

3.5.2.4 torqueCalc

```
float torqueCalc
```

Calculated torque in N·m

The documentation for this struct was generated from the following file:

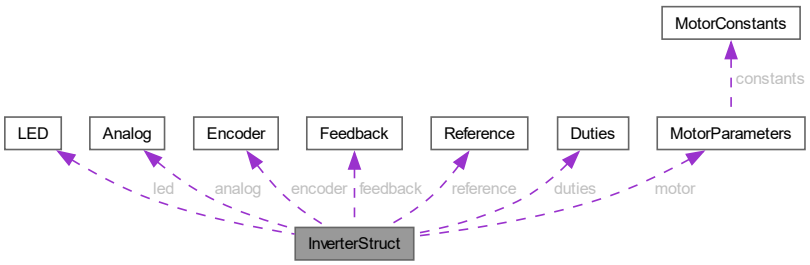
- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h

3.6 InverterStruct Struct Reference

Inverter structure.

`#include <INVERTER.h>`

Collaboration diagram for InverterStruct:



Data Fields

- LED * led
- GPIO_TypeDef * enable_port
- uint16_t enable_pin
- TIM_HandleTypeDef * htim
- ADC_HandleTypeDef * hadc
- InverterState state
- Analog analog
- Encoder encoder
- Feedback feedback
- Reference reference
- Duties duties
- int8_t direction
- float tempInverter
- float tempMotor
- MotorParameters * motor
- pi_struct idLoop
- pi_struct iqLoop
- float vsMax
- float vd
- float vq
- pi_struct speedLoop
- InverterError errors
- bool enable
- bool enableSW

3.6.1 Detailed Description

Inverter structure.

3.6.2 Field Documentation

3.6.2.1 analog

```
Analog analog
```

Structure for phase currents and DC voltage measurements

3.6.2.2 direction

```
int8_t direction
```

Motor direction: 1 CW, -1 CCW, 0 stopped

3.6.2.3 duties

```
Duties duties
```

Structure for duty cycles for phases A, B, and C

3.6.2.4 enable

```
bool enable
```

Enable bit for transitioning states

3.6.2.5 enable_pin

```
uint16_t enable_pin
```

Pin number for enabling/disabling the inverter

3.6.2.6 enable_port

```
GPIO_TypeDef* enable_port
```

Pointer to GPIO port for enabling/disabling the inverter

3.6.2.7 enableSW

```
bool enableSW
```

External enable order (needs HW enable to set inv.enable to 1, and if the FAULT state is entered, enableSW must be set to 0 to transition to the IDLE state)

3.6.2.8 encoder

```
Encoder encoder
```

Structure for encoder input

3.6.2.9 errors

```
InverterError errors
```

Error field storing error bits, using InverterError enum

3.6.2.10 feedback

```
Feedback feedback
```

Structure for measured currents and calculated mechanical torque and speed

3.6.2.11 hadc

```
ADC_HandleTypeDef* hadc
```

Handle of the ADC peripheral for current phase currents and DC voltage sensing

3.6.2.12 htim

```
TIM_HandleTypeDef* htim
```

Handle of the timer peripheral for PWM output

3.6.2.13 idLoop

```
pi_struct idLoop
```

PI controller for d-axis current

3.6.2.14 iqLoop

```
pi_struct iqLoop
```

PI controller for q-axis current

3.6.2.15 led

```
LED* led
```

Pointer to LED control structure

3.6.2.16 motor

```
MotorParameters* motor
```

Motor parameters struct

3.6.2.17 reference

```
Reference reference
```

Structure for referece currents and torque

3.6.2.18 speedLoop

```
pi_struct speedLoop
```

PI controller for motor speed

3.6.2.19 state

```
InverterState state
```

Current state of inverter operation

3.6.2.20 tempInverter

```
float tempInverter
```

Semiconductor temperature in degC

3.6.2.21 tempMotor

```
float tempMotor
```

Motor temperature in degC

3.6.2.22 vd

```
float vd
```

d-axis voltage

3.6.2.23 vq

```
float vq
```

q-axis voltage

3.6.2.24 vsMax

```
float vsMax
```

Maximum output voltage, should be calculated as vDC / sqrt3 in volts

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h

3.7 LED Struct Reference

LED structure.

```
#include <PCB_IO.h>
```

Data Fields

- GPIO_TypeDef * port
- uint16_t pin
- LEDMode mode

3.7.1 Detailed Description

LED structure.

3.7.2 Field Documentation

3.7.2.1 mode

```
LEDMode mode
```

Current LED mode

3.7.2.2 pin

```
uint16_t pin
```

Pin number for controlling the LED

3.7.2.3 port

```
GPIO_TypeDef* port
```

GPIO port for controlling the LED

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PCB_IO.h

3.8 MotorConstants Struct Reference

Structure to hold precomputed motor constants.

`#include <MOTOR.h>`

Data Fields

- float threePpLambda
- float threePpLdMinusLq
- float invThreePpLambda
- float isc
- float torqueBase
- float invTorqueBase
- float xi
- float xiSquared
- float oneMinusXi
- float twoMinusXi
- float fourTimesOneMinusXi
- float eightTimesOneMinusXiSquared
- float twoMinusXiSquared
- float twoTimesOneMinusXiOnePlusXiSquared
- float twoTimesOneMinusXiXiSquared
- float fourTimesOneMinusXiOnePlusXiSquared
- float fourTimesOneMinusXiXiSquared
- float lambdaDivLqMinusLd
- float betaMinusIsc

3.8.1 Detailed Description

Structure to hold precomputed motor constants.

3.8.2 Field Documentation

3.8.2.1 betaMinusIsc

`float betaMinusIsc`

lambda / (Lq - Ld) - lambda / Ld

3.8.2.2 eightTimesOneMinusXiSquared

`float eightTimesOneMinusXiSquared`

8 * (1 - Lq / Ld)^2

3.8.2.3 fourTimesOneMinusXi

```
float fourTimesOneMinusXi
```

4 ∗ (1 - Lq / Ld)

3.8.2.4 fourTimesOneMinusXiOnePlusXiSquared

```
float fourTimesOneMinusXiOnePlusXiSquared
```

4 ∗ (1 - Lq / Ld) ∗ (1 + (Lq / Ld)^2)

3.8.2.5 fourTimesOneMinusXiXiSquared

```
float fourTimesOneMinusXiXiSquared
```

4 ∗ (1 - Lq / Ld) ∗ (Lq / Ld)^2

3.8.2.6 invThreePpLambda

```
float invThreePpLambda
```

1 / (3 ∗ pp ∗ lambda)

3.8.2.7 invTorqueBase

```
float invTorqueBase
```

1 / (3 ∗ pp ∗ lambda^2 / Ld)

3.8.2.8 isc

```
float isc
```

-lambda / Ld

3.8.2.9 lambdaDivLqMinusLd

```
float lambdaDivLqMinusLd
```

lambda / (Lq - Ld)

3.8.2.10 oneMinusXi

```
float oneMinusXi
```

1 - Lq / Ld

3.8.2.11 threePpLambda

```
float threePpLambda
```

3 ∗ pp ∗ lambda

3.8.2.12 threePpLdMinusLq

```
float threePpLdMinusLq
```

3 ∗ pp ∗ (Ld - Lq)

3.8.2.13 torqueBase

```
float torqueBase
```

3 ∗ pp ∗ lambda^2 / Ld

3.8.2.14 twoMinusXi

```
float twoMinusXi
```

2 - Lq / Ld

3.8.2.15 twoMinusXiSquared

```
float twoMinusXiSquared
```

(2 - Lq / Ld)^2

3.8.2.16 twoTimesOneMinusXiOnePlusXiSquared

```
float twoTimesOneMinusXiOnePlusXiSquared
```

2 ∗ (1 - Lq / Ld) ∗ (1 + (Lq / Ld)^2)

3.8.2.17 twoTimesOneMinusXiXiSquared

```
float twoTimesOneMinusXiXiSquared
```

2 ∗ (1 - Lq / Ld) ∗ (Lq / Ld)^2

3.8.2.18 xi

```
float xi
```

Lq / Ld

3.8.2.19 xiSquared

```
float xiSquared
```

(Lq / Ld)^2

The documentation for this struct was generated from the following file:

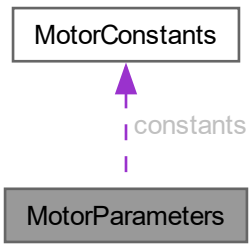
- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h

3.9 MotorParameters Struct Reference

Structure to hold motor parameters.

```
#include <MOTOR.h>
```

Collaboration diagram for MotorParameters:



Data Fields

- float Ld
- float Lq
- float Rs
- float lambda
- uint8_t pp
- float J
- float b
- float torqueMax
- float dTorqueMax
- float speedMax_RPM
- float iMax
- float vDCMax
- MotorConstants constants

3.9.1 Detailed Description

Structure to hold motor parameters.

3.9.2 Field Documentation

3.9.2.1 b

```
float b
```

Viscous friction in N·m·s

3.9.2.2 constants

```
MotorConstants constants
```

Precomputed motor constants

3.9.2.3 dTorqueMax

```
float dTorqueMax
```

Maximum torque increment in N·m/s

3.9.2.4 iMax

```
float iMax
```

Maximum phase current (peak value, or RMS∗sqrt2)

3.9.2.5 J

```
float J
```

Rotational inertia in N·m·s^2

3.9.2.6 lambda

```
float lambda
```

Magnet flux linkage measured V_pk_ph-n · s (phase-neutral peak voltage divided by electrical speed in rad/s)

3.9.2.7 Ld

```
float Ld
```

D-axis inductance in Henries

3.9.2.8 Lq

```
float Lq
```

Q-axis inductance in Henries

3.9.2.9 pp

```
uint8_t pp
```

Pole pairs (total number of poles divided by 2)

3.9.2.10 Rs

```
float Rs
```

Stator resistance in Ohms

3.9.2.11 speedMax_RPM

```
float speedMax_RPM
```

Maximum speed in RPM

3.9.2.12 torqueMax

```
float torqueMax
```

Maximum torque in N·m

3.9.2.13 vDCMax

```
float vDCMax
```

Maximum DC bus voltage in volts

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h

3.10 Reference Struct Reference

Structure for reference values.

`#include <REFERENCE.h>`

Data Fields

- float idRef
- float iqRef
- float isMaxRef
- float torqueRef

3.10.1 Detailed Description

Structure for reference values.

3.10.2 Field Documentation

3.10.2.1 idRef

`float idRef`

Reference d-axis current in A

3.10.2.2 iqRef

`float iqRef`

Reference q-axis current in A

3.10.2.3 isMaxRef

`float isMaxRef`

Maximum reference current in A

3.10.2.4 torqueRef

`float torqueRef`

Reference torque in N·m

The documentation for this struct was generated from the following file:

- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/REFERENCE.h

Chapter 4

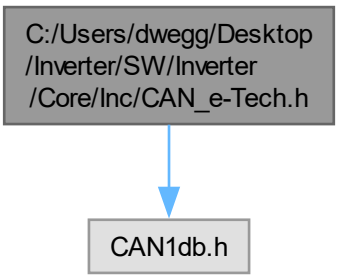
File Documentation

4.1 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CAN_e-Tech.h File Reference

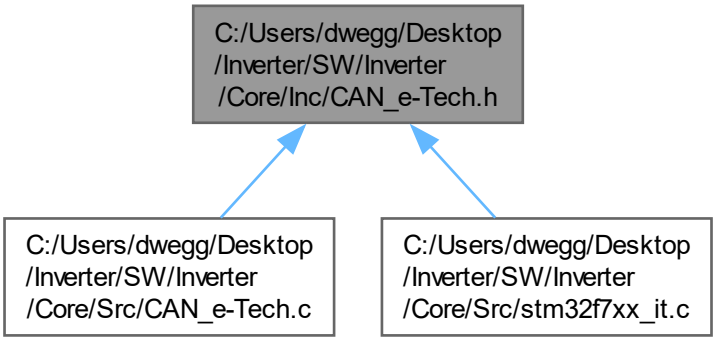
Header file for handling CAN communication with the car.

```
#include "CAN1db.h"
```

Include dependency graph for CAN_e-Tech.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct CANMessageInfo

Functions

- void handle_CAN (CAN_HandleTypeDef *hcan)

  Handle CAN messages.
- void send_CAN_message (CAN_HandleTypeDef *hcan, void *dbc_msg, const float *data)

  Send a CAN message using CAN1db.h information.

Variables

- uint8_t enableCAN

4.1.1 Detailed Description

Header file for handling CAN communication with the car.

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4.1.2 Function Documentation

4.1.2.1 handle_CAN()

```
void handle_CAN (
            CAN_HandleTypeDef * hcan )
```

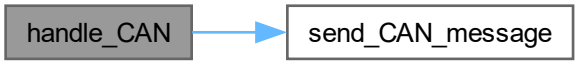
Handle CAN messages.

This function implements the logic to handle received CAN messages.

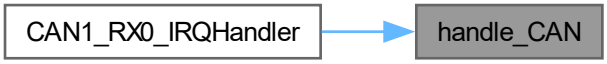
Parameters

hcan	Pointer to the CAN handle structure.

Here is the call graph for this function:



Here is the caller graph for this function:



4.1.2.2 send_CAN_message()

```
void send_CAN_message (
            CAN_HandleTypeDef * hcan,
            void * dbc_msg,
            const float * data )
```

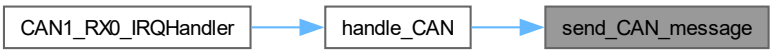
Send a CAN message using CAN1db.h information.

This function prepares and sends a CAN message using information from CAN1db.h.

Parameters

hcan	Pointer to the CAN handle structure.
dbc_msg	Pointer to the structure containing CAN message information from CAN1db.h.
data	Pointer to the array of float data to be sent.

Here is the caller graph for this function:



4.1.3 Variable Documentation

4.1.3.1 enableCAN

```
uint8_t enableCAN  [extern]
```

4.2 CAN_e-Tech.h

Go to the documentation of this file.

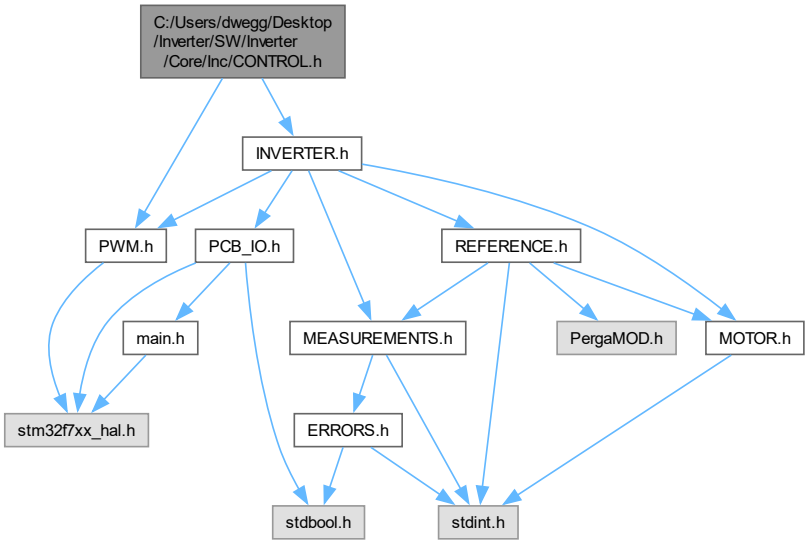
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef CAN_E_TECH_H
00021 #define CAN_E_TECH_H
00022
00023 #include "CAN1db.h" // needs the CAN1db and its types
00024
00025 extern uint8_t enableCAN;
00026
00027 typedef struct {
00028     const uint32_t ID;
00029     const uint8_t IDE;
00030     const uint8_t DLC;
00031     const signal_positioned *getSig;
00032 } CANMessageInfo;
00033
00041 void handle_CAN(CAN_HandleTypeDef *hcan);
00042
00052 void send_CAN_message(CAN_HandleTypeDef *hcan, void *dbc_msg, const float *data);
00053
00054 #endif /* CAN_E_TECH_H */
```

4.3 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CONTROL.h File Reference

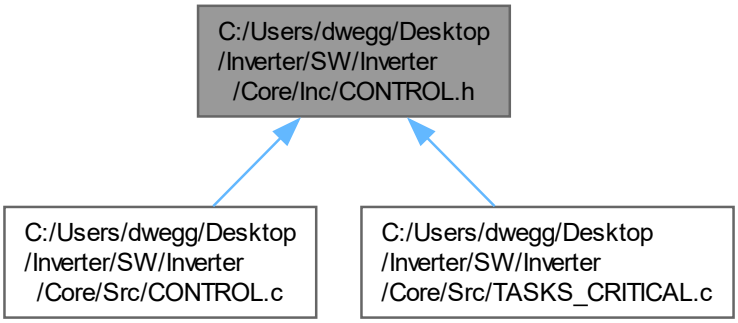
Header file for the control loop.

```
#include "PWM.h"
#include "INVERTER.h"
```

Include dependency graph for CONTROL.h:



This graph shows which files directly or indirectly include this file:



Functions

- void calc_current_reference (MotorParameters *motor, volatile Reference *reference)

  Calculates the current references using a FOC algorithm. It computes the current vector for the MTPA trajectory and limits the current reference to isMaxRef (calculated by derating, starting from the motor's maximum current). The MTPV trajectory is not implemented to save some computation time due to the nature of the motors expected. In order to implement field weakening, an external voltage loop modifying gammaRef is needed and should be called inside here. When implementing field weakening, special attention must be put to the torque reference being near 0 or differing from the speed sign (regeneration). A minimum id current must be set for speeds higher than Vs/lambda. Study thoroughly, simulate first.
- void calc_current_loop (volatile InverterStruct *inv)

Calculates the id-iq loops.

- void saturate_voltage (volatile InverterStruct *inv)

  Saturates PI output to not surpass DC voltage.

- void calc_duties (float vd, float vq, float vDC, float sinTheta_e, float cosTheta_e, volatile Duties *duties)

  function.

4.3.1 Detailed Description

Header file for the control loop.

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4.3.2 Function Documentation

4.3.2.1 calc_current_loop()

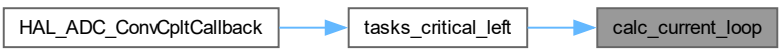
```
void calc_current_loop (
            volatile InverterStruct * inv )
```

Calculates the id-iq loops.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.3.2.2 calc_current_reference()

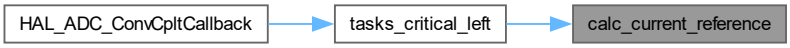
```
void calc_current_reference (
            MotorParameters * motor,
            volatile Reference * reference )
```

Calculates the current references using a FOC algorithm. It computes the current vector for the MTPA trajectory and limits the current reference to isMaxRef (calculated by derating, starting from the motor's maximum current). The MTPV trajectory is not implemented to save some computation time due to the nature of the motors expected. In order to implement field weakening, an external voltage loop modifying gammaRef is needed and should be called inside here. When implementing field weakening, special attention must be put to the torque reference being near 0 or differing from the speed sign (regeneration). A minimum id current must be set for speeds higher than Vs/lambda. Study thoroughly, simulate first.

Parameters

in	*motor*	Pointer to the motor parameters structure.
in,out	*reference*	Pointer to the reference struct.

Here is the caller graph for this function:



4.3.2.3 calc_duties()

```
void calc_duties (
            float vd,
            float vq,
            float vDC,
            float sinTheta_e,
            float cosTheta_e,
            volatile Duties * duties )
```

function.

This function calculates the inverse Park transform and the duty cycles using SVPWM

Parameters

in	*vd*	Voltage in the d-axis.
in	*vq*	Voltage in the q-axis.
in	*vDC*	DC voltage.
in	*sinTheta_e*	Electrical angle sine (-1..1)
in	*cosTheta_e*	Electrical angle cosine (-1..1)
out	*duties*	Pointer to the duties structure.

Here is the caller graph for this function:

4.3.2.4 saturate_voltage()

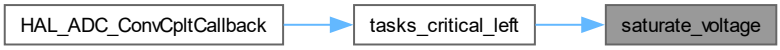
```
void saturate_voltage (
            volatile InverterStruct * inv )
```

Saturates PI output to not surpass DC voltage.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.4 CONTROL.h

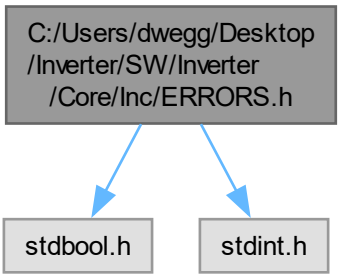
Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef CONTROL_H
00021 #define CONTROL_H
00022
00023 #include "PWM.h" // duties struct
00024 #include "INVERTER.h" // TS & Inverter struct
00025
00041 void calc_current_reference(MotorParameters * motor, volatile Reference * reference);
00042
00048 void calc_current_loop(volatile InverterStruct *inv);
00049
00055 void saturate_voltage(volatile InverterStruct *inv);
00056
00069 void calc_duties(float vd, float vq, float vDC, float sinTheta_e, float cosTheta_e, volatile Duties
      *duties);
00070
00071 #endif /* CONTROL_H */
```

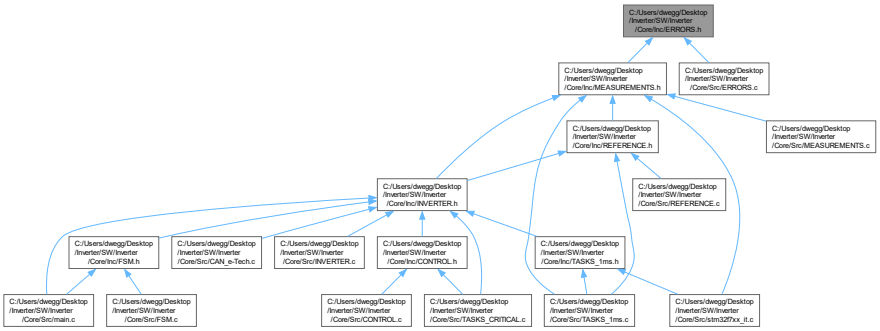
4.5 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/ERRORS.h File Reference

```
#include <stdbool.h>
#include <stdint.h>
```

Include dependency graph for ERRORS.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define OVERTEMPERATURE_INVERTER_TH 60.0f
- #define OVERVOLTAGE_TH 600.0f
- #define OVERCURRENT_TH 100.0f
- #define OVERSPEED_TH 20000.0f
- #define UNDERVOLTAGE_TH 10.0f
- #define OVERTEMPERATURE_MOTOR_TH 90.0f

Enumerations

- enum InverterError {
  NONE = 0 , POWER_FAULT = (1 << 0) , OVERTEMPERATURE_INV = (1 << 1) , OVERVOLTAGE = (1 << 2) ,
  OVERCURRENT = (1 << 3) , OVERSPEED = (1 << 4) , UNDERVOLTAGE = (1 << 5) , CONTROL_FAULT = (1 << 6) ,
  WARNING = (1 << 7) , OVERTEMPERATURE_MOT = (1 << 8) , FEEDBACK_FAULT = (1 << 9) }

  Enumeration of inverter error states.

Functions

- void set_error (volatile void *data, InverterError error)
  Sets an error in the error field of a data structure.
- void clear_error (volatile void *data, InverterError error)
  Clears an error in the error field of a data structure.
- bool is_error_set (volatile void *data, InverterError error)
  Checks if an error is set in the error field of a data structure.

4.5.1 Macro Definition Documentation

4.5.1.1 OVERCURRENT_TH

```
#define OVERCURRENT_TH 100.0f
```

[A] Threshold for instantaneous overcurrent fault

4.5.1.2 OVERSPEED_TH

```
#define OVERSPEED_TH 20000.0f
```

[RPM] Threshold for motor overspeed fault

4.5.1.3 OVERTEMPERATURE_INVERTER_TH

```
#define OVERTEMPERATURE_INVERTER_TH 60.0f
```

[degC] Threshold for inverter overtemperature fault

4.5.1.4 OVERTEMPERATURE_MOTOR_TH

```
#define OVERTEMPERATURE_MOTOR_TH 90.0f
```

[degC] Threshold for motor overtemperature fault

4.5.1.5 OVERVOLTAGE_TH

```
#define OVERVOLTAGE_TH 600.0f
```

[V] Threshold for overvoltage fault

4.5.1.6 UNDERVOLTAGE_TH

```
#define UNDERVOLTAGE_TH 10.0f
```

[V] Threshold for undervoltage fault

4.5.2 Enumeration Type Documentation

4.5.2.1 InverterError

```
enum InverterError
```

Enumeration of inverter error states.

Enumerator

NONE	
POWER_FAULT	Power fault error bit
OVERTEMPERATURE_INV	Inverter overtemperature error bit
OVERVOLTAGE	Overvoltage error bit
OVERCURRENT	Overcurrent error bit
OVERSPEED	Overspeed error bit
UNDERVOLTAGE	Undervoltage error bit
CONTROL_FAULT	Control fault error bit
WARNING	Warning error bit
OVERTEMPERATURE_MOT	Motor overtemperature error bit
FEEDBACK_FAULT	Feedback fault error bit

4.5.3 Function Documentation

4.5.3.1 clear_error()

```
void clear_error (
            volatile void * data,
            InverterError error )
```

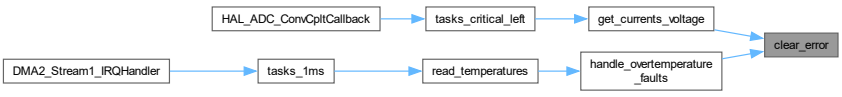
Clears an error in the error field of a data structure.

This function clears the specified error bit in the error field of a data structure.

Parameters

out	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be cleared. This should be one of the values from the InverterError enumeration.

Here is the caller graph for this function:



4.5.3.2 is_error_set()

```
bool is_error_set (
            volatile void * data,
            InverterError error )
```

Checks if an error is set in the error field of a data structure.

This function checks if the specified error bit is set in the error field of a data structure.

Parameters

in	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be checked. This should be one of the values from the InverterError enumeration.

Returns

true if the specified error is set, false otherwise.

4.5.3.3 set_error()

```
void set_error (
            volatile void * data,
            InverterError error )
```

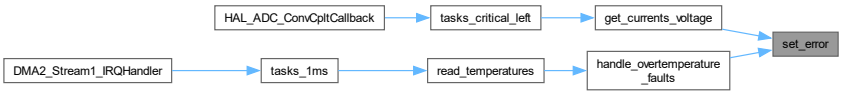
Sets an error in the error field of a data structure.

This function sets the specified error bit in the error field of a data structure.

Parameters

out	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be set. This should be one of the values from the InverterError enumeration.

Here is the caller graph for this function:



4.6 ERRORS.h

Go to the documentation of this file.

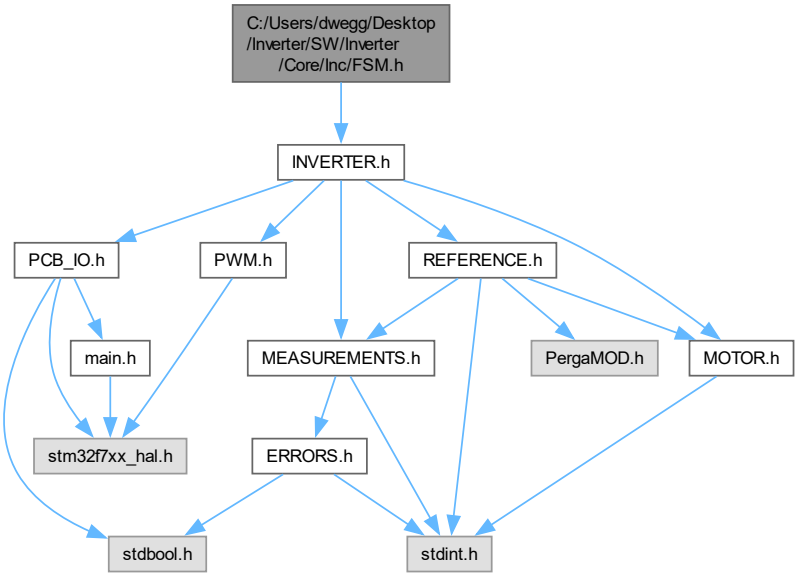
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019 #include <stdbool.h>
00020 #include <stdint.h>
00021
00025 typedef enum {
00026     NONE = 0,
00027     POWER_FAULT = (1 << 0),
00028     OVERTEMPERATURE_INV = (1 << 1),
00029     OVERVOLTAGE = (1 << 2),
00030     OVERCURRENT = (1 << 3),
00031     OVERSPEED = (1 << 4),
00032     UNDERVOLTAGE = (1 << 5),
00033     CONTROL_FAULT = (1 << 6),
00034     WARNING = (1 << 7),
00035     OVERTEMPERATURE_MOT = (1 << 8),
00036     FEEDBACK_FAULT = (1 << 9)
00037 } InverterError;
00038
00039 /* Define fault thresholds */
```

```
00040 #define OVERTEMPERATURE_INVERTER_TH 60.0f
00041 #define OVERVOLTAGE_TH 600.0f
00042 #define OVERCURRENT_TH 100.0f
00043 #define OVERSPEED_TH 20000.0f
00044 #define UNDERVOLTAGE_TH 10.0f
00045 #define OVERTEMPERATURE_MOTOR_TH 90.0f
00055 void set_error(volatile void *data, InverterError error);
00056
00065 void clear_error(volatile void *data, InverterError error);
00066
00076 bool is_error_set(volatile void *data, InverterError error);
```

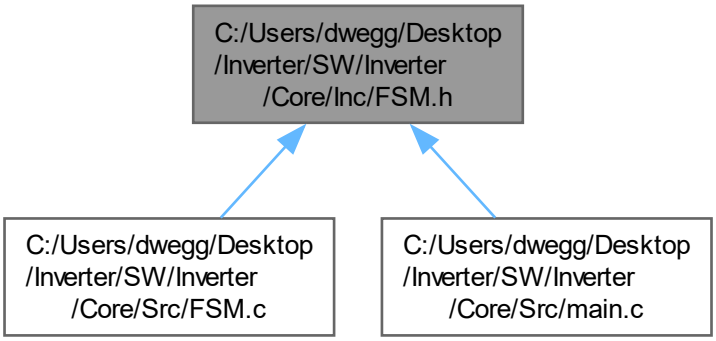
4.7 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/FSM.h File Reference

Header for the inverter Finite State Machine.

`#include "INVERTER.h"`
Include dependency graph for FSM.h:



This graph shows which files directly or indirectly include this file:



Functions

- void eval_inv_FSM (volatile InverterStruct *inv)

  Run the Finite State Machine (FSM) for inverter operation control.

4.7.1 Detailed Description

Header for the inverter Finite State Machine.

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4.7.2 Function Documentation

4.7.2.1 eval_inv_FSM()

```
void eval_inv_FSM (
            volatile InverterStruct * inv )
```

Run the Finite State Machine (FSM) for inverter operation control.

Parameters

inv	Pointer to the inverter structure.

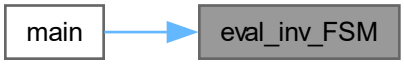
Run the Finite State Machine (FSM) for inverter operation control.

This function executes the finite state machine to control the inverter based on its current state.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.8 FSM.h

Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef FSM_H
00021 #define FSM_H
00022 #include "INVERTER.h" // inverter struct
00023
00024
00030 void eval_inv_FSM(volatile InverterStruct *inv);
00031
00032 #endif /* FSM_H */
```

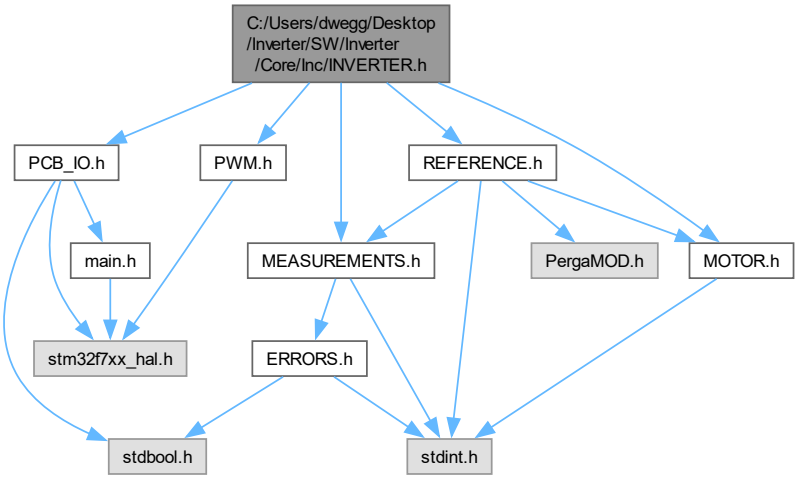
4.9 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h File Reference

Header file for the inverter struct and extern variables.

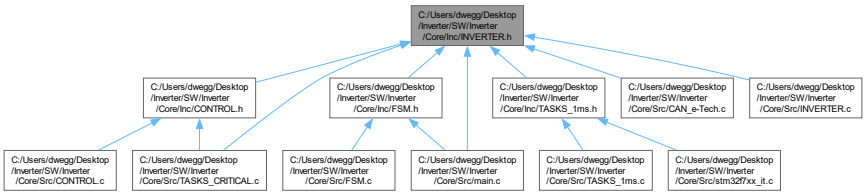
```
#include "PCB_IO.h"
#include "MEASUREMENTS.h"
#include "REFERENCE.h"
#include "MOTOR.h"
```

```
#include "PWM.h"
```

Include dependency graph for INVERTER.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct InverterStruct

  Inverter structure.

Macros

- #define TS 0.000025
- #define DT 0.0000005

Enumerations

- enum InverterState { INV_STATE_IDLE , INV_STATE_STARTUP , INV_STATE_RUNNING , INV_STATE_FAULT }

  Enumeration of inverter operation states.

Functions

- void initialize_inverter (volatile InverterStruct *inv, LED *led, GPIO_TypeDef *enable_port, uint16_t enable_pin, TIM_HandleTypeDef *htim, ADC_HandleTypeDef *hadc, MotorParameters *motor, volatile uint16_t *rawADC)

  Initialize the inverter.
- void init_control_loops (volatile InverterStruct *inv, MotorParameters *motor)

  Initializes the id-iq current control PI controllers.
- void enable_control_loops (volatile InverterStruct *inv)

  Enables the PI controllers.
- void disable_control_loops (volatile InverterStruct *inv)

  Disables the PI controllers.

Variables

- volatile InverterStruct inverter_left

  Left inverter structure.
- volatile InverterStruct inverter_right

  Right inverter structure.

4.9.1 Detailed Description

Header file for the inverter struct and extern variables.

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4.9.2 Macro Definition Documentation

4.9.2.1 DT

```
#define DT 0.0000005
```

Dead time in seconds (500 ns), time in which both top and bottom transistors are open

4.9.2.2 TS

```
#define TS 0.000025
```

Switching time in seconds (25 us), inverse of the switching frequency of 40 kHz

4.9.3 Enumeration Type Documentation

4.9.3.1 InverterState

```
enum InverterState
```

Enumeration of inverter operation states.

Enumerator

INV_STATE_IDLE	Inverter idle state
INV_STATE_STARTUP	Inverter startup state
INV_STATE_RUNNING	Inverter running state
INV_STATE_FAULT	Inverter fault state

4.9.4 Function Documentation

4.9.4.1 disable_control_loops()

```
void disable_control_loops (
            volatile InverterStruct * inv )
```

Disables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.9.4.2 enable_control_loops()

```
void enable_control_loops (
            volatile InverterStruct * inv )
```

Enables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.9.4.3 init_control_loops()

```
void init_control_loops (
            volatile InverterStruct * inv,
            MotorParameters * motor )
```

Initializes the id-iq current control PI controllers.

Parameters

inv	Pointer to the inverter structure.

Initializes the id-iq current control PI controllers.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:

4.9.4.4 initialize_inverter()

```
void initialize_inverter (
            volatile InverterStruct * inv,
            LED * led,
            GPIO_TypeDef * enable_port,
            uint16_t enable_pin,
            TIM_HandleTypeDef * htim,
            ADC_HandleTypeDef * hadc,
            MotorParameters * motor,
            volatile uint16_t * rawADC )
```

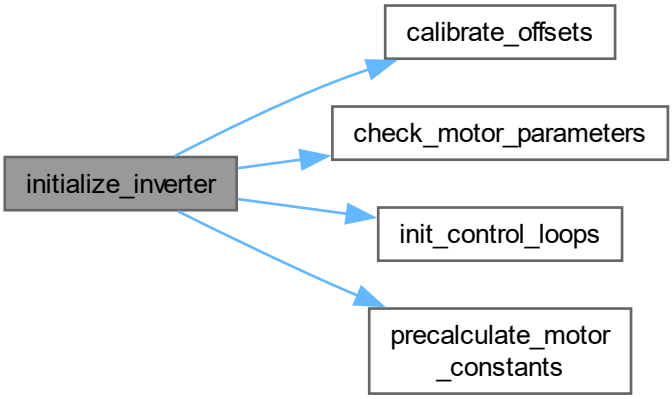
Initialize the inverter.

This function initializes the inverter structure with the specified LED, GPIO port, and pin.

Parameters

out	*inv*	Pointer to the inverter structure.
in	*led*	Pointer to the LED structure.
in	*enable_port*	Pointer to the GPIO port for enabling/disabling the inverter.
in	*enable_pin*	Pin number for enabling/disabling the inverter.
in	*htim*	Timer peripheral for the PWM output.
in	*hadc*	ADC peripheral for the current phase current and DC voltage sensing.
in	*motor*	MotorParameters struct.

Here is the call graph for this function:



Here is the caller graph for this function:

4.9.5 Variable Documentation

4.9.5.1 inverter_left

```
volatile InverterStruct inverter_left  [extern]
```

Left inverter structure.

External declaration of the left inverter structure

External declaration of the left inverter structure.

4.9.5.2 inverter_right

```
volatile InverterStruct inverter_right  [extern]
```

Right inverter structure.

External declaration of the right inverter structure

External declaration of the right inverter structure.

4.10 INVERTER.h

Go to the documentation of this file.

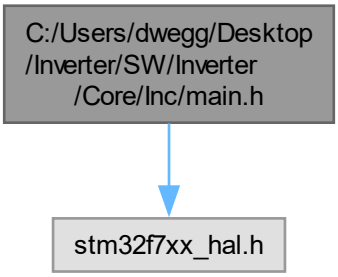
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef INVERTER_H
00021 #define INVERTER_H
00022
00023 #include "PCB_IO.h" // peripheral types
00024 #include "MEASUREMENTS.h" // a few structs
00025 #include "REFERENCE.h" // reference struct
00026 #include "MOTOR.h" // motor struct
00027 #include "PWM.h" // duties struct
00028
00029
00030 #define TS 0.000025
00031 #define DT 0.0000005
00037 typedef enum {
00038     INV_STATE_IDLE,
00039     INV_STATE_STARTUP,
00040     INV_STATE_RUNNING,
00041     INV_STATE_FAULT
00042 } InverterState;
00043
00047 typedef struct {
00048     LED *led;
00049     GPIO_TypeDef *enable_port;
00050     uint16_t enable_pin;
00051     TIM_HandleTypeDef *htim;
00052     ADC_HandleTypeDef *hadc;
00053     InverterState state;
00054     Analog analog;
00055     Encoder encoder;
00056     Feedback feedback;
00057     Reference reference;
00058     Duties duties;
00059     int8_t direction;
00060     float tempInverter;
00061     float tempMotor;
00062     MotorParameters *motor;
00063     pi_struct idLoop;
00064     pi_struct iqLoop;
00065     float vsMax;
00066     float vd;
00067     float vq;
00068     pi_struct speedLoop;
00069     InverterError errors;
00070     bool enable;
00071     bool enableSW;
00073 } InverterStruct;
00074
00075 extern volatile InverterStruct inverter_left;
00076 extern volatile InverterStruct inverter_right;
00091 void initialize_inverter(volatile InverterStruct *inv, LED *led, GPIO_TypeDef *enable_port, uint16_t
      enable_pin, TIM_HandleTypeDef *htim, ADC_HandleTypeDef *hadc, MotorParameters *motor, volatile
      uint16_t *rawADC);
00092
00098 void init_control_loops(volatile InverterStruct *inv, MotorParameters *motor);
00099
00105 void enable_control_loops(volatile InverterStruct *inv);
00106
00112 void disable_control_loops(volatile InverterStruct *inv);
00113
00114 #endif /* INVERTER_H */
```

4.11 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/main.h File Reference

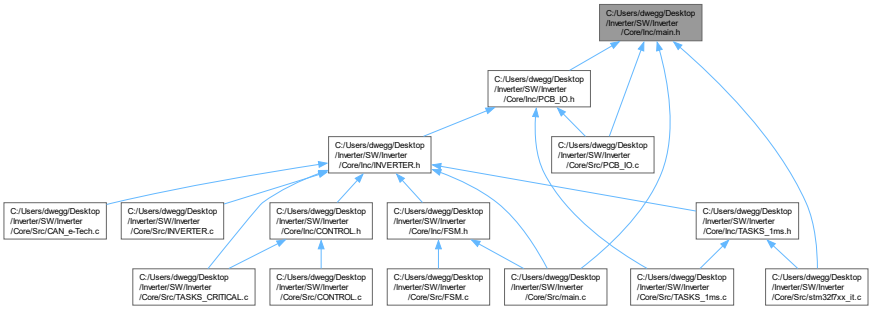
: Header for main.c file. This file contains the common defines of the application.

```
#include "stm32f7xx_hal.h"
```

Include dependency graph for main.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define Tinv_L_Pin GPIO_PIN_0
- #define Tinv_L_GPIO_Port GPIOC
- #define Tinv_R_Pin GPIO_PIN_1
- #define Tinv_R_GPIO_Port GPIOC
- #define Tmot_L_Pin GPIO_PIN_2
- #define Tmot_L_GPIO_Port GPIOC
- #define Tmot_R_Pin GPIO_PIN_3
- #define Tmot_R_GPIO_Port GPIOC
- #define ia_L_Pin GPIO_PIN_0
- #define ia_L_GPIO_Port GPIOA
- #define ib_L_Pin GPIO_PIN_1
- #define ib_L_GPIO_Port GPIOA
- #define ic_L_Pin GPIO_PIN_2
- #define ic_L_GPIO_Port GPIOA
- #define VDC_L_Pin GPIO_PIN_3
- #define VDC_L_GPIO_Port GPIOA
- #define DAC_Pin GPIO_PIN_4

- #define DAC_GPIO_Port GPIOA
- #define PWM1_R_Pin GPIO_PIN_5
- #define PWM1_R_GPIO_Port GPIOA
- #define ia_R_Pin GPIO_PIN_6
- #define ia_R_GPIO_Port GPIOA
- #define ib_R_Pin GPIO_PIN_7
- #define ib_R_GPIO_Port GPIOA
- #define SC_det_Pin GPIO_PIN_4
- #define SC_det_GPIO_Port GPIOC
- #define ic_R_Pin GPIO_PIN_0
- #define ic_R_GPIO_Port GPIOB
- #define VDC_R_Pin GPIO_PIN_1
- #define VDC_R_GPIO_Port GPIOB
- #define ENABLE_R_Pin GPIO_PIN_2
- #define ENABLE_R_GPIO_Port GPIOB
- #define ENABLE_L_Pin GPIO_PIN_7
- #define ENABLE_L_GPIO_Port GPIOE
- #define PWM1_L_Pin GPIO_PIN_8
- #define PWM1_L_GPIO_Port GPIOE
- #define PWM2_L_Pin GPIO_PIN_9
- #define PWM2_L_GPIO_Port GPIOE
- #define PWM3_L_Pin GPIO_PIN_10
- #define PWM3_L_GPIO_Port GPIOE
- #define PWM4_L_Pin GPIO_PIN_11
- #define PWM4_L_GPIO_Port GPIOE
- #define PWM5_L_Pin GPIO_PIN_12
- #define PWM5_L_GPIO_Port GPIOE
- #define PWM6_L_Pin GPIO_PIN_13
- #define PWM6_L_GPIO_Port GPIOE
- #define WRN_L_Pin GPIO_PIN_14
- #define WRN_L_GPIO_Port GPIOE
- #define WRN_R_Pin GPIO_PIN_15
- #define WRN_R_GPIO_Port GPIOE
- #define B_R_Pin GPIO_PIN_10
- #define B_R_GPIO_Port GPIOB
- #define Z_R_Pin GPIO_PIN_11
- #define Z_R_GPIO_Port GPIOB
- #define PWM3_R_Pin GPIO_PIN_14
- #define PWM3_R_GPIO_Port GPIOB
- #define PWM5_R_Pin GPIO_PIN_15
- #define PWM5_R_GPIO_Port GPIOB
- #define A_L_Pin GPIO_PIN_12
- #define A_L_GPIO_Port GPIOD
- #define B_L_Pin GPIO_PIN_14
- #define B_L_GPIO_Port GPIOD
- #define Z_L_Pin GPIO_PIN_15
- #define Z_L_GPIO_Port GPIOD
- #define PWM2_R_Pin GPIO_PIN_6
- #define PWM2_R_GPIO_Port GPIOC
- #define PWM4_R_Pin GPIO_PIN_7
- #define PWM4_R_GPIO_Port GPIOC
- #define PWM6_R_Pin GPIO_PIN_8
- #define PWM6_R_GPIO_Port GPIOC
- #define TRIP_R_Pin GPIO_PIN_9
- #define TRIP_R_GPIO_Port GPIOC

- #define TRIP_L_Pin GPIO_PIN_8
- #define TRIP_L_GPIO_Port GPIOA
- #define A_R_Pin GPIO_PIN_15
- #define A_R_GPIO_Port GPIOA
- #define DIR_Pin GPIO_PIN_3
- #define DIR_GPIO_Port GPIOD
- #define LED_LEFT_Pin GPIO_PIN_4
- #define LED_LEFT_GPIO_Port GPIOD
- #define LED_RIGHT_Pin GPIO_PIN_5
- #define LED_RIGHT_GPIO_Port GPIOD
- #define LED_ERR_Pin GPIO_PIN_6
- #define LED_ERR_GPIO_Port GPIOD

Functions

- void Error_Handler (void)

  This function is executed in case of error occurrence.

4.11.1 Detailed Description

: Header for main.c file. This file contains the common defines of the application.

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4.11.2 Macro Definition Documentation

4.11.2.1 A_L_GPIO_Port

```
#define A_L_GPIO_Port GPIOD
```

4.11.2.2 A_L_Pin

```
#define A_L_Pin GPIO_PIN_12
```

4.11.2.3 A_R_GPIO_Port

```
#define A_R_GPIO_Port GPIOA
```

4.11.2.4 A_R_Pin

```
#define A_R_Pin GPIO_PIN_15
```

4.11.2.5 B_L_GPIO_Port

```
#define B_L_GPIO_Port GPIOD
```

4.11.2.6 B_L_Pin

```
#define B_L_Pin GPIO_PIN_14
```

4.11.2.7 B_R_GPIO_Port

```
#define B_R_GPIO_Port GPIOB
```

4.11.2.8 B_R_Pin

```
#define B_R_Pin GPIO_PIN_10
```

4.11.2.9 DAC_GPIO_Port

```
#define DAC_GPIO_Port GPIOA
```

4.11.2.10 DAC_Pin

```
#define DAC_Pin GPIO_PIN_4
```

4.11.2.11 DIR_GPIO_Port

```
#define DIR_GPIO_Port GPIOD
```

4.11.2.12 DIR_Pin

```
#define DIR_Pin GPIO_PIN_3
```

4.11.2.13 ENABLE_L_GPIO_Port

```
#define ENABLE_L_GPIO_Port GPIOE
```

4.11.2.14 ENABLE_L_Pin

```
#define ENABLE_L_Pin GPIO_PIN_7
```

4.11.2.15 ENABLE_R_GPIO_Port

```
#define ENABLE_R_GPIO_Port GPIOB
```

4.11.2.16 ENABLE_R_Pin

```
#define ENABLE_R_Pin GPIO_PIN_2
```

4.11.2.17 ia_L_GPIO_Port

```
#define ia_L_GPIO_Port GPIOA
```

4.11.2.18 ia_L_Pin

```
#define ia_L_Pin GPIO_PIN_0
```

4.11.2.19 ia_R_GPIO_Port

```
#define ia_R_GPIO_Port GPIOA
```

4.11.2.20 ia_R_Pin

```
#define ia_R_Pin GPIO_PIN_6
```

4.11.2.21 ib_L_GPIO_Port

```
#define ib_L_GPIO_Port GPIOA
```

4.11.2.22 ib_L_Pin

```
#define ib_L_Pin GPIO_PIN_1
```

4.11.2.23 ib_R_GPIO_Port

```
#define ib_R_GPIO_Port GPIOA
```

4.11.2.24 ib_R_Pin

```
#define ib_R_Pin GPIO_PIN_7
```

4.11.2.25 ic_L_GPIO_Port

```
#define ic_L_GPIO_Port GPIOA
```

4.11.2.26 ic_L_Pin

```
#define ic_L_Pin GPIO_PIN_2
```

4.11.2.27 ic_R_GPIO_Port

```
#define ic_R_GPIO_Port GPIOB
```

4.11.2.28 ic_R_Pin

```
#define ic_R_Pin GPIO_PIN_0
```

4.11.2.29 LED_ERR_GPIO_Port

```
#define LED_ERR_GPIO_Port GPIOD
```

4.11.2.30 LED_ERR_Pin

```
#define LED_ERR_Pin GPIO_PIN_6
```

4.11.2.31 LED_LEFT_GPIO_Port

```
#define LED_LEFT_GPIO_Port GPIOD
```

4.11.2.32 LED_LEFT_Pin

```
#define LED_LEFT_Pin GPIO_PIN_4
```

4.11.2.33 LED_RIGHT_GPIO_Port

```
#define LED_RIGHT_GPIO_Port GPIOD
```

4.11.2.34 LED_RIGHT_Pin

```
#define LED_RIGHT_Pin GPIO_PIN_5
```

4.11.2.35 PWM1_L_GPIO_Port

```
#define PWM1_L_GPIO_Port GPIOE
```

4.11.2.36 PWM1_L_Pin

```
#define PWM1_L_Pin GPIO_PIN_8
```

4.11.2.37 PWM1_R_GPIO_Port

```
#define PWM1_R_GPIO_Port GPIOA
```

4.11.2.38 PWM1_R_Pin

```
#define PWM1_R_Pin GPIO_PIN_5
```

4.11.2.39 PWM2_L_GPIO_Port

```
#define PWM2_L_GPIO_Port GPIOE
```

4.11.2.40 PWM2_L_Pin

```
#define PWM2_L_Pin GPIO_PIN_9
```

4.11.2.41 PWM2_R_GPIO_Port

```
#define PWM2_R_GPIO_Port GPIOC
```

4.11.2.42 PWM2_R_Pin

```
#define PWM2_R_Pin GPIO_PIN_6
```

4.11.2.43 PWM3_L_GPIO_Port

```
#define PWM3_L_GPIO_Port GPIOE
```

4.11.2.44 PWM3_L_Pin

```
#define PWM3_L_Pin GPIO_PIN_10
```

4.11.2.45 PWM3_R_GPIO_Port

```
#define PWM3_R_GPIO_Port GPIOB
```

4.11.2.46 PWM3_R_Pin

```
#define PWM3_R_Pin GPIO_PIN_14
```

4.11.2.47 PWM4_L_GPIO_Port

```
#define PWM4_L_GPIO_Port GPIOE
```

4.11.2.48 PWM4_L_Pin

```
#define PWM4_L_Pin GPIO_PIN_11
```

4.11.2.49 PWM4_R_GPIO_Port

```
#define PWM4_R_GPIO_Port GPIOC
```

4.11.2.50 PWM4_R_Pin

```
#define PWM4_R_Pin GPIO_PIN_7
```

4.11.2.51 PWM5_L_GPIO_Port

```
#define PWM5_L_GPIO_Port GPIOE
```

4.11.2.52 PWM5_L_Pin

```
#define PWM5_L_Pin GPIO_PIN_12
```

4.11.2.53 PWM5_R_GPIO_Port

```
#define PWM5_R_GPIO_Port GPIOB
```

4.11.2.54 PWM5_R_Pin

```
#define PWM5_R_Pin GPIO_PIN_15
```

4.11.2.55 PWM6_L_GPIO_Port

```
#define PWM6_L_GPIO_Port GPIOE
```

4.11.2.56 PWM6_L_Pin

```
#define PWM6_L_Pin GPIO_PIN_13
```

4.11.2.57 PWM6_R_GPIO_Port

```
#define PWM6_R_GPIO_Port GPIOC
```

4.11.2.58 PWM6_R_Pin

```
#define PWM6_R_Pin GPIO_PIN_8
```

4.11.2.59 SC_det_GPIO_Port

```
#define SC_det_GPIO_Port GPIOC
```

4.11.2.60 SC_det_Pin

```
#define SC_det_Pin GPIO_PIN_4
```

4.11.2.61 Tinv_L_GPIO_Port

```
#define Tinv_L_GPIO_Port GPIOC
```

4.11.2.62 Tinv_L_Pin

```
#define Tinv_L_Pin GPIO_PIN_0
```

4.11.2.63 Tinv_R_GPIO_Port

```
#define Tinv_R_GPIO_Port GPIOC
```

4.11.2.64 Tinv_R_Pin

```
#define Tinv_R_Pin GPIO_PIN_1
```

4.11.2.65 Tmot_L_GPIO_Port

```
#define Tmot_L_GPIO_Port GPIOC
```

4.11.2.66 Tmot_L_Pin

```
#define Tmot_L_Pin GPIO_PIN_2
```

4.11.2.67 Tmot_R_GPIO_Port

```
#define Tmot_R_GPIO_Port GPIOC
```

4.11.2.68 Tmot_R_Pin

```
#define Tmot_R_Pin GPIO_PIN_3
```

4.11.2.69 TRIP_L_GPIO_Port

```
#define TRIP_L_GPIO_Port GPIOA
```

4.11.2.70 TRIP_L_Pin

```
#define TRIP_L_Pin GPIO_PIN_8
```

4.11.2.71 TRIP_R_GPIO_Port

```
#define TRIP_R_GPIO_Port GPIOC
```

4.11.2.72 TRIP_R_Pin

```
#define TRIP_R_Pin GPIO_PIN_9
```

4.11.2.73 VDC_L_GPIO_Port

```
#define VDC_L_GPIO_Port GPIOA
```

4.11.2.74 VDC_L_Pin

```
#define VDC_L_Pin GPIO_PIN_3
```

4.11.2.75 VDC_R_GPIO_Port

```
#define VDC_R_GPIO_Port GPIOB
```

4.11.2.76 VDC_R_Pin

```
#define VDC_R_Pin GPIO_PIN_1
```

4.11.2.77 WRN_L_GPIO_Port

```
#define WRN_L_GPIO_Port GPIOE
```

4.11.2.78 WRN_L_Pin

```
#define WRN_L_Pin GPIO_PIN_14
```

4.11.2.79 WRN_R_GPIO_Port

```
#define WRN_R_GPIO_Port GPIOE
```

4.11.2.80 WRN_R_Pin

```
#define WRN_R_Pin GPIO_PIN_15
```

4.11.2.81 Z_L_GPIO_Port

```
#define Z_L_GPIO_Port GPIOD
```

4.11.2.82 Z_L_Pin

```
#define Z_L_Pin GPIO_PIN_15
```

4.11.2.83 Z_R_GPIO_Port

```
#define Z_R_GPIO_Port GPIOB
```

4.11.2.84 Z_R_Pin

```
#define Z_R_Pin GPIO_PIN_11
```

4.11.3 Function Documentation

4.11.3.1 Error_Handler()

```
void Error_Handler (
            void  )
```

This function is executed in case of error occurrence.

Return values

None	

Here is the caller graph for this function:

4.12 main.h

Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00019 /* USER CODE END Header */
00020
00021 /* Define to prevent recursive inclusion -------------------------------------*/
00022 #ifndef __MAIN_H
00023 #define __MAIN_H
00024
00025 #ifdef __cplusplus
00026 extern "C" {
00027 #endif
00028
00029 /* Includes ------------------------------------------------------------------*/
00030 #include "stm32f7xx_hal.h"
00031
00032 /* Private includes ----------------------------------------------------------*/
00033 /* USER CODE BEGIN Includes */
00034
00035 /* USER CODE END Includes */
00036
00037 /* Exported types ------------------------------------------------------------*/
00038 /* USER CODE BEGIN ET */
00039
00040 /* USER CODE END ET */
00041
00042 /* Exported constants --------------------------------------------------------*/
00043 /* USER CODE BEGIN EC */
00044
00045 /* USER CODE END EC */
00046
00047 /* Exported macro ------------------------------------------------------------*/
00048 /* USER CODE BEGIN EM */
00049
00050 /* USER CODE END EM */
00051
00052 /* Exported functions prototypes ---------------------------------------------*/
00053 void Error_Handler(void);
00054
00055 /* USER CODE BEGIN EFP */
00056
00057 /* USER CODE END EFP */
00058
00059 /* Private defines -----------------------------------------------------------*/
00060 #define Tinv_L_Pin GPIO_PIN_0
00061 #define Tinv_L_GPIO_Port GPIOC
00062 #define Tinv_R_Pin GPIO_PIN_1
00063 #define Tinv_R_GPIO_Port GPIOC
00064 #define Tmot_L_Pin GPIO_PIN_2
00065 #define Tmot_L_GPIO_Port GPIOC
00066 #define Tmot_R_Pin GPIO_PIN_3
00067 #define Tmot_R_GPIO_Port GPIOC
00068 #define ia_L_Pin GPIO_PIN_0
00069 #define ia_L_GPIO_Port GPIOA
00070 #define ib_L_Pin GPIO_PIN_1
```

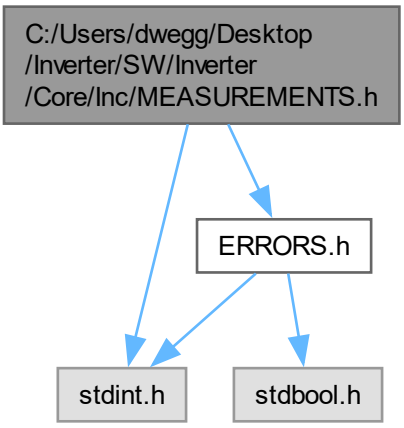
```
00071 #define ib_L_GPIO_Port GPIOA
00072 #define ic_L_Pin GPIO_PIN_2
00073 #define ic_L_GPIO_Port GPIOA
00074 #define VDC_L_Pin GPIO_PIN_3
00075 #define VDC_L_GPIO_Port GPIOA
00076 #define DAC_Pin GPIO_PIN_4
00077 #define DAC_GPIO_Port GPIOA
00078 #define PWM1_R_Pin GPIO_PIN_5
00079 #define PWM1_R_GPIO_Port GPIOA
00080 #define ia_R_Pin GPIO_PIN_6
00081 #define ia_R_GPIO_Port GPIOA
00082 #define ib_R_Pin GPIO_PIN_7
00083 #define ib_R_GPIO_Port GPIOA
00084 #define SC_det_Pin GPIO_PIN_4
00085 #define SC_det_GPIO_Port GPIOC
00086 #define ic_R_Pin GPIO_PIN_0
00087 #define ic_R_GPIO_Port GPIOB
00088 #define VDC_R_Pin GPIO_PIN_1
00089 #define VDC_R_GPIO_Port GPIOB
00090 #define ENABLE_R_Pin GPIO_PIN_2
00091 #define ENABLE_R_GPIO_Port GPIOB
00092 #define ENABLE_L_Pin GPIO_PIN_7
00093 #define ENABLE_L_GPIO_Port GPIOE
00094 #define PWM1_L_Pin GPIO_PIN_8
00095 #define PWM1_L_GPIO_Port GPIOE
00096 #define PWM2_L_Pin GPIO_PIN_9
00097 #define PWM2_L_GPIO_Port GPIOE
00098 #define PWM3_L_Pin GPIO_PIN_10
00099 #define PWM3_L_GPIO_Port GPIOE
00100 #define PWM4_L_Pin GPIO_PIN_11
00101 #define PWM4_L_GPIO_Port GPIOE
00102 #define PWM5_L_Pin GPIO_PIN_12
00103 #define PWM5_L_GPIO_Port GPIOE
00104 #define PWM6_L_Pin GPIO_PIN_13
00105 #define PWM6_L_GPIO_Port GPIOE
00106 #define WRN_L_Pin GPIO_PIN_14
00107 #define WRN_L_GPIO_Port GPIOE
00108 #define WRN_R_Pin GPIO_PIN_15
00109 #define WRN_R_GPIO_Port GPIOE
00110 #define B_R_Pin GPIO_PIN_10
00111 #define B_R_GPIO_Port GPIOB
00112 #define Z_R_Pin GPIO_PIN_11
00113 #define Z_R_GPIO_Port GPIOB
00114 #define PWM3_R_Pin GPIO_PIN_14
00115 #define PWM3_R_GPIO_Port GPIOB
00116 #define PWM5_R_Pin GPIO_PIN_15
00117 #define PWM5_R_GPIO_Port GPIOB
00118 #define A_L_Pin GPIO_PIN_12
00119 #define A_L_GPIO_Port GPIOD
00120 #define B_L_Pin GPIO_PIN_14
00121 #define B_L_GPIO_Port GPIOD
00122 #define Z_L_Pin GPIO_PIN_15
00123 #define Z_L_GPIO_Port GPIOD
00124 #define PWM2_R_Pin GPIO_PIN_6
00125 #define PWM2_R_GPIO_Port GPIOC
00126 #define PWM4_R_Pin GPIO_PIN_7
00127 #define PWM4_R_GPIO_Port GPIOC
00128 #define PWM6_R_Pin GPIO_PIN_8
00129 #define PWM6_R_GPIO_Port GPIOC
00130 #define TRIP_R_Pin GPIO_PIN_9
00131 #define TRIP_R_GPIO_Port GPIOC
00132 #define TRIP_L_Pin GPIO_PIN_8
00133 #define TRIP_L_GPIO_Port GPIOA
00134 #define A_R_Pin GPIO_PIN_15
00135 #define A_R_GPIO_Port GPIOA
00136 #define DIR_Pin GPIO_PIN_3
00137 #define DIR_GPIO_Port GPIOD
00138 #define LED_LEFT_Pin GPIO_PIN_4
00139 #define LED_LEFT_GPIO_Port GPIOD
00140 #define LED_RIGHT_Pin GPIO_PIN_5
00141 #define LED_RIGHT_GPIO_Port GPIOD
00142 #define LED_ERR_Pin GPIO_PIN_6
00143 #define LED_ERR_GPIO_Port GPIOD
00144
00145 /* USER CODE BEGIN Private defines */
00146
00147 /* USER CODE END Private defines */
00148
00149 #ifdef __cplusplus
00150 }
00151 #endif
00152
00153 #endif /* __MAIN_H */
```

4.13 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/↩ MEASUREMENTS.h File Reference

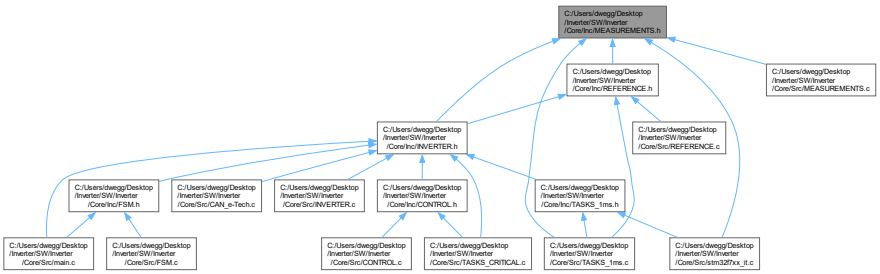
Header file for handling measurements.

```
#include <stdint.h>
#include "ERRORS.h"
```

Include dependency graph for MEASUREMENTS.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct Encoder

  Structure for encoder reading.
- struct Analog

  Structure for ADC measurements in units.
- struct Feedback

  Structure for feedback values.

Macros

- #define CURRENT_SLOPE 117.57704f
- #define CURRENT_OFFSET 1.70068027211f
- #define VOLTAGE_SLOPE 263.435f
- #define VOLTAGE_OFFSET 0.02083f

Functions

- void get_currents_voltage (volatile uint16_t rawADC[ ], volatile Analog ∗analog, volatile Feedback ∗feedback, volatile InverterError ∗errors, float sinTheta_e, float cosTheta_e)

  Get electrical ADC measurements.
- float get_linear (uint32_t bits, float slope, float offset)

  Convert ADC reading to physical measurement with linear response.
- void get_idiq (float ia, float ib, float ic, float sinTheta_e, float cosTheta_e, float ∗idMeas, float ∗iqMeas)

  Computes d-q currents from current measurements and electrical angle.
- float get_temperature (uint32_t bits, const float tempLUT[ ])

  Retrieves temperature from a lookup table based on ADC bits.
- void calibrate_offsets (volatile uint16_t rawADC[ ], volatile float currentOffsets[ ], uint32_t numSamples)

  Calibrate the current sensor offsets.

Variables

- const float tempInverterLUT [ ]
- const float tempMotorLUT [ ]
- volatile uint16_t rawADC_left [4]

  Raw ADC data for the left inverter.
- volatile uint16_t rawADC_right [4]

  Raw ADC data for the right inverter.
- volatile uint16_t rawADC_temp [4]

  Raw ADC data for the temperatures.

4.13.1 Detailed Description

Header file for handling measurements.

Attention

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4.13.2 Macro Definition Documentation

4.13.2.1 CURRENT_OFFSET

```
#define CURRENT_OFFSET 1.70068027211f
```

[V] (10/(4.7+10))∗ 2.5 V (not actually used, self calibration at start)

4.13.2.2 CURRENT_SLOPE

```
#define CURRENT_SLOPE 117.57704f
```

[A/V] ((4.7+10)/10) ∗ (1 / (12.5 mV / A))

4.13.2.3 VOLTAGE_OFFSET

```
#define VOLTAGE_OFFSET 0.02083f
```

[V] (100/(4700+100) ∗ 5 V

4.13.2.4 VOLTAGE_SLOPE

```
#define VOLTAGE_SLOPE 263.435f
```

[V/V] 1/(1/3 ∗ 0.011388) V

4.13.3 Function Documentation

4.13.3.1 calibrate_offsets()

```
void calibrate_offsets (
            volatile uint16_t rawADC[],
            volatile float currentOffsets[],
            uint32_t numSamples )
```

Calibrate the current sensor offsets.

This function calculates the average offset for each current sensor channel by reading the ADC values when no current is flowing. The calculated offsets are used to correct the sensor readings.

Parameters

in	*rawADC*	Buffer containing the raw ADC values for the channels.
out	*currentOffsets*	Array to store the calculated offsets for each current channel.
in	*numSamples*	Number of samples to average for the offset calculation.

Here is the caller graph for this function:

4.13.3.2 get_currents_voltage()

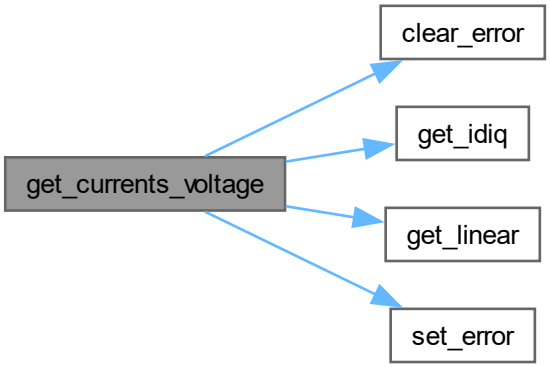
```
void get_currents_voltage (
            volatile uint16_t rawADC[],
            volatile Analog * analog,
            volatile Feedback * feedback,
            volatile InverterError * errors,
            float sinTheta_e,
            float cosTheta_e )
```

Get electrical ADC measurements.

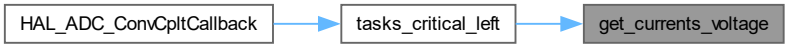
Parameters

in	*rawADC*	Pointer to the raw ADC values array.
out	*analog*	Pointer to the ADC struct to store the results.
out	*feedback*	Pointer to the Feedback struct to store id and iq.
in	*sinTheta_e*	Electrical angle sine (-1..1)
in	*cosTheta_e*	Electrical angle cosine (-1..1)

Here is the call graph for this function:



Here is the caller graph for this function:



4.13.3.3 get_idiq()

```
void get_idiq (
            float ia,
            float ib,
            float ic,
            float sinTheta_e,
            float cosTheta_e,
            float * idMeas,
            float * iqMeas )
```

Computes d-q currents from current measurements and electrical angle.

This function computes the d-q currents from phase currents (ABC), theta_e, and stores the results in the provided pointers.

Parameters

in	*ia*	Phase A current in A.
in	*ib*	Phase B current in A.
in	*ic*	Phase C current in A.
in	*sinTheta_e*	Electrical angle sine (-1..1)

Parameters

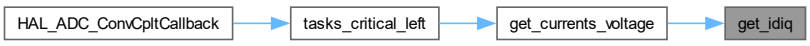
in	*cosTheta_e*	Electrical angle cosine (-1..1)
out	*idMeas*	Pointer to store the d-axis current.
out	*iqMeas*	Pointer to store the q-axis current.

This function computes the d-q currents from phase currents (ABC), theta_e, and stores the results in the provided pointers.

Parameters

in	*ia*	Phase A current in A.
in	*ib*	Phase B current in A.
in	*ic*	Phase C current in A.
in	*sinTheta_e*	Electrical angle sine (-1..1)
in	*cosTheta_e*	Electrical angle cosine (-1..1)
out	*idMeas*	Pointer to store the D-axis current.
out	*iqMeas*	Pointer to store the Q-axis current.

Here is the caller graph for this function:



4.13.3.4 get_linear()

```
float get_linear (
            uint32_t bits,
            float slope,
            float offset )
```

Convert ADC reading to physical measurement with linear response.

Parameters

in	*bits*	The ADC reading.
in	*slope*	The slope (volts per unit).
in	*offset*	The offset (volts at zero).

Return values

measurement	The physical measurement.

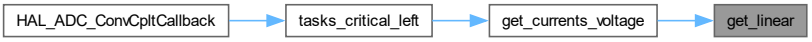
Parameters

in	*bits*	The ADC reading.
in	*slope*	The slope (units per volt).
in	*offset*	The offset (volts at zero).

Return values

measurement	The physical measurement.

Here is the caller graph for this function:



4.13.3.5 get_temperature()

```
float get_temperature (
            uint32_t bits,
            const float tempLUT[] )
```

Retrieves temperature from a lookup table based on ADC bits.

This function retrieves temperature from a lookup table based on the ADC bits. The lookup table (LUT) must have a value for each possible ADC bit combination.

Parameters

in	*bits*	ADC reading converted to bits.
in	*tempLUT*	Lookup table containing temperature values.

Returns

Temperature corresponding to the provided ADC bits.

Here is the caller graph for this function:

4.13.4 Variable Documentation

4.13.4.1 rawADC_left

```
volatile uint16_t rawADC_left[4]  [extern]
```

Raw ADC data for the left inverter.

External declaration of raw ADC data for the left inverter

External declaration of raw ADC data for the left inverter.

4.13.4.2 rawADC_right

```
volatile uint16_t rawADC_right[4]  [extern]
```

Raw ADC data for the right inverter.

External declaration of raw ADC data for the right inverter

External declaration of raw ADC data for the right inverter.

4.13.4.3 rawADC_temp

```
volatile uint16_t rawADC_temp[4]  [extern]
```

Raw ADC data for the temperatures.

External declaration of raw ADC data for the temperatures

External declaration of raw ADC data for the temperature readings.

4.13.4.4 tempInverterLUT

```
const float tempInverterLUT[]  [extern]
```

4.13.4.5 tempMotorLUT

```
const float tempMotorLUT[]  [extern]
```

4.14 MEASUREMENTS.h

Go to the documentation of this file.

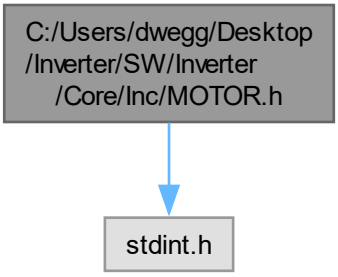
```
00001 /* USER CODE BEGIN Header */
00017 /* USER CODE END Header */
00018
00019
00020 #ifndef MEASUREMENTS_H
00021 #define MEASUREMENTS_H
00022
00023 #include <stdint.h>
00024 #include "ERRORS.h"
00025
00026 /* Define current and voltage gains/offsets */
00027 #define CURRENT_SLOPE  117.57704f
00028 #define CURRENT_OFFSET 1.70068027211f
00030 #define VOLTAGE_SLOPE  263.435f
00031 #define VOLTAGE_OFFSET 0.02083f
00033 extern const float tempInverterLUT[];
00034 extern const float tempMotorLUT[];
00035
00036 extern volatile uint16_t rawADC_left[4];
00037 extern volatile uint16_t rawADC_right[4];
00038 extern volatile uint16_t rawADC_temp[4];
00044 typedef struct {
00045     uint16_t A;
00046     uint16_t B;
00047     uint16_t Z;
00048     float we;
00049     float theta_e;
00050     float sinTheta_e;
00051       float cosTheta_e;
00052     uint8_t directionMeas;
00053 } Encoder;
00054
00055
00059 typedef struct {
00060     float ia;
00061     float ib;
00062     float ic;
00063     float vDC;
00064     float currentOffsets[3];
00065 } Analog;
00066
00067
00071 typedef struct {
00072     float idMeas;
00073     float iqMeas;
00074     float torqueCalc;
00075     float speedMeas;
00076 } Feedback;
00077
00078
00079
00088 void get_currents_voltage(volatile uint16_t rawADC[], volatile Analog* analog, volatile Feedback*
      feedback, volatile InverterError *errors, float sinTheta_e, float cosTheta_e);
00089
00097 float get_linear(uint32_t bits, float slope, float offset);
00098
00099
00114 void get_idiq(float ia, float ib, float ic, float sinTheta_e, float cosTheta_e, float *idMeas, float
      *iqMeas);
00115
00116
00127 float get_temperature(uint32_t bits, const float tempLUT[]);
00128
00129
00141 void calibrate_offsets(volatile uint16_t rawADC[], volatile float currentOffsets[], uint32_t
      numSamples);
00142
00143
00144 #endif /* MEASUREMENTS_H */
```

4.15 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h File Reference

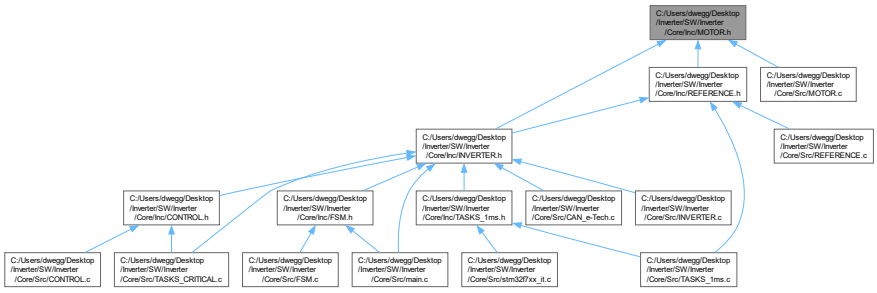
Header file for motor parameters.

```
#include <stdint.h>
```

Include dependency graph for MOTOR.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct MotorConstants

  Structure to hold precomputed motor constants.
- struct MotorParameters

  Structure to hold motor parameters.

Functions

- void precalculate_motor_constants (MotorParameters ∗motor)

  Precomputes the constants for a motor and updates the MotorParameters structure.
- int check_motor_parameters (MotorParameters ∗motor, float Ts)

  Perform a parameter check and correct possible errors.

Variables

- MotorParameters motor_left

  Left motor parameters.
- MotorParameters motor_right

  Right motor parameters.

4.15.1 Detailed Description

Header file for motor parameters.

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4.15.2 Function Documentation

4.15.2.1 check_motor_parameters()

```
int check_motor_parameters (
            MotorParameters * motor,
            float Ts )
```

Perform a parameter check and correct possible errors.

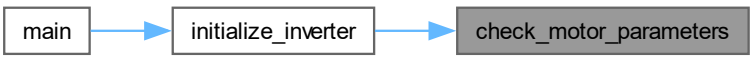
Parameters

in	*motor*	Pointer to the MotorParameters struct.

Return values

OK	0 if an error occurred, 1 if successful.

Here is the caller graph for this function:



4.15.2.2 precalculate_motor_constants()

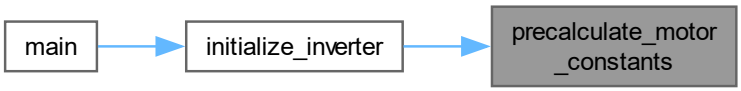
```
void precalculate_motor_constants (
            MotorParameters * motor )
```

Precomputes the constants for a motor and updates the MotorParameters structure.

Parameters

motor	[in, out] Pointer to the motor parameters structure

Here is the caller graph for this function:



4.15.3 Variable Documentation

4.15.3.1 motor_left

```
MotorParameters motor_left  [extern]
```

Left motor parameters.

4.15.3.2 motor_right

```
MotorParameters motor_right  [extern]
```

Right motor parameters.

4.16 MOTOR.h

Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00017 /* USER CODE END Header */
00018
00019 #ifndef MOTOR_H
00020 #define MOTOR_H
00021
00022 #include <stdint.h>
00023
00027 typedef struct {
00028     float threePpLambda;
00029     float threePpLdMinusLq;
00030     float invThreePpLambda;
00031     float isc;
00032     float torqueBase;
00033     float invTorqueBase;
00034     float xi;
00035     float xiSquared;
00036     float oneMinusXi;
00037     float twoMinusXi;
00038     float fourTimesOneMinusXi;
00039     float eightTimesOneMinusXiSquared;
00040     float twoMinusXiSquared;
00041     float twoTimesOneMinusXiOnePlusXiSquared;
00042     float twoTimesOneMinusXiXiSquared;
00043     float fourTimesOneMinusXiOnePlusXiSquared;
```

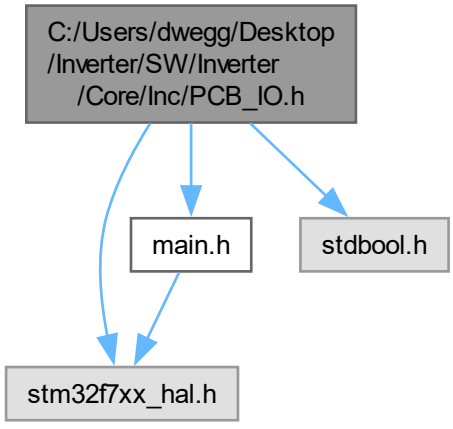
```
00044     float fourTimesOneMinusXiXiSquared;
00045     float lambdaDivLqMinusLd;
00046     float betaMinusIsc;
00047 } MotorConstants;
00048
00052 typedef struct {
00053     float Ld;
00054     float Lq;
00055     float Rs;
00056     float lambda;
00057     uint8_t pp;
00058     float J;
00059     float b;
00060     float torqueMax;
00061     float dTorqueMax;
00062     float speedMax_RPM;
00063     float iMax;
00064     float vDCMax;
00065     MotorConstants constants;
00066 } MotorParameters;
00067
00068 extern MotorParameters motor_left;
00069 extern MotorParameters motor_right;
00070
00076 void precalculate_motor_constants(MotorParameters* motor);
00077
00083 int check_motor_parameters(MotorParameters *motor, float Ts);
00084 #endif /* MOTOR_H */
```

4.17 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PCB_IO.h File Reference

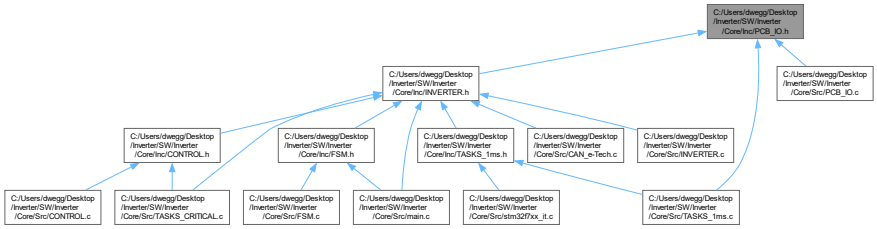
Header file for handling GPIOs.

```
#include "stm32f7xx_hal.h"
#include "main.h"
#include <stdbool.h>
```

Include dependency graph for PCB_IO.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct LED

  LED structure.

Macros

- #define SC_DET_STATE() (HAL_GPIO_ReadPin(SC_det_GPIO_Port, SC_det_Pin))
- #define DIR_STATE() (HAL_GPIO_ReadPin(DIR_GPIO_Port, DIR_Pin))
- #define WRN_STATE(port, pin) (HAL_GPIO_ReadPin(port, pin))
- #define ENABLE(port, pin) do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_SET); } while(0)
- #define DISABLE(port, pin) do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_RESET); } while(0)

Enumerations

- enum LEDMode { LED_MODE_BLINK_FAST , LED_MODE_BLINK_SLOW , LED_MODE_ON , LED_MODE_OFF }

Functions

- void handle_LED (LED *led, uint32_t ms_counter)

  LED handler function.
- void handle_direction (volatile int8_t *dir_left, volatile int8_t *dir_right)

  Handles the direction of the motors.
- void enable_inverters (volatile bool enableSW_left, volatile bool enableSW_right, volatile bool *enable_left, volatile bool *enable_right)

  Handles the direction of the motors and enables/disables the inverters.

Variables

- LED led_left
- LED led_right
- LED ledError

4.17.1 Detailed Description

Header file for handling GPIOs.

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4.17.2 Macro Definition Documentation

4.17.2.1 DIR_STATE

```
#define DIR_STATE( ) (HAL_GPIO_ReadPin(DIR_GPIO_Port, DIR_Pin))
```

4.17.2.2 DISABLE

```
#define DISABLE(
              port,
              pin ) do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_RESET); } while(0)
```

4.17.2.3 ENABLE

```
#define ENABLE(
              port,
              pin ) do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_SET); } while(0)
```

4.17.2.4 SC_DET_STATE

```
#define SC_DET_STATE( ) (HAL_GPIO_ReadPin(SC_det_GPIO_Port, SC_det_Pin))
```

4.17.2.5 WRN_STATE

```
#define WRN_STATE(
              port,
              pin ) (HAL_GPIO_ReadPin(port, pin))
```

4.17.3 Enumeration Type Documentation

4.17.3.1 LEDMode

```
enum LEDMode
```

Enumerator

LED_MODE_BLINK_FAST	Fast blink mode
LED_MODE_BLINK_SLOW	Slow blink mode
LED_MODE_ON	LED on mode
LED_MODE_OFF	LED off mode

4.17.4 Function Documentation

4.17.4.1 enable_inverters()

```
void enable_inverters (
            volatile bool enableSW_left,
            volatile bool enableSW_right,
            volatile bool * enable_left,
            volatile bool * enable_right )
```

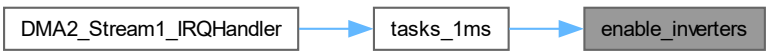
Handles the direction of the motors and enables/disables the inverters.

This function reads the state of the shutdown chain (SC or SDC) and enables/disables the inverters based on that and an external software enable bool.

Parameters

in	*enableSW_left*	The software enable state for the left inverter.
in	*enableSW_right*	The software enable state for the right inverter.
out	*enable_left*	Output parameter for the left inverter's enable state.
out	*enable_right*	Output parameter for the right inverter's enable state.

Here is the caller graph for this function:



4.17.4.2 handle_direction()

```
void handle_direction (
            volatile int8_t * dir_left,
            volatile int8_t * dir_right )
```

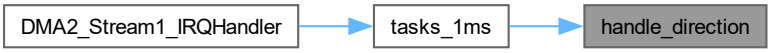
Handles the direction of the motors.

This function reads the state of the DIR switch and updates the directions of both the left and right motors. If one motor is set to rotate clockwise (CW), the other one is set to rotate counterclockwise (CCW), and vice versa.

Parameters

dir_left	Pointer to the direction parameter in the left inverter structure.
dir_right	Pointer to the direction parameter in the right inverter structure.

Here is the caller graph for this function:



4.17.4.3 handle_LED()

```
void handle_LED (
            LED * led,
            uint32_t ms_counter )
```

LED handler function.

This function handles the LED blinking modes based on the LED mode and current millisecond counter.

Parameters

led	Pointer to the LED structure.
ms_counter	Millisecond counter for timing.

This function handles the LED blinking modes based on the LED mode and current millisecond counter.

Parameters

led	Pointer to the LED structure.
ms_counter	Current millisecond counter.

Here is the caller graph for this function:

4.17.5 Variable Documentation

4.17.5.1 led_left

```
LED led_left  [extern]
```

4.17.5.2 led_right

```
LED led_right  [extern]
```

4.17.5.3 ledError

```
LED ledError  [extern]
```

4.18 PCB_IO.h

Go to the documentation of this file.

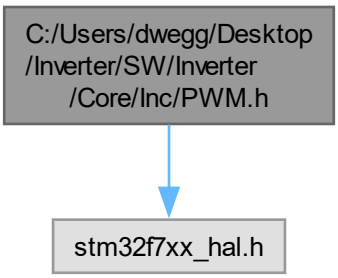
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020
00021 #ifndef PCB_IO_H
00022 #define PCB_IO_H
00023
00024 #include "stm32f7xx_hal.h"
00025 #include "main.h" // pin names/ports
00026 #include <stdbool.h>
00027
00028 // Read SC_det and DIR GPIOs
00029 #define SC_DET_STATE()              (HAL_GPIO_ReadPin(SC_det_GPIO_Port, SC_det_Pin))
00030 #define DIR_STATE()                 (HAL_GPIO_ReadPin(DIR_GPIO_Port, DIR_Pin))
00031
00032 // Read WRN GPIOs
00033 #define WRN_STATE(port, pin)        (HAL_GPIO_ReadPin(port, pin))
00034
00035 // Control ENABLE GPIOs
00036 #define ENABLE(port, pin)           do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_SET); } while(0)
00037 #define DISABLE(port, pin)          do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_RESET); } while(0)
00038
00039 // Define LED modes
00040 typedef enum {
00041     LED_MODE_BLINK_FAST,
00042     LED_MODE_BLINK_SLOW,
00043     LED_MODE_ON,
00044     LED_MODE_OFF
00045 } LEDMode;
00046
00050 typedef struct {
00051     GPIO_TypeDef *port;
00052     uint16_t pin;
00053     LEDMode mode;
00054 } LED;
00055
00056 // Declare LED variables as extern
00057 extern LED led_left;
00058 extern LED led_right;
00059 extern LED ledError;
00060
00061 // Function prototypes
00070 void handle_LED(LED *led, uint32_t ms_counter);
00071
00083 void handle_direction(volatile int8_t *dir_left, volatile int8_t *dir_right);
00084
00096 void enable_inverters(volatile bool enableSW_left, volatile bool enableSW_right, volatile bool
      *enable_left, volatile bool *enable_right);
00097
00098
00099 #endif /* PCB_IO_H */
```

4.19 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PWM.h File Reference

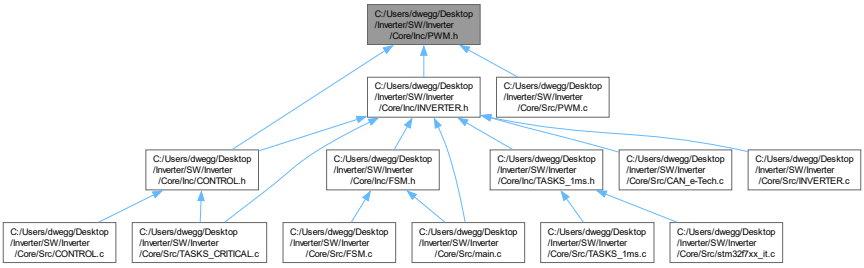
Header file for controlling PWM output.

```
#include "stm32f7xx_hal.h"
```

Include dependency graph for PWM.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct Duties

  Structure to hold PWM configuration parameters.

Functions

- void enable_PWM (TIM_HandleTypeDef ∗htim)

  Enable PWM output.
- void disable_PWM (TIM_HandleTypeDef ∗htim)

  Disable PWM output.
- void update_PWM (TIM_HandleTypeDef ∗htim, Duties duties)

  Set PWM duty cycles.

4.19.1 Detailed Description

Header file for controlling PWM output.

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4.19.2 Function Documentation

4.19.2.1 disable_PWM()

```
void disable_PWM (
            TIM_HandleTypeDef * htim )
```

Disable PWM output.

This function disables PWM output for the specified timer.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.

4.19.2.2 enable_PWM()

```
void enable_PWM (
            TIM_HandleTypeDef * htim )
```

Enable PWM output.

This function enables PWM output for the specified timer.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.

4.19.2.3 update_PWM()

```
void update_PWM (
            TIM_HandleTypeDef * htim,
            Duties duties )
```

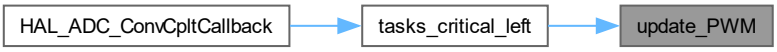
Set PWM duty cycles.

This function sets the duty cycles for the PWM channels.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.
duties	Duties structure containing duty cycle values.

Here is the caller graph for this function:



4.20 PWM.h

Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef PWM_H
00021 #define PWM_H
00022
00023 #include "stm32f7xx_hal.h"
00024
00028 typedef struct {
00029     float Da;
00030     float Db;
00031     float Dc;
00032 } Duties;
00033
00041 void enable_PWM(TIM_HandleTypeDef *htim);
00042
00050 void disable_PWM(TIM_HandleTypeDef *htim);
00051
00052
00061 void update_PWM(TIM_HandleTypeDef *htim, Duties duties);
00062
00063 #endif /* PWM_H */
```

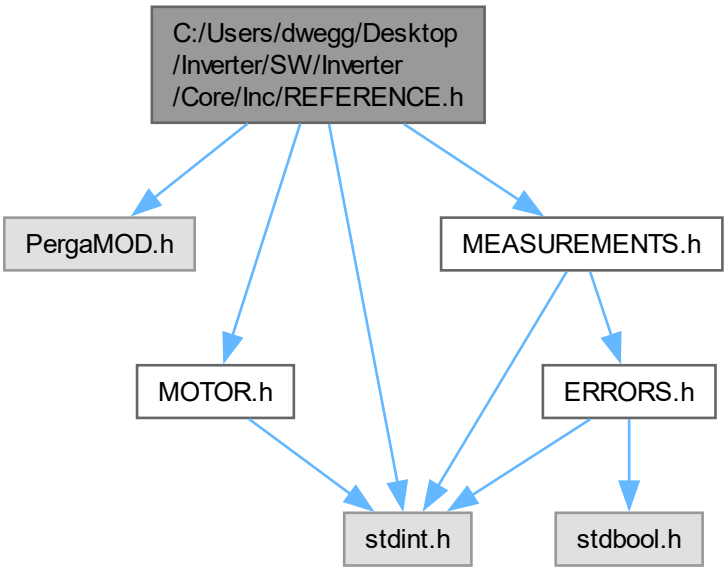
4.21 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/↩ REFERENCE.h File Reference

Header file for torque reference handling.

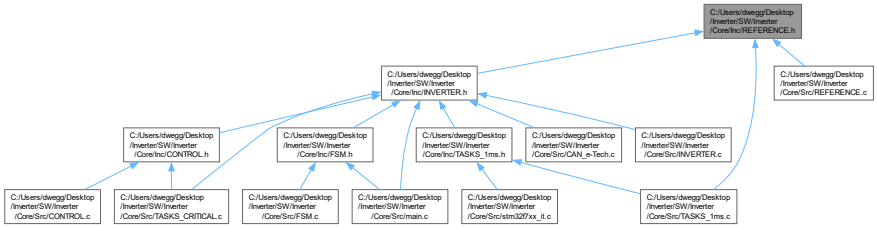
```
#include "PergaMOD.h"
#include "MOTOR.h"
#include "MEASUREMENTS.h"
```

```
#include <stdint.h>
```

Include dependency graph for REFERENCE.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct Reference

  Structure for reference values.

Macros

- #define TEMP_MOTOR_DERATING (OVERTEMPERATURE_MOTOR_TH - 20.0F)
- #define TEMP_INVERTER_DERATING (OVERTEMPERATURE_INVERTER_TH - 20.0F)
- #define TEMP_MOTOR_MAX (OVERTEMPERATURE_MOTOR_TH + 10.0F)
- #define TEMP_INVERTER_MAX (OVERTEMPERATURE_INVERTER_TH + 10.0F)

Functions

- float handle_torqueRef (float torqueRefIn, int8_t direction, float torqueMax, float speedMaxRPM, float speedMeas, volatile pi_struct *loopSpeed)

  Handles torque control based on the reference torque, direction, maximum torque, maximum speed, measured speed, maximum torque rate of change, speed control loop parameters, and sampling time.
- float set_torque_direction (float torqueRef, int8_t direction)

  Set torque direction based on inverter direction.
- float saturate_symmetric (float ref, float max)

  Symmetrically saturate a reference value.
- float limit_torque_to_prevent_overspeed (float speedMax, float speedMeas, float torqueRefIn, volatile pi_struct *loopSpeed)

  Speed loop acts as a torque saturation, reducing torque in order to limit the maximum speed.
- float calculate_derated_current (float temperature, float tempStart, float tempMax, float iMax)

  Calculate derated current based on temperature thresholds. It implements a simple linear derating from tempStart to tempMax.
- float derate_current_reference (float tempMotor, float tempInverter, float iMax)

  Derate the current reference based on both motor and inverter temperatures.

Variables

- float torqueRefIn_left
- float torqueRefIn_right

4.21.1 Detailed Description

Header file for torque reference handling.

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4.21.2 Macro Definition Documentation

4.21.2.1 TEMP_INVERTER_DERATING

```
#define TEMP_INVERTER_DERATING (OVERTEMPERATURE_INVERTER_TH - 20.0F)
```

Temperature at which linear derating starts for the inverter (20 degC before the fault)

4.21.2.2 TEMP_INVERTER_MAX

```
#define TEMP_INVERTER_MAX (OVERTEMPERATURE_INVERTER_TH + 10.0F)
```

Temperature at which derating is 0 for the inverter (10 degC more than the fault)

4.21.2.3 TEMP_MOTOR_DERATING

```
#define TEMP_MOTOR_DERATING (OVERTEMPERATURE_MOTOR_TH - 20.0F)
```

Temperature at which linear derating starts for the motor (20 degC before the fault)

4.21.2.4 TEMP_MOTOR_MAX

```
#define TEMP_MOTOR_MAX (OVERTEMPERATURE_MOTOR_TH + 10.0F)
```

Temperature at which derating is 0 for the motor (10 degC more than the fault)

4.21.3 Function Documentation

4.21.3.1 calculate_derated_current()

```
float calculate_derated_current (
            float temperature,
            float tempStart,
            float tempMax,
            float iMax )
```

Calculate derated current based on temperature thresholds. It implements a simple linear derating from tempStart to tempMax.

Parameters

in	*temperature*	The current temperature.
in	*tempStart*	The temperature at which derating starts.
in	*tempMax*	The temperature at which the current is fully derated to 0.
in	*iMax*	The maximum current.

Returns

The derated current.

Here is the caller graph for this function:

4.21.3.2 derate_current_reference()

```
float derate_current_reference (
            float tempMotor,
```

```
            float tempInverter,
            float iMax )
```

Derate the current reference based on both motor and inverter temperatures.

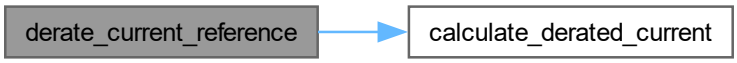
Parameters

in	*tempMotor*	The motor temperature.
in	*tempInverter*	The inverter temperature.
in	*iMax*	The maximum current.

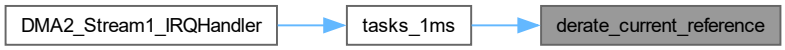
Returns

The derated current reference.

Here is the call graph for this function:



Here is the caller graph for this function:



4.21.3.3 handle_torqueRef()

```
float handle_torqueRef (
            float torqueRefIn,
            int8_t direction,
            float torqueMax,
            float speedMaxRPM,
            float speedMeas,
            volatile pi_struct * loopSpeed )
```

Handles torque control based on the reference torque, direction, maximum torque, maximum speed, measured speed, maximum torque rate of change, speed control loop parameters, and sampling time.

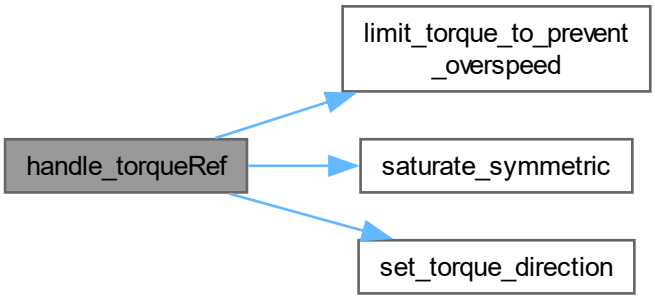
Parameters

torqueRefIn	Input reference torque.
direction	Direction of torque (1 for positive torque, -1 for negative torque).
torqueMax	Maximum allowable torque.
speedMaxRPM	Maximum allowable speed in RPM.
speedMeas	Measured speed.
loopSpeed	Speed control loop parameters.

Returns

The output torque after handling direction, saturation, and rate limiting.

Here is the call graph for this function:



Here is the caller graph for this function:

4.21.3.4 limit_torque_to_prevent_overspeed()

```
float limit_torque_to_prevent_overspeed (
            float speedMaxRPM,
            float speedMeas,
            float torqueRefIn,
            volatile pi_struct * loopSpeed )
```

Speed loop acts as a torque saturation, reducing torque in order to limit the maximum speed.

Parameters

in	*speedMax*	The maximum speed value in RPM.
in	*speedMeas*	The measured speed value in RPM.
in	*torque↩ RefIn*	The torque reference value before this saturation.
in	*loopSpeed*	Pointer to the speed PI controller structure.

Returns

torqueRef_out The limited torque reference value after this saturation.

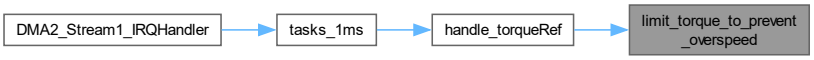
Parameters

in	*speedMaxRPM*	The maximum speed value in RPM.
in	*speedMeas*	The measured speed value in RPM.
in	*torqueRefIn*	The torque reference value before this saturation.
in	*loopSpeed*	Pointer to the speed PI controller structure.

Returns

torqueRefOut The limited torque reference value after this saturation.

Here is the caller graph for this function:



4.21.3.5 saturate_symmetric()

```
float saturate_symmetric (
            float ref,
            float max )
```

Symmetrically saturate a reference value.

This function symmetrically saturates a reference value based on the maximum allowed value. If the reference value exceeds the maximum allowed value, it is saturated to the maximum value. If the reference value is less than the negative of the maximum allowed value, it is saturated to the negative of the maximum value.

Parameters

in	*ref*	The reference value to saturate.
in	*max*	The maximum allowed value for saturation.

Returns

The saturated reference value.

Here is the caller graph for this function:

4.21.3.6 set_torque_direction()

```
float set_torque_direction (
            float torqueRefIn,
            int8_t direction )
```

Set torque direction based on inverter direction.

This function adjusts the torque reference based on the direction of the inverter. If the inverter is set to rotate counterclockwise (CCW), positive torque represents braking. If the inverter is set to rotate clockwise (CW), positive torque represents traction.

Parameters

in	*torqueRef*	The torque reference value to adjust.
in	*direction*	Pointer to the direction of the inverter (1 for CW, -1 for CCW).

Returns

The adjusted torque reference value.

This function adjusts the torque reference based on the desired direction. If the motor is set to rotate counterclockwise (CCW), positive torque represents traction, negative is braking. If the motor is set to rotate clockwise (CW), negative torque represents traction, positive is braking.

Parameters

in	*torque↩ RefIn*	The torque reference value to adjust.
in	*direction*	Pointer to the direction of the inverter (1 for CW, -1 for CCW).

Returns

torqueRefOut The adjusted torque reference value.

Here is the caller graph for this function:

4.21.4 Variable Documentation

4.21.4.1 torqueRefIn_left

```
float torqueRefIn_left  [extern]
```

4.21.4.2 torqueRefIn_right

```
float torqueRefIn_right  [extern]
```

4.22 REFERENCE.h

Go to the documentation of this file.

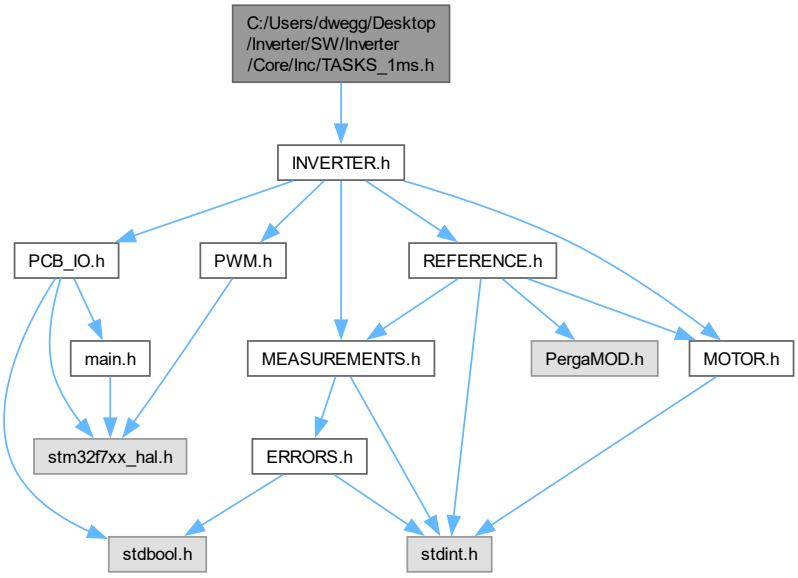
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef REFERENCE_H
00021 #define REFERENCE_H
00022
00023 #include "PergaMOD.h" // ramp, pi struct
00024 #include "MOTOR.h" // motor struct
00025 #include "MEASUREMENTS.h" // overtemperature defines
00026 #include <stdint.h>
00027
00028 // Define temperature derating tresholds
00029 #define TEMP_MOTOR_DERATING (OVERTEMPERATURE_MOTOR_TH - 20.0F)
00030 #define TEMP_INVERTER_DERATING (OVERTEMPERATURE_INVERTER_TH - 20.0F)
00032 #define TEMP_MOTOR_MAX (OVERTEMPERATURE_MOTOR_TH + 10.0F)
00033 #define TEMP_INVERTER_MAX (OVERTEMPERATURE_INVERTER_TH + 10.0F)
00036 // These variables should be updated via CAN
00037 extern float torqueRefIn_left;
00038 extern float torqueRefIn_right;
00039
00043 typedef struct {
00044     float idRef;
00045     float iqRef;
00046     float isMaxRef;
00047     float torqueRef;
00048 } Reference;
00049
00050
00064 float handle_torqueRef(float torqueRefIn, int8_t direction, float torqueMax, float speedMaxRPM, float
      speedMeas, volatile pi_struct *loopSpeed);
00065
00066
00078 float set_torque_direction(float torqueRef, int8_t direction);
00079
00091 float saturate_symmetric(float ref, float max);
00092
00101 float limit_torque_to_prevent_overspeed(float speedMax, float speedMeas, float torqueRefIn, volatile
      pi_struct *loopSpeed);
00102
00103
00115 float calculate_derated_current(float temperature, float tempStart, float tempMax, float iMax);
00116
00126 float derate_current_reference(float tempMotor, float tempInverter, float iMax);
00127 #endif /* REFERENCE_H */
```

4.23 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_↩ 1ms.h File Reference

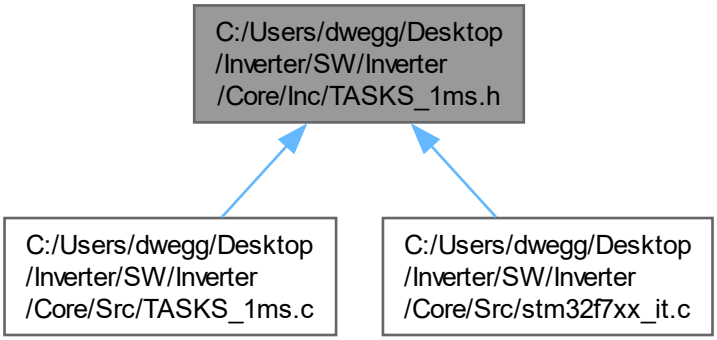
Header file for functions related to tasks executed every 1ms.

```
#include "INVERTER.h"
```

Include dependency graph for TASKS_1ms.h:



This graph shows which files directly or indirectly include this file:



Functions

- void tasks_1ms (void)

Function to be executed every 1ms.

- void read_temperatures (void)

  Function to read temperatures and handle overtemperature faults.

- void handle_overtemperature_faults (volatile InverterStruct *inv)

  Function to handle overtemperature faults.

4.23.1 Detailed Description

Header file for functions related to tasks executed every 1ms.

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4.23.2 Function Documentation

4.23.2.1 handle_overtemperature_faults()

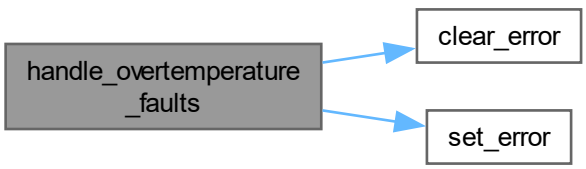
```
void handle_overtemperature_faults (
            volatile InverterStruct * inv )
```

Function to handle overtemperature faults.

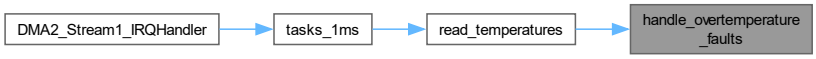
Parameters

in,out	*inv*	Pointer to the InverterStruct structure.

Here is the call graph for this function:



Here is the caller graph for this function:

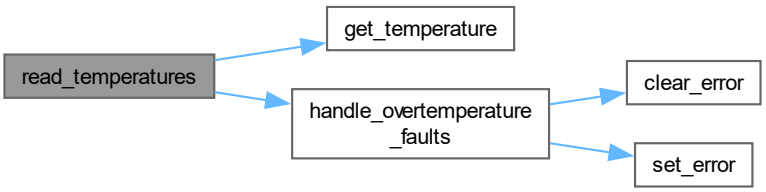


4.23.2.2 read_temperatures()

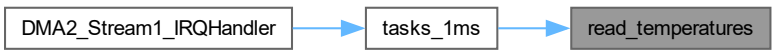
```
void read_temperatures (
            void  )
```

Function to read temperatures and handle overtemperature faults.

Here is the call graph for this function:



Here is the caller graph for this function:



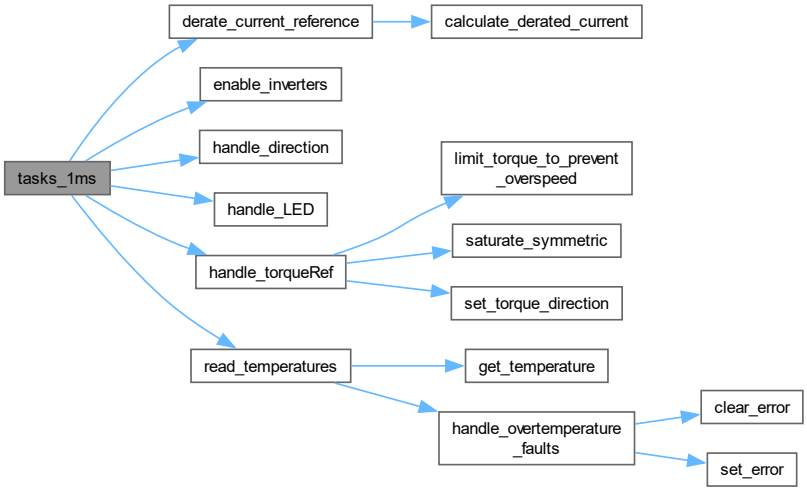
4.23.2.3 tasks_1ms()

```
void tasks_1ms (
            void  )
```

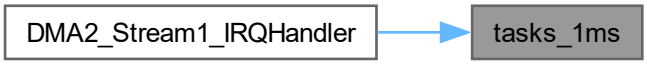
Function to be executed every 1ms.

This function is called by the TIM6 IRQ handler every millisecond.

This function is called by the TIM6 IRQ handler every millisecond. It increments the millisecond counter and executes all the low priority tasks. Here is the call graph for this function:



Here is the caller graph for this function:



4.24 TASKS_1ms.h

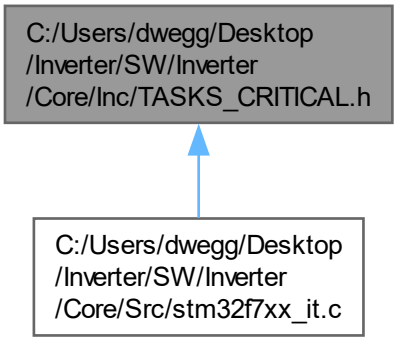
Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020
00021 #ifndef TASKS_1MS_H
00022 #define TASKS_1MS_H
00023
00024 #include "INVERTER.h" // needs invLeft/invRight
00025
00026
00032 void tasks_1ms(void);
00033
00037 void read_temperatures(void);
00038
00044 void handle_overtemperature_faults(volatile InverterStruct *inv);
00045
00046 #endif /* TASKS_1MS_H */
```

4.25 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_↩ CRITICAL.h File Reference

Header file for functions related to tasks executed in each PWM timer interruption.

This graph shows which files directly or indirectly include this file:



Functions

- void tasks_critical_left ()

  Function to be executed every TS.
- void tasks_critical_right ()

  Function to be executed every TS.

4.25.1 Detailed Description

Header file for functions related to tasks executed in each PWM timer interruption.

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4.25.2 Function Documentation

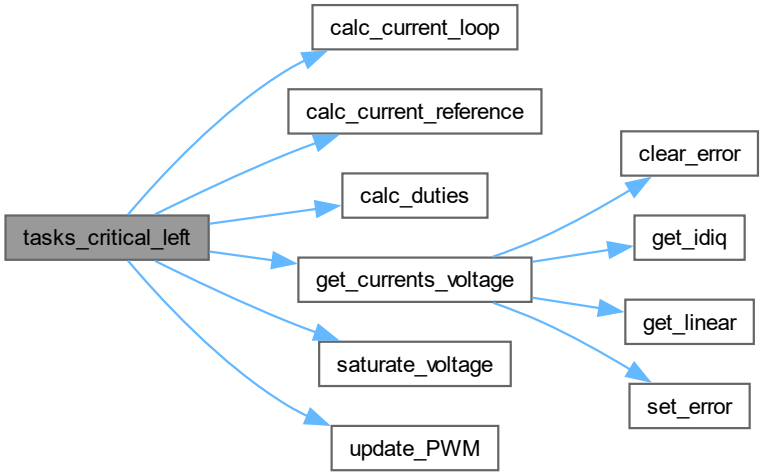
4.25.2.1 tasks_critical_left()

```
void tasks_critical_left (
            void  )
```

Function to be executed every TS.

This function is called by the TIM1 trigger out handler every TS.

This function is called by the TIM1 trigger handler every TS. Here is the call graph for this function:



Here is the caller graph for this function:

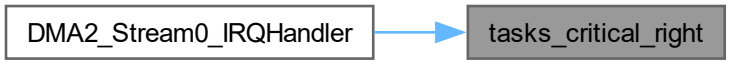
4.25.2.2 tasks_critical_right()

```
void tasks_critical_right (
            void  )
```

Function to be executed every TS.

This function is called by the TIM8 trigger out handler every TS.

This function is called by the TIM8 trigger handler every TS. Here is the caller graph for this function:



4.26 TASKS_CRITICAL.h

Go to the documentation of this file.

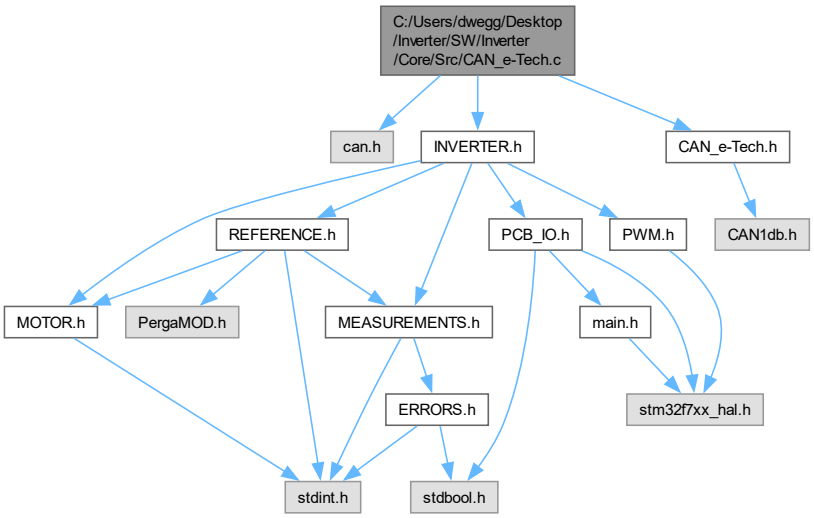
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00025 void tasks_critical_left();
00026
00032 void tasks_critical_right();
```

4.27 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CAN_e-Tech.c File Reference

This file contains functions to handle CAN communication with the car.

```
#include "can.h"
#include "INVERTER.h"
#include "CAN_e-Tech.h"
```

Include dependency graph for CAN_e-Tech.c:



Functions

- void handle_CAN (CAN_HandleTypeDef *hcan)

  Handle CAN messages.
- void send_CAN_message (CAN_HandleTypeDef *hcan, void *dbc_msg, const float *data)

  Send a CAN message using CAN1db.h information.

Variables

- uint8_t keepAlive

4.27.1 Detailed Description

This file contains functions to handle CAN communication with the car.

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4.27.2 Function Documentation

4.27.2.1 handle_CAN()

```
void handle_CAN (
            CAN_HandleTypeDef * hcan )
```

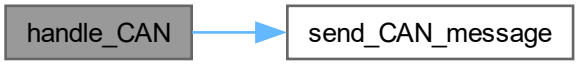
Handle CAN messages.

This function implements the logic to handle received CAN messages.

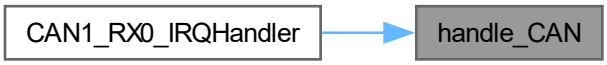
Parameters

hcan	Pointer to the CAN handle structure.

Here is the call graph for this function:



Here is the caller graph for this function:



4.27.2.2 send_CAN_message()

```
void send_CAN_message (
            CAN_HandleTypeDef * hcan,
            void * dbc_msg,
            const float * data )
```

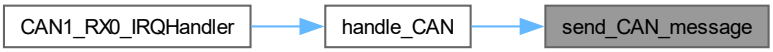
Send a CAN message using CAN1db.h information.

This function prepares and sends a CAN message using information from CAN1db.h.

Parameters

hcan	Pointer to the CAN handle structure.
dbc_msg	Pointer to the structure containing CAN message information from CAN1db.h.
data	Pointer to the array of float data to be sent.

Here is the caller graph for this function:



4.27.3 Variable Documentation

4.27.3.1 keepAlive

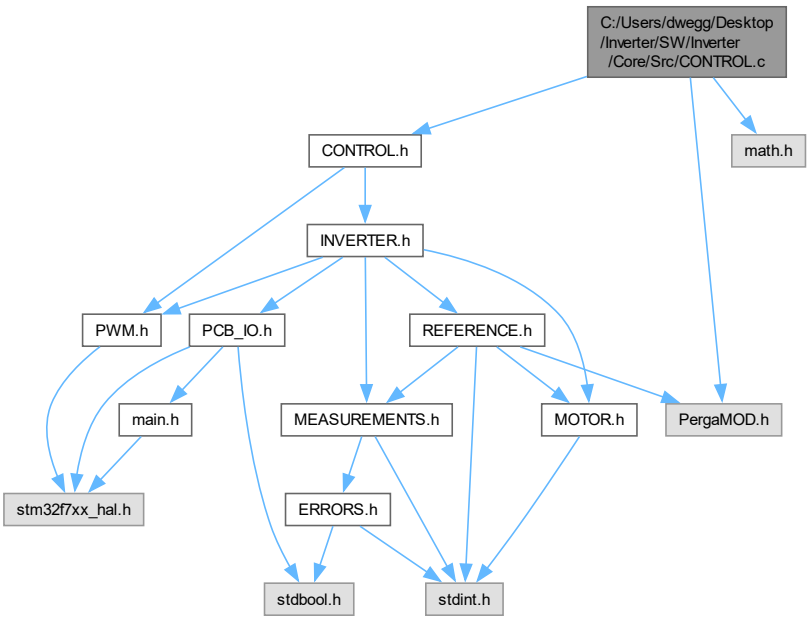
```
uint8_t keepAlive
```

4.28 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CONTROL.c File Reference

This file provides code for the control loop.

```
#include "CONTROL.h"
#include <math.h>
#include <PergaMOD.h>
```

Include dependency graph for CONTROL.c:



Functions

- void calc_current_reference (MotorParameters *motor, volatile Reference *reference)

  Calculates the current references using a FOC algorithm. It computes the current vector for the MTPA trajectory and limits the current reference to isMaxRef (calculated by derating, starting from the motor's maximum current). The MTPV trajectory is not implemented to save some computation time due to the nature of the motors expected. In order to implement field weakening, an external voltage loop modifying gammaRef is needed and should be called inside here. When implementing field weakening, special attention must be put to the torque reference being near 0 or differing from the speed sign (regeneration). A minimum id current must be set for speeds higher than Vs/lambda. Study thoroughly, simulate first.
- void calc_current_loop (volatile InverterStruct *inv)

  Calculates the id-iq loops.
- void saturate_voltage (volatile InverterStruct *inv)

  Saturates PI output to not surpass DC voltage.
- void calc_duties (float vd, float vq, float vDC, float sinTheta_e, float cosTheta_e, volatile Duties *duties)

  function.

4.28.1 Detailed Description

This file provides code for the control loop.

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4.28.2 Function Documentation

4.28.2.1 calc_current_loop()

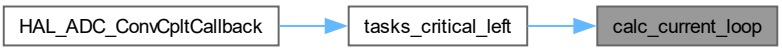
```
void calc_current_loop (
            volatile InverterStruct * inv )
```

Calculates the id-iq loops.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.28.2.2 calc_current_reference()

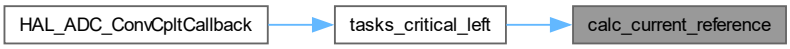
```
void calc_current_reference (
            MotorParameters * motor,
            volatile Reference * reference )
```

Calculates the current references using a FOC algorithm. It computes the current vector for the MTPA trajectory and limits the current reference to isMaxRef (calculated by derating, starting from the motor's maximum current). The MTPV trajectory is not implemented to save some computation time due to the nature of the motors expected. In order to implement field weakening, an external voltage loop modifying gammaRef is needed and should be called inside here. When implementing field weakening, special attention must be put to the torque reference being near 0 or differing from the speed sign (regeneration). A minimum id current must be set for speeds higher than Vs/lambda. Study thoroughly, simulate first.

Parameters

in	*motor*	Pointer to the motor parameters structure.
in,out	*reference*	Pointer to the reference struct.

Here is the caller graph for this function:



4.28.2.3 calc_duties()

```
void calc_duties (
            float vd,
            float vq,
            float vDC,
            float sinTheta_e,
            float cosTheta_e,
            volatile Duties * duties )
```

function.

This function calculates the inverse Park transform and the duty cycles using SVPWM

Parameters

in	*vd*	Voltage in the d-axis.
in	*vq*	Voltage in the q-axis.
in	*vDC*	DC voltage.
in	*sinTheta_e*	Electrical angle sine (-1..1)
in	*cosTheta_e*	Electrical angle cosine (-1..1)
out	*duties*	Pointer to the duties structure.

Here is the caller graph for this function:

4.28.2.4 saturate_voltage()

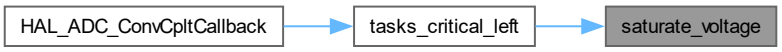
```
void saturate_voltage (
            volatile InverterStruct * inv )
```

Saturates PI output to not surpass DC voltage.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:

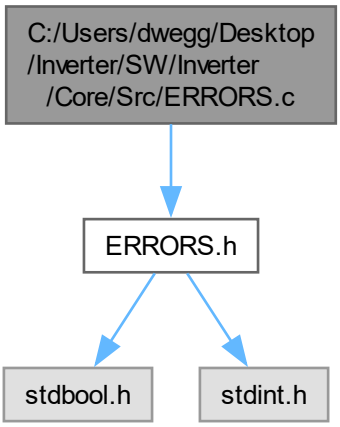


4.29 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/ERRORS.c File Reference

Header file for the necessary components to set, read and clear ERRORS.

```
#include "ERRORS.h"
```

Include dependency graph for ERRORS.c:



Functions

- void set_error (volatile void *data, InverterError error)

  Sets an error in the error field of a data structure.
- void clear_error (volatile void *data, InverterError error)

  Clears an error in the error field of a data structure.
- bool is_error_set (volatile void *data, InverterError error)

  Checks if an error is set in the error field of a data structure.

4.29.1 Detailed Description

Header file for the necessary components to set, read and clear ERRORS.

This file contains the necessary components to set, read and clear ERRORS.

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4.29.2 Function Documentation

4.29.2.1 clear_error()

```
void clear_error (
            volatile void * data,
            InverterError error )
```

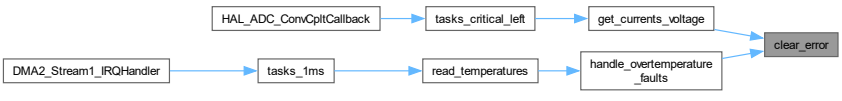
Clears an error in the error field of a data structure.

This function clears the specified error bit in the error field of a data structure.

Parameters

out	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be cleared. This should be one of the values from the InverterError enumeration.

Here is the caller graph for this function:



4.29.2.2 is_error_set()

```
bool is_error_set (
            volatile void * data,
            InverterError error )
```

Checks if an error is set in the error field of a data structure.

This function checks if the specified error bit is set in the error field of a data structure.

Parameters

in	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be checked. This should be one of the values from the InverterError enumeration.

Returns

true if the specified error is set, false otherwise.

4.29.2.3 set_error()

```
void set_error (
            volatile void * data,
            InverterError error )
```

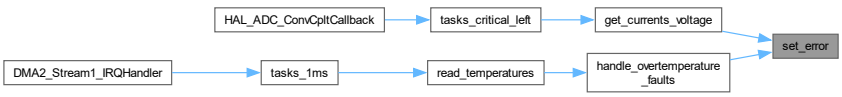
Sets an error in the error field of a data structure.

This function sets the specified error bit in the error field of a data structure.

Parameters

out	*data*	Pointer to the data structure containing the error field.
in	*error*	The error to be set. This should be one of the values from the InverterError enumeration.

Here is the caller graph for this function:

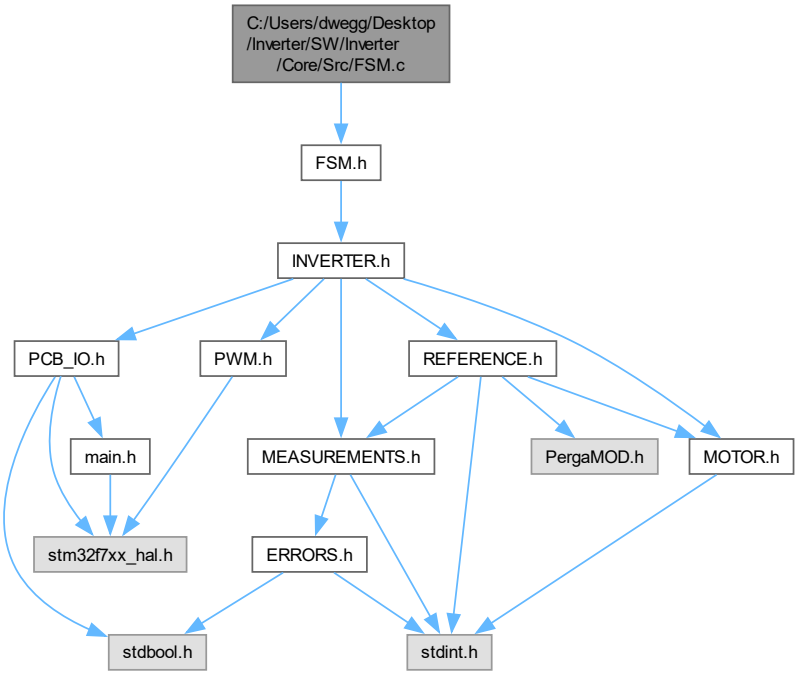


4.30 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/FSM.c File Reference

This file provides code for the inverter Finite State Machine.

```
#include "FSM.h"
```

Include dependency graph for FSM.c:



Functions

- void eval_inv_FSM (volatile InverterStruct *inv)

  Execute the finite state machine for inverter.

4.30.1 Detailed Description

This file provides code for the inverter Finite State Machine.

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0/legalcode

4.30.2 Function Documentation

4.30.2.1 eval_inv_FSM()

```
void eval_inv_FSM (
            volatile InverterStruct * inv )
```

Execute the finite state machine for inverter.

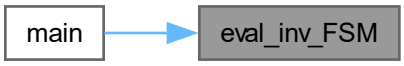
Run the Finite State Machine (FSM) for inverter operation control.

This function executes the finite state machine to control the inverter based on its current state.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:

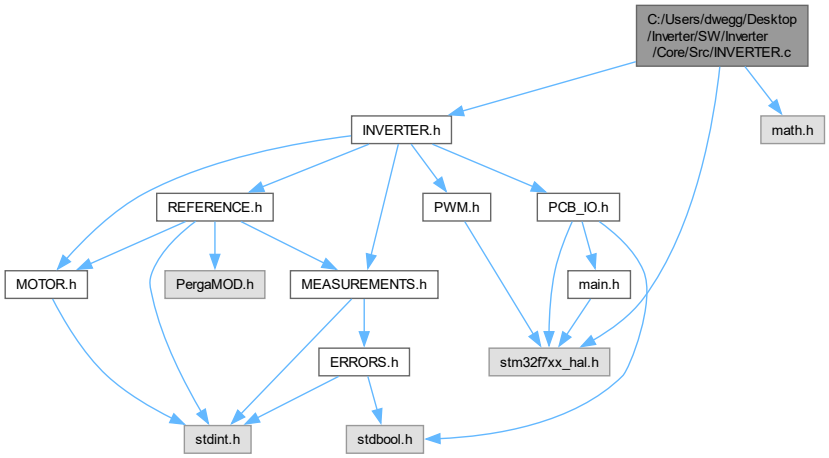


4.31 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/INVERTER.c File Reference

This file provides code for the inverter struct.

```
#include "INVERTER.h"
#include "stm32f7xx_hal.h"
#include <math.h>
```

Include dependency graph for INVERTER.c:



Functions

- void initialize_inverter (volatile InverterStruct ∗inv, LED ∗led, GPIO_TypeDef ∗enable_port, uint16_t enable↩ _pin, TIM_HandleTypeDef ∗htim, ADC_HandleTypeDef ∗hadc, MotorParameters ∗motor, volatile uint16_t ∗rawADC)

  Initialize the inverter.
- void init_control_loops (volatile InverterStruct ∗inv, MotorParameters ∗motor)

  Initializes the PI controllers.
- void enable_control_loops (volatile InverterStruct ∗inv)

  Enables the PI controllers.
- void disable_control_loops (volatile InverterStruct ∗inv)

  Disables the PI controllers.

Variables

- volatile InverterStruct inverter_left = {0}

  Left inverter structure.
- volatile InverterStruct inverter_right = {0}

  Right inverter structure.

4.31.1 Detailed Description

This file provides code for the inverter struct.

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4.31.2 Function Documentation

4.31.2.1 disable_control_loops()

```
void disable_control_loops (
            volatile InverterStruct * inv )
```

Disables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.31.2.2 enable_control_loops()

```
void enable_control_loops (
            volatile InverterStruct * inv )
```

Enables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.31.2.3 init_control_loops()

```
void init_control_loops (
            volatile InverterStruct * inv,
            MotorParameters * motor )
```

Initializes the PI controllers.

Initializes the id-iq current control PI controllers.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:

4.31.2.4 initialize_inverter()

```
void initialize_inverter (
            volatile InverterStruct * inv,
            LED * led,
            GPIO_TypeDef * enable_port,
            uint16_t enable_pin,
            TIM_HandleTypeDef * htim,
            ADC_HandleTypeDef * hadc,
            MotorParameters * motor,
            volatile uint16_t * rawADC )
```

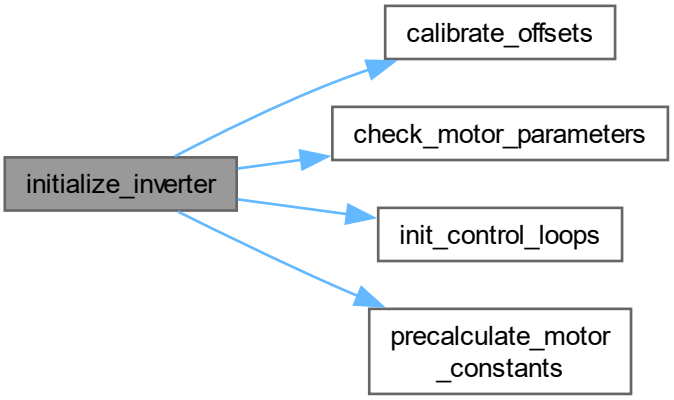
Initialize the inverter.

This function initializes the inverter structure with the specified LED, GPIO port, and pin.

Parameters

out	*inv*	Pointer to the inverter structure.
in	*led*	Pointer to the LED structure.
in	*enable_port*	Pointer to the GPIO port for enabling/disabling the inverter.
in	*enable_pin*	Pin number for enabling/disabling the inverter.
in	*htim*	Timer peripheral for the PWM output.
in	*hadc*	ADC peripheral for the current phase current and DC voltage sensing.
in	*motor*	MotorParameters struct.

Here is the call graph for this function:



Here is the caller graph for this function:

4.31.3 Variable Documentation

4.31.3.1 inverter_left

```
volatile InverterStruct inverter_left = {0}
```

Left inverter structure.

External declaration of the left inverter structure.

4.31.3.2 inverter_right

```
volatile InverterStruct inverter_right = {0}
```

Right inverter structure.

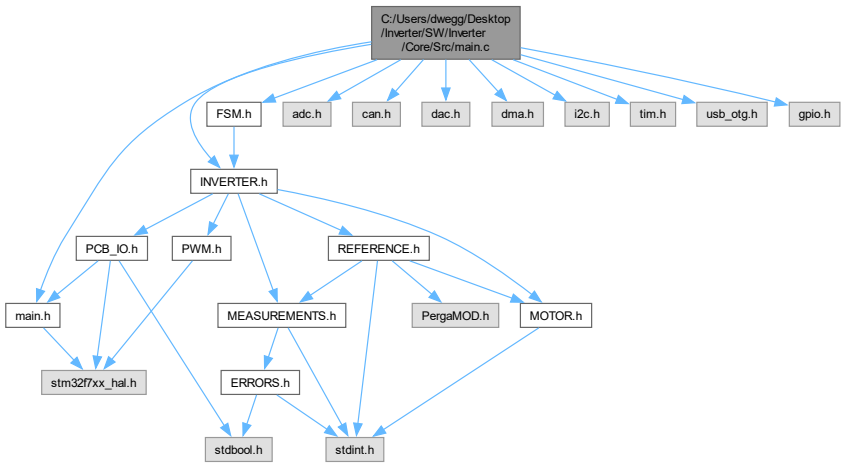
External declaration of the right inverter structure.

4.32 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/main.c File Reference

: Main program body

```
#include "main.h"
#include "adc.h"
#include "can.h"
#include "dac.h"
#include "dma.h"
#include "i2c.h"
#include "tim.h"
#include "usb_otg.h"
#include "gpio.h"
#include "FSM.h"
```

`#include "INVERTER.h"`
Include dependency graph for main.c:



Functions

- void SystemClock_Config (void)

  System Clock Configuration.
- int main (void)

  The application entry point.
- void Error_Handler (void)

  This function is executed in case of error occurrence.

4.32.1 Detailed Description

: Main program body

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4.32.2 Function Documentation

4.32.2.1 Error_Handler()

```
void Error_Handler (
            void  )
```

This function is executed in case of error occurrence.

Return values

None	

Here is the caller graph for this function:

4.32.2.2 main()

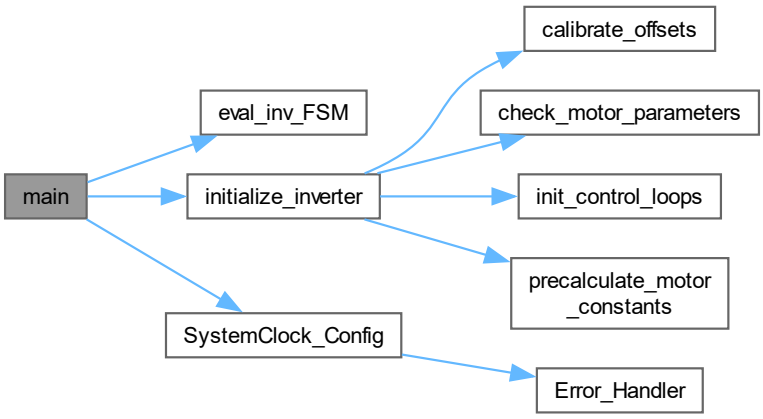
```
int main (
            void  )
```

The application entry point.

Return values

int	

Here is the call graph for this function:



4.32.2.3 SystemClock_Config()

```
void SystemClock_Config (
```

```
            void  )
```

System Clock Configuration.

Return values

None	

Configure the main internal regulator output voltage

Initializes the RCC Oscillators according to the specified parameters in the RCC_OscInitTypeDef structure.

Activate the Over-Drive mode

Initializes the CPU, AHB and APB buses clocksHere is the call graph for this function:

Here is the caller graph for this function:

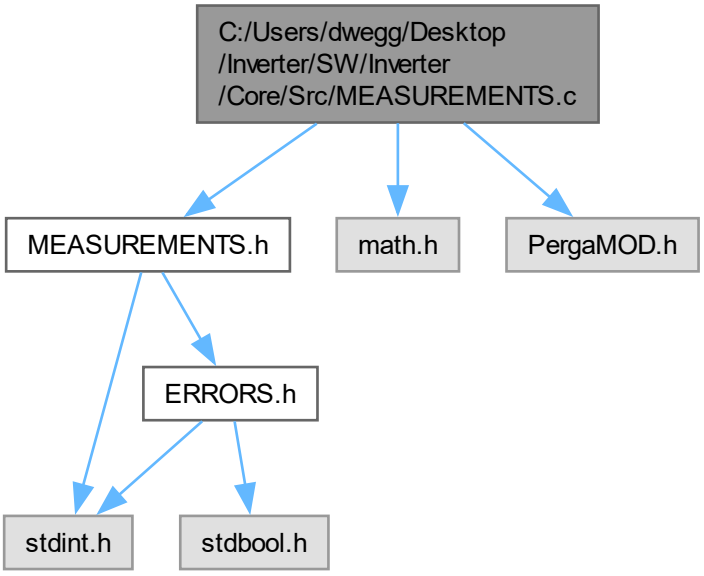
4.33 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/↩ MEASUREMENTS.c File Reference

This file provides functions for handling measurements.

```
#include "MEASUREMENTS.h"
#include <math.h>
```

```
#include <PergaMOD.h>
```

Include dependency graph for MEASUREMENTS.c:



Functions

- void get_currents_voltage (volatile uint16_t rawADC[ ], volatile Analog ∗analog, volatile Feedback ∗feedback, volatile InverterError ∗errors, float sinTheta_e, float cosTheta_e)

  Get electrical ADC measurements.
- float get_linear (uint32_t bits, float slope, float offset)

  Convert ADC reading to physical measurement with linear response.
- void get_idiq (float ia, float ib, float ic, float sinTheta_e, float cosTheta_e, float ∗idMeas, float ∗iqMeas)

  Computes d-q currents from current measurements and electrical angle.
- float get_temperature (uint32_t bits, const float tempLUT[ ])

  Retrieves temperature from a lookup table based on ADC bits.
- void calibrate_offsets (volatile uint16_t rawADC[ ], volatile float currentOffsets[ ], uint32_t numSamples)

  Calibrate the current sensor offsets.

Variables

- const float tempInverterLUT [ ] = {-2.45, -2.44, -2.44, -2.43, -2.42, -2.42, -2.41, -2.41, -2.40, -2.39, -2.39, -2.38, -2.37, -2.37, -2.36, -2.36, -2.35, -2.34, -2.34, -2.33, -2.32, -2.32, -2.31, -2.31, -2.30, -2.29, -2.29, -2.28, -2.27, -2.27, -2.26, -2.26, -2.25, -2.24, -2.24, -2.23, -2.22, -2.22, -2.21, -2.20, -2.20, -2.19, -2.19, -2.18, -2.17, -2.17, -2.16, -2.15, -2.15, -2.14, -2.14, -2.13, -2.12, -2.12, -2.11, -2.10, -2.10, -2.09, -2.08, -2.08, -2.07, -2.07, -2.06, -2.05, -2.05, -2.04, -2.03, -2.03, -2.02, -2.01, -2.01, -2.00, -2.00, -1.99, -1.98, -1.98, -1.97, -1.96, -1.96, -1.95, -1.94, -1.94, -1.93, -1.93, -1.92, -1.91, -1.91, -1.90, -1.89, -1.89, -1.88, -1.87, -1.87, -1.86, -1.86, -1.85, -1.84, -1.84, -1.83, -1.82, -1.82, -1.81, -1.80, -1.80, -1.79, -1.78, -1.78, -1.77, -1.77, -1.76, -1.75, -1.75, -1.74, -1.73, -1.73, -1.72, -1.71, -1.71, -1.70, -1.69, -1.69, -1.68, -1.67, -1.67, -1.66, -1.66, -1.65, -1.64, -1.64, -1.63, -1.62, -1.62, -1.61, -1.60, -1.60, -1.59, -1.58, -1.58, -1.57, -1.56, -1.56, -1.55, -1.54, -1.54, -1.53, -1.53, -1.52,

-1.51, -1.51, -1.50, -1.49, -1.49, -1.48, -1.47, -1.47, -1.46, -1.45, -1.45, -1.44, -1.43, -1.43, -1.42, -1.41, -1.41, -1.40, -1.39, -1.39, -1.38, -1.37, -1.37, -1.36, -1.36, -1.35, -1.34, -1.34, -1.33, -1.32, -1.32, -1.31, -1.30, -1.30, -1.29, -1.28, -1.28, -1.27, -1.26, -1.26, -1.25, -1.24, -1.24, -1.23, -1.22, -1.22, -1.21, -1.20, -1.20, -1.19, -1.18, -1.18, -1.17, -1.16, -1.16, -1.15, -1.14, -1.14, -1.13, -1.12, -1.12, -1.11, -1.10, -1.10, -1.09, -1.08, -1.08, -1.07, -1.06, -1.06, -1.05, -1.04, -1.04, -1.03, -1.02, -1.02, -1.01, -1.00, -1.00, -0.99, -0.98, -0.98, -0.97, -0.96, -0.96, -0.95, -0.94, -0.94, -0.93, -0.92, -0.92, -0.91, -0.90, -0.90, -0.89, -0.88, -0.88, -0.87, -0.86, -0.86, -0.85, -0.84, -0.84, -0.83, -0.82, -0.82, -0.81, -0.80, -0.80, -0.79, -0.78, -0.78, -0.77, -0.76, -0.76, -0.75, -0.74, -0.73, -0.73, -0.72, -0.71, -0.71, -0.70, -0.69, -0.69, -0.68, -0.67, -0.67, -0.66, -0.65, -0.65, -0.64, -0.63, -0.63, -0.62, -0.61, -0.61, -0.60, -0.59, -0.59, -0.58, -0.57, -0.56, -0.56, -0.55, -0.54, -0.54, -0.53, -0.52, -0.52, -0.51, -0.50, -0.50, -0.49, -0.48, -0.48, -0.47, -0.46, -0.46, -0.45, -0.44, -0.43, -0.43, -0.42, -0.41, -0.41, -0.40, -0.39, -0.39, -0.38, -0.37, -0.37, -0.36, -0.35, -0.35, -0.34, -0.33, -0.32, -0.32, -0.31, -0.30, -0.30, -0.29, -0.28, -0.28, -0.27, -0.26, -0.26, -0.25, -0.24, -0.23, -0.23, -0.22, -0.21, -0.21, -0.20, -0.19, -0.19, -0.18, -0.17, -0.17, -0.16, -0.15, -0.14, -0.14, -0.13, -0.12, -0.12, -0.11, -0.10, -0.10, -0.09, -0.08, -0.07, -0.07, -0.06, -0.05, -0.05, -0.04, -0.03, -0.03, -0.02, -0.01, -0.00, 0.00, 0.01, 0.02, 0.02, 0.03, 0.04, 0.04, 0.05, 0.06, 0.07, 0.07, 0.08, 0.09, 0.09, 0.10, 0.11, 0.12, 0.12, 0.13, 0.14, 0.14, 0.15, 0.16, 0.16, 0.17, 0.18, 0.19, 0.19, 0.20, 0.21, 0.21, 0.22, 0.23, 0.24, 0.24, 0.25, 0.26, 0.26, 0.27, 0.28, 0.29, 0.29, 0.30, 0.31, 0.31, 0.32, 0.33, 0.34, 0.34, 0.35, 0.36, 0.36, 0.37, 0.38, 0.39, 0.39, 0.40, 0.41, 0.41, 0.42, 0.43, 0.44, 0.44, 0.45, 0.46, 0.46, 0.47, 0.48, 0.49, 0.49, 0.50, 0.51, 0.51, 0.52, 0.53, 0.54, 0.54, 0.55, 0.56, 0.56, 0.57, 0.58, 0.59, 0.59, 0.60, 0.61, 0.61, 0.62, 0.63, 0.64, 0.64, 0.65, 0.66, 0.67, 0.67, 0.68, 0.69, 0.69, 0.70, 0.71, 0.72, 0.72, 0.73, 0.74, 0.75, 0.75, 0.76, 0.77, 0.77, 0.78, 0.79, 0.80, 0.80, 0.81, 0.82, 0.83, 0.83, 0.84, 0.85, 0.85, 0.86, 0.87, 0.88, 0.88, 0.89, 0.90, 0.91, 0.91, 0.92, 0.93, 0.94, 0.94, 0.95, 0.96, 0.96, 0.97, 0.98, 0.99, 0.99, 1.00, 1.01, 1.02, 1.02, 1.03, 1.04, 1.05, 1.05, 1.06, 1.07, 1.08, 1.08, 1.09, 1.10, 1.10, 1.11, 1.12, 1.13, 1.13, 1.14, 1.15, 1.16, 1.16, 1.17, 1.18, 1.19, 1.19, 1.20, 1.21, 1.22, 1.22, 1.23, 1.24, 1.25, 1.25, 1.26, 1.27, 1.28, 1.28, 1.29, 1.30, 1.31, 1.31, 1.32, 1.33, 1.34, 1.34, 1.35, 1.36, 1.37, 1.37, 1.38, 1.39, 1.40, 1.40, 1.41, 1.42, 1.43, 1.43, 1.44, 1.45, 1.46, 1.46, 1.47, 1.48, 1.49, 1.49, 1.50, 1.51, 1.52, 1.52, 1.53, 1.54, 1.55, 1.55, 1.56, 1.57, 1.58, 1.58, 1.59, 1.60, 1.61, 1.61, 1.62, 1.63, 1.64, 1.64, 1.65, 1.66, 1.67, 1.67, 1.68, 1.69, 1.70, 1.71, 1.71, 1.72, 1.73, 1.74, 1.74, 1.75, 1.76, 1.77, 1.77, 1.78, 1.79, 1.80, 1.80, 1.81, 1.82, 1.83, 1.84, 1.84, 1.85, 1.86, 1.87, 1.87, 1.88, 1.89, 1.90, 1.90, 1.91, 1.92, 1.93, 1.93, 1.94, 1.95, 1.96, 1.97, 1.97, 1.98, 1.99, 2.00, 2.00, 2.01, 2.02, 2.03, 2.04, 2.04, 2.05, 2.06, 2.07, 2.07, 2.08, 2.09, 2.10, 2.10, 2.11, 2.12, 2.13, 2.14, 2.14, 2.15, 2.16, 2.17, 2.17, 2.18, 2.19, 2.20, 2.21, 2.21, 2.22, 2.23, 2.24, 2.25, 2.25, 2.26, 2.27, 2.28, 2.28, 2.29, 2.30, 2.31, 2.32, 2.32, 2.33, 2.34, 2.35, 2.35, 2.36, 2.37, 2.38, 2.39, 2.39, 2.40, 2.41, 2.42, 2.43, 2.43, 2.44, 2.45, 2.46, 2.46, 2.47, 2.48, 2.49, 2.50, 2.50, 2.51, 2.52, 2.53, 2.54, 2.54, 2.55, 2.56, 2.57, 2.58, 2.58, 2.59, 2.60, 2.61, 2.62, 2.62, 2.63, 2.64, 2.65, 2.66, 2.66, 2.67, 2.68, 2.69, 2.70, 2.70, 2.71, 2.72, 2.73, 2.74, 2.74, 2.75, 2.76, 2.77, 2.78, 2.78, 2.79, 2.80, 2.81, 2.82, 2.82, 2.83, 2.84, 2.85, 2.86, 2.86, 2.87, 2.88, 2.89, 2.90, 2.90, 2.91, 2.92, 2.93, 2.94, 2.94, 2.95, 2.96, 2.97, 2.98, 2.98, 2.99, 3.00, 3.01, 3.02, 3.02, 3.03, 3.04, 3.05, 3.06, 3.07, 3.07, 3.08, 3.09, 3.10, 3.11, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.16, 3.17, 3.18, 3.19, 3.20, 3.20, 3.21, 3.22, 3.23, 3.24, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29, 3.29, 3.30, 3.31, 3.32, 3.33, 3.34, 3.34, 3.35, 3.36, 3.37, 3.38, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48, 3.48, 3.49, 3.50, 3.51, 3.52, 3.53, 3.53, 3.54, 3.55, 3.56, 3.57, 3.58, 3.58, 3.59, 3.60, 3.61, 3.62, 3.63, 3.63, 3.64, 3.65, 3.66, 3.67, 3.68, 3.68, 3.69, 3.70, 3.71, 3.72, 3.73, 3.73, 3.74, 3.75, 3.76, 3.77, 3.78, 3.78, 3.79, 3.80, 3.81, 3.82, 3.83, 3.83, 3.84, 3.85, 3.86, 3.87, 3.88, 3.89, 3.89, 3.90, 3.91, 3.92, 3.93, 3.94, 3.94, 3.95, 3.96, 3.97, 3.98, 3.99, 4.00, 4.00, 4.01, 4.02, 4.03, 4.04, 4.05, 4.05, 4.06, 4.07, 4.08, 4.09, 4.10, 4.11, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.17, 4.18, 4.19, 4.20, 4.21, 4.22, 4.23, 4.23, 4.24, 4.25, 4.26, 4.27, 4.28, 4.29, 4.29, 4.30, 4.31, 4.32, 4.33, 4.34, 4.35, 4.35, 4.36, 4.37, 4.38, 4.39, 4.40, 4.41, 4.42, 4.42, 4.43, 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75, 20.76, 20.78, 20.80, 20.82, 20.84, 20.85, 20.87, 20.89, 20.91, 20.93, 20.95, 20.96, 20.98, 21.00, 21.02, 21.04, 21.06, 21.07, 21.09, 21.11, 21.13, 21.15, 21.17, 21.18, 21.20, 21.22, 21.24, 21.26, 21.28, 21.29, 21.↩
31, 21.33, 21.35, 21.37, 21.39, 21.41, 21.42, 21.44, 21.46, 21.48, 21.50, 21.52, 21.54, 21.55, 21.57, 21.59, 21.61, 21.63, 21.65, 21.67, 21.69, 21.70, 21.72, 21.74, 21.76, 21.78, 21.80, 21.82, 21.84, 21.86, 21.87, 21.↩
89, 21.91, 21.93, 21.95, 21.97, 21.99, 22.01, 22.03, 22.05, 22.06, 22.08, 22.10, 22.12, 22.14, 22.16, 22.18, 22.20, 22.22, 22.24, 22.26, 22.28, 22.30, 22.31, 22.33, 22.35, 22.37, 22.39, 22.41, 22.43, 22.45, 22.47, 22.↩
49, 22.51, 22.53, 22.55, 22.57, 22.59, 22.61, 22.63, 22.64, 22.66, 22.68, 22.70, 22.72, 22.74, 22.76, 22.78, 22.80, 22.82, 22.84, 22.86, 22.88, 22.90, 22.92, 22.94, 22.96, 22.98, 23.00, 23.02, 23.04, 23.06, 23.08, 23.↩
10, 23.12, 23.14, 23.16, 23.18, 23.20, 23.22, 23.24, 23.26, 23.28, 23.30, 23.32, 23.34, 23.36, 23.38, 23.40, 23.42, 23.44, 23.46, 23.48, 23.50, 23.52, 23.54, 23.56, 23.58, 23.60, 23.62, 23.65, 23.67, 23.69, 23.71, 23.↩
73, 23.75, 23.77, 23.79, 23.81, 23.83, 23.85, 23.87, 23.89, 23.91, 23.93, 23.95, 23.97, 24.00, 24.02, 24.04, 24.06, 24.08, 24.10, 24.12, 24.14, 24.16, 24.18, 24.20, 24.22, 24.25, 24.27, 24.29, 24.31, 24.33, 24.35, 24.↩
37, 24.39, 24.41, 24.43, 24.46, 24.48, 24.50, 24.52, 24.54, 24.56, 24.58, 24.60, 24.63, 24.65, 24.67, 24.69, 24.71, 24.73, 24.75, 24.78, 24.80, 24.82, 24.84, 24.86, 24.88, 24.90, 24.93, 24.95, 24.97, 24.99, 25.01, 25.↩
03, 25.06, 25.08, 25.10, 25.12, 25.14, 25.16, 25.19, 25.21, 25.23, 25.25, 25.27, 25.30, 25.32, 25.34, 25.36, 25.38, 25.41, 25.43, 25.45, 25.47, 25.49, 25.52, 25.54, 25.56, 25.58, 25.60, 25.63, 25.65, 25.67, 25.69, 25.↩
72, 25.74, 25.76, 25.78, 25.81, 25.83, 25.85, 25.87, 25.89, 25.92, 25.94, 25.96, 25.98, 26.01, 26.03, 26.05, 26.08, 26.10, 26.12, 26.14, 26.17, 26.19, 26.21, 26.23, 26.26, 26.28, 26.30, 26.33, 26.35, 26.37, 26.39, 26.↩
42, 26.44, 26.46, 26.49, 26.51, 26.53, 26.56, 26.58, 26.60, 26.63, 26.65, 26.67, 26.69, 26.72, 26.74, 26.76, 26.79, 26.81, 26.83, 26.86, 26.88, 26.90, 26.93, 26.95, 26.98, 27.00, 27.02, 27.05, 27.07, 27.09, 27.12, 27.↩
14, 27.16, 27.19, 27.21, 27.24, 27.26, 27.28, 27.31, 27.33, 27.35, 27.38, 27.40, 27.43, 27.45, 27.47, 27.50, 27.52, 27.55, 27.57, 27.59, 27.62, 27.64, 27.67, 27.69, 27.72, 27.74, 27.76, 27.79, 27.81, 27.84, 27.86, 27.↩
89, 27.91, 27.93, 27.96, 27.98, 28.01, 28.03, 28.06, 28.08, 28.11, 28.13, 28.16, 28.18, 28.21, 28.23, 28.26, 28.28, 28.30, 28.33, 28.35, 28.38, 28.40, 28.43, 28.45, 28.48, 28.50, 28.53, 28.55, 28.58, 28.60, 28.63, 28.↩
66, 28.68, 28.71, 28.73, 28.76, 28.78, 28.81, 28.83, 28.86, 28.88, 28.91, 28.93, 28.96, 28.99, 29.01, 29.04, 29.06, 29.09, 29.11, 29.14, 29.17, 29.19, 29.22, 29.24, 29.27, 29.29, 29.32, 29.35, 29.37, 29.40, 29.42, 29.↩
45, 29.48, 29.50, 29.53, 29.55, 29.58, 29.61, 29.63, 29.66, 29.69, 29.71, 29.74, 29.76, 29.79, 29.82, 29.84, 29.87, 29.90, 29.92, 29.95, 29.98, 30.00, 30.03, 30.06, 30.08, 30.11, 30.14, 30.16, 30.19, 30.22, 30.24, 30.↩

27, 30.30, 30.33, 30.35, 30.38, 30.41, 30.43, 30.46, 30.49, 30.52, 30.54, 30.57, 30.60, 30.62, 30.65, 30.68, 30.71, 30.73, 30.76, 30.79, 30.82, 30.84, 30.87, 30.90, 30.93, 30.96, 30.98, 31.01, 31.04, 31.07, 31.09, 31.↩
12, 31.15, 31.18, 31.21, 31.23, 31.26, 31.29, 31.32, 31.35, 31.37, 31.40, 31.43, 31.46, 31.49, 31.52, 31.54, 31.57, 31.60, 31.63, 31.66, 31.69, 31.72, 31.74, 31.77, 31.80, 31.83, 31.86, 31.89, 31.92, 31.95, 31.97, 32.↩
00, 32.03, 32.06, 32.09, 32.12, 32.15, 32.18, 32.21, 32.24, 32.27, 32.29, 32.32, 32.35, 32.38, 32.41, 32.44, 32.47, 32.50, 32.53, 32.56, 32.59, 32.62, 32.65, 32.68, 32.71, 32.74, 32.77, 32.80, 32.83, 32.86, 32.89, 32.↩
92, 32.95, 32.98, 33.01, 33.04, 33.07, 33.10, 33.13, 33.16, 33.19, 33.22, 33.25, 33.28, 33.31, 33.34, 33.37, 33.40, 33.43, 33.46, 33.49, 33.53, 33.56, 33.59, 33.62, 33.65, 33.68, 33.71, 33.74, 33.77, 33.80, 33.84, 33.↩
87, 33.90, 33.93, 33.96, 33.99, 34.02, 34.05, 34.09, 34.12, 34.15, 34.18, 34.21, 34.24, 34.28, 34.31, 34.34, 34.37, 34.40, 34.43, 34.47, 34.50, 34.53, 34.56, 34.59, 34.63, 34.66, 34.69, 34.72, 34.76, 34.79, 34.82, 34.↩
85, 34.89, 34.92, 34.95, 34.98, 35.02, 35.05, 35.08, 35.11, 35.15, 35.18, 35.21, 35.25, 35.28, 35.31, 35.35, 35.38, 35.41, 35.44, 35.48, 35.51, 35.54, 35.58, 35.61, 35.65, 35.68, 35.71, 35.75, 35.78, 35.81, 35.85, 35.↩
88, 35.91, 35.95, 35.98, 36.02, 36.05, 36.08, 36.12, 36.15, 36.19, 36.22, 36.26, 36.29, 36.33, 36.36, 36.39, 36.43, 36.46, 36.50, 36.53, 36.57, 36.60, 36.64, 36.67, 36.71, 36.74, 36.78, 36.81, 36.85, 36.88, 36.92, 36.↩
95, 36.99, 37.02, 37.06, 37.09, 37.13, 37.17, 37.20, 37.24, 37.27, 37.31, 37.34, 37.38, 37.42, 37.45, 37.49, 37.52, 37.56, 37.60, 37.63, 37.67, 37.71, 37.74, 37.78, 37.82, 37.85, 37.89, 37.93, 37.96, 38.00, 38.04, 38.↩
07, 38.11, 38.15, 38.18, 38.22, 38.26, 38.30, 38.33, 38.37, 38.41, 38.44, 38.48, 38.52, 38.56, 38.60, 38.63, 38.67, 38.71, 38.75, 38.78, 38.82, 38.86, 38.90, 38.94, 38.97, 39.01, 39.05, 39.09, 39.13, 39.17, 39.21, 39.↩
24, 39.28, 39.32, 39.36, 39.40, 39.44, 39.48, 39.52, 39.56, 39.59, 39.63, 39.67, 39.71, 39.75, 39.79, 39.83, 39.87, 39.91, 39.95, 39.99, 40.03, 40.07, 40.11, 40.15, 40.19, 40.23, 40.27, 40.31, 40.35, 40.39, 40.43, 40.↩
47, 40.51, 40.55, 40.59, 40.64, 40.68, 40.72, 40.76, 40.80, 40.84, 40.88, 40.92, 40.96, 41.01, 41.05, 41.09, 41.13, 41.17, 41.21, 41.26, 41.30, 41.34, 41.38, 41.42, 41.47, 41.51, 41.55, 41.59, 41.64, 41.68, 41.72, 41.↩
76, 41.81, 41.85, 41.89, 41.93, 41.98, 42.02, 42.06, 42.11, 42.15, 42.19, 42.24, 42.28, 42.32, 42.37, 42.41, 42.46, 42.50, 42.54, 42.59, 42.63, 42.68, 42.72, 42.76, 42.81, 42.85, 42.90, 42.94, 42.99, 43.03, 43.08, 43.↩
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56, 44.60, 44.65, 44.70, 44.75, 44.80, 44.84, 44.89, 44.94, 44.99, 45.04, 45.08, 45.13, 45.18, 45.23, 45.28, 45.33, 45.38, 45.43, 45.48, 45.53, 45.57, 45.62, 45.67, 45.72, 45.77, 45.82, 45.87, 45.92, 45.97, 46.02, 46.↩
07, 46.12, 46.17, 46.23, 46.28, 46.33, 46.38, 46.43, 46.48, 46.53, 46.58, 46.63, 46.69, 46.74, 46.79, 46.84, 46.89, 46.95, 47.00, 47.05, 47.10, 47.15, 47.21, 47.26, 47.31, 47.37, 47.42, 47.47, 47.52, 47.58, 47.63, 47.↩
69, 47.74, 47.79, 47.85, 47.90, 47.95, 48.01, 48.06, 48.12, 48.17, 48.23, 48.28, 48.34, 48.39, 48.45, 48.50, 48.56, 48.61, 48.67, 48.72, 48.78, 48.84, 48.89, 48.95, 49.00, 49.06, 49.12, 49.17, 49.23, 49.29, 49.34, 49.↩
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91, 63.00, 63.10, 63.19, 63.29, 63.38, 63.48, 63.57, 63.67, 63.76, 63.86, 63.96, 64.06, 64.15, 64.25, 64.35, 64.45, 64.55, 64.65, 64.75, 64.85, 64.95, 65.05, 65.15, 65.25, 65.35, 65.46, 65.56, 65.66, 65.76, 65.87, 65.↩
97, 66.08, 66.18, 66.29, 66.39, 66.50, 66.61, 66.71, 66.82, 66.93, 67.03, 67.14, 67.25, 67.36, 67.47, 67.58, 67.69, 67.80, 67.91, 68.03, 68.14, 68.25, 68.36, 68.48, 68.59, 68.71, 68.82, 68.94, 69.05, 69.17, 69.29, 69.↩
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78, 77.94, 78.10, 78.26, 78.42, 78.58, 78.74, 78.90, 79.06, 79.23, 79.39, 79.55, 79.72, 79.89, 80.06, 80.23, 80.40, 80.57, 80.74, 80.91, 81.08, 81.26, 81.44, 81.61, 81.79, 81.97, 82.15, 82.33, 82.51, 82.70, 82.88, 83.↩
07, 83.25, 83.44, 83.63, 83.82, 84.01, 84.20, 84.40, 84.59, 84.79, 84.98, 85.18, 85.38, 85.58, 85.79, 85.99, 86.20, 86.40, 86.61, 86.82, 87.03, 87.24, 87.46, 87.67, 87.89, 88.11, 88.33, 88.55, 88.77, 89.00, 89.22, 89.↩
45, 89.68, 89.91, 90.14, 90.38, 90.62, 90.85, 91.09, 91.34, 91.58, 91.82, 92.07, 92.32, 92.57, 92.83, 93.08, 93.34, 93.60, 93.86, 94.13, 94.39, 94.66, 94.93, 95.20, 95.48, 95.76, 96.04, 96.32, 96.61, 96.89, 97.18, 97.↩

48, 97.77, 98.07, 98.37, 98.68, 98.98, 99.29, 99.61, 99.92, 100.24, 100.56, 100.89, 101.22, 101.55, 101.88, 102.22, 102.56, 102.91, 103.26, 103.61, 103.97, 104.33, 104.70, 105.07, 105.44, 105.82, 106.20, 106.58, 106.98, 107.37, 107.77, 108.18, 108.59, 109.00, 109.42, 109.85, 110.28, 110.71, 111.16, 111.60, 112.06, 112.52, 112.99, 113.46, 113.94, 114.43, 114.92, 115.42, 115.93, 116.44, 116.97, 117.50, 118.04, 118.59, 119.14, 119.71, 120.29, 120.87, 121.47, 122.07, 122.69, 123.32, 123.95, 124.61, 125.27, 125.94, 126.63, 127.33, 128.05, 128.78, 129.52, 130.29, 131.06, 131.86, 132.67, 133.50, 134.35, 135.22, 136.12, 137.03, 137.97, 138.93, 139.92, 140.93, 141.97, 143.05, 144.15, 145.29, 146.46, 147.67, 148.92, 150.22, 151.55, 152.94, 154.38, 155.87, 157.42, 159.04, 160.72, 162.48, 164.33, 166.26, 168.29, 170.42, 172.68, 175.07, 177.60, 180.30, 183.19, 186.29, 189.63, 193.26, 197.23, 201.59, 206.43, 211.86, 218.04, 225.19, 233.64, 243.93, 257.02, 274.82, 302.24, 360.00, 421.98}

- volatile uint16_t rawADC_left [4] = {0}

  Raw ADC data for the left inverter.
- volatile uint16_t rawADC_right [4] = {0}

  Raw ADC data for the right inverter.
- volatile uint16_t rawADC_temp [4] = {0}

  Raw ADC data for the temperatures.

4.33.1 Detailed Description

This file provides functions for handling measurements.

Attention

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4.33.2 Function Documentation

4.33.2.1 calibrate_offsets()

```
void calibrate_offsets (
            volatile uint16_t rawADC[],
            volatile float currentOffsets[],
            uint32_t numSamples )
```

Calibrate the current sensor offsets.

This function calculates the average offset for each current sensor channel by reading the ADC values when no current is flowing. The calculated offsets are used to correct the sensor readings.

Parameters

in	*rawADC*	Buffer containing the raw ADC values for the channels.
out	*currentOffsets*	Array to store the calculated offsets for each current channel.
in	*numSamples*	Number of samples to average for the offset calculation.

Here is the caller graph for this function:

4.33.2.2 get_currents_voltage()

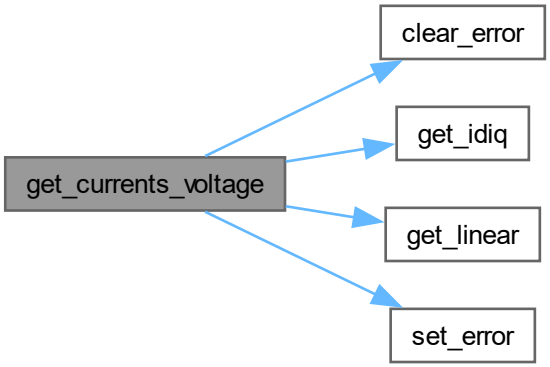
```
void get_currents_voltage (
            volatile uint16_t rawADC[],
            volatile Analog * analog,
            volatile Feedback * feedback,
            volatile InverterError * errors,
            float sinTheta_e,
            float cosTheta_e )
```

Get electrical ADC measurements.

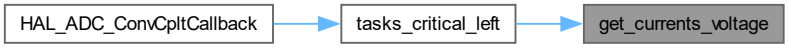
Parameters

in	*rawADC*	Pointer to the raw ADC values array.
out	*analog*	Pointer to the ADC struct to store the results.
out	*feedback*	Pointer to the Feedback struct to store id and iq.
in	*sinTheta_e*	Electrical angle sine (-1..1)
in	*cosTheta_e*	Electrical angle cosine (-1..1)

Here is the call graph for this function:



Here is the caller graph for this function:



4.33.2.3 get_idiq()

```
void get_idiq (
            float ia,
            float ib,
            float ic,
            float sinTheta_e,
            float cosTheta_e,
            float * idMeas,
            float * iqMeas )
```

Computes d-q currents from current measurements and electrical angle.

This function computes the d-q currents from phase currents (ABC), theta_e, and stores the results in the provided pointers.

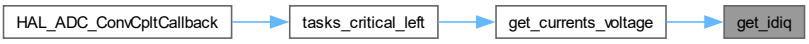
Parameters

in	*ia*	Phase A current in A.
in	*ib*	Phase B current in A.
in	*ic*	Phase C current in A.
in	*sinTheta_e*	Electrical angle sine (-1..1)

Parameters

in	*cosTheta_e*	Electrical angle cosine (-1..1)
out	*idMeas*	Pointer to store the D-axis current.
out	*iqMeas*	Pointer to store the Q-axis current.

Here is the caller graph for this function:



4.33.2.4 get_linear()

```
float get_linear (
            uint32_t bits,
            float slope,
            float offset )
```

Convert ADC reading to physical measurement with linear response.

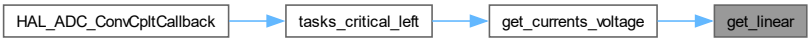
Parameters

in	*bits*	The ADC reading.
in	*slope*	The slope (units per volt).
in	*offset*	The offset (volts at zero).

Return values

measurement	The physical measurement.

Here is the caller graph for this function:



4.33.2.5 get_temperature()

```
float get_temperature (
            uint32_t bits,
            const float tempLUT[] )
```

Retrieves temperature from a lookup table based on ADC bits.

This function retrieves temperature from a lookup table based on the ADC bits. The lookup table (LUT) must have a value for each possible ADC bit combination.

Parameters

in	*bits*	ADC reading converted to bits.
in	*tempLUT*	Lookup table containing temperature values.

Returns

Temperature corresponding to the provided ADC bits.

Here is the caller graph for this function:

4.33.3 Variable Documentation

4.33.3.1 rawADC_left

```
volatile uint16_t rawADC_left[4] = {0}
```

Raw ADC data for the left inverter.

External declaration of raw ADC data for the left inverter.

4.33.3.2 rawADC_right

```
volatile uint16_t rawADC_right[4] = {0}
```

Raw ADC data for the right inverter.

External declaration of raw ADC data for the right inverter.

4.33.3.3 rawADC_temp

```
volatile uint16_t rawADC_temp[4] = {0}
```

Raw ADC data for the temperatures.

External declaration of raw ADC data for the temperature readings.

4.33.3.4 tempInverterLUT

```
const float tempInverterLUT[] = {-2.45, -2.44, -2.44, -2.43, -2.42, -2.42, -2.41, -2.41, -2.↩
40, -2.39, -2.39, -2.38, -2.37, -2.37, -2.36, -2.36, -2.35, -2.34, -2.34, -2.33, -2.32, -2.↩
32, -2.31, -2.31, -2.30, -2.29, -2.29, -2.28, -2.27, -2.27, -2.26, -2.26, -2.25, -2.24, -2.↩
24, -2.23, -2.22, -2.22, -2.21, -2.20, -2.20, -2.19, -2.19, -2.18, -2.17, -2.17, -2.16, -2.↩
15, -2.15, -2.14, -2.14, -2.13, -2.12, -2.12, -2.11, -2.10, -2.10, -2.09, -2.08, -2.08, -2.↩
07, -2.07, -2.06, -2.05, -2.05, -2.04, -2.03, -2.03, -2.02, -2.01, -2.01, -2.00, -2.00, -1.↩
99, -1.98, -1.98, -1.97, -1.96, -1.96, -1.95, -1.94, -1.94, -1.93, -1.93, -1.92, -1.91, -1.↩
91, -1.90, -1.89, -1.89, -1.88, -1.87, -1.87, -1.86, -1.86, -1.85, -1.84, -1.84, -1.83, -1.↩
82, -1.82, -1.81, -1.80, -1.80, -1.79, -1.78, -1.78, -1.77, -1.77, -1.76, -1.75, -1.75, -1.↩
74, -1.73, -1.73, -1.72, -1.71, -1.71, -1.70, -1.69, -1.69, -1.68, -1.67, -1.67, -1.66, -1.↩
66, -1.65, -1.64, -1.64, -1.63, -1.62, -1.62, -1.61, -1.60, -1.60, -1.59, -1.58, -1.58, -1.↩
57, -1.56, -1.56, -1.55, -1.54, -1.54, -1.53, -1.53, -1.52, -1.51, -1.51, -1.50, -1.49, -1.↩
49, -1.48, -1.47, -1.47, -1.46, -1.45, -1.45, -1.44, -1.43, -1.43, -1.42, -1.41, -1.41, -1.↩
40, -1.39, -1.39, -1.38, -1.37, -1.37, -1.36, -1.36, -1.35, -1.34, -1.34, -1.33, -1.32, -1.↩
32, -1.31, -1.30, -1.30, -1.29, -1.28, -1.28, -1.27, -1.26, -1.26, -1.25, -1.24, -1.24, -1.↩
23, -1.22, -1.22, -1.21, -1.20, -1.20, -1.19, -1.18, -1.18, -1.17, -1.16, -1.16, -1.15, -1.↩
14, -1.14, -1.13, -1.12, -1.12, -1.11, -1.10, -1.10, -1.09, -1.08, -1.08, -1.07, -1.06, -1.↩
06, -1.05, -1.04, -1.04, -1.03, -1.02, -1.02, -1.01, -1.00, -1.00, -0.99, -0.98, -0.98, -0.↩
97, -0.96, -0.96, -0.95, -0.94, -0.94, -0.93, -0.92, -0.92, -0.91, -0.90, -0.90, -0.89, -0.↩
88, -0.88, -0.87, -0.86, -0.86, -0.85, -0.84, -0.84, -0.83, -0.82, -0.82, -0.81, -0.80, -0.↩
80, -0.79, -0.78, -0.78, -0.77, -0.76, -0.76, -0.75, -0.74, -0.73, -0.73, -0.72, -0.71, -0.↩
71, -0.70, -0.69, -0.69, -0.68, -0.67, -0.67, -0.66, -0.65, -0.65, -0.64, -0.63, -0.63, -0.↩
62, -0.61, -0.61, -0.60, -0.59, -0.59, -0.58, -0.57, -0.56, -0.56, -0.55, -0.54, -0.54, -0.↩
53, -0.52, -0.52, -0.51, -0.50, -0.50, -0.49, -0.48, -0.48, -0.47, -0.46, -0.46, -0.45, -0.↩
44, -0.43, -0.43, -0.42, -0.41, -0.41, -0.40, -0.39, -0.39, -0.38, -0.37, -0.37, -0.36, -0.↩
35, -0.35, -0.34, -0.33, -0.32, -0.32, -0.31, -0.30, -0.30, -0.29, -0.28, -0.28, -0.27, -0.↩
26, -0.26, -0.25, -0.24, -0.23, -0.23, -0.22, -0.21, -0.21, -0.20, -0.19, -0.19, -0.18, -0.↩
17, -0.17, -0.16, -0.15, -0.14, -0.14, -0.13, -0.12, -0.12, -0.11, -0.10, -0.10, -0.09, -0.08,
-0.07, -0.07, -0.06, -0.05, -0.05, -0.04, -0.03, -0.03, -0.02, -0.01, -0.00, 0.00, 0.01, 0.02,
0.02, 0.03, 0.04, 0.04, 0.05, 0.06, 0.07, 0.07, 0.08, 0.09, 0.09, 0.10, 0.11, 0.12, 0.12, 0.↩
13, 0.14, 0.14, 0.15, 0.16, 0.16, 0.17, 0.18, 0.19, 0.19, 0.20, 0.21, 0.21, 0.22, 0.23, 0.24,
0.24, 0.25, 0.26, 0.26, 0.27, 0.28, 0.29, 0.29, 0.30, 0.31, 0.31, 0.32, 0.33, 0.34, 0.34, 0.↩
35, 0.36, 0.36, 0.37, 0.38, 0.39, 0.39, 0.40, 0.41, 0.41, 0.42, 0.43, 0.44, 0.44, 0.45, 0.46,
0.46, 0.47, 0.48, 0.49, 0.49, 0.50, 0.51, 0.51, 0.52, 0.53, 0.54, 0.54, 0.55, 0.56, 0.56, 0.↩
57, 0.58, 0.59, 0.59, 0.60, 0.61, 0.61, 0.62, 0.63, 0.64, 0.64, 0.65, 0.66, 0.67, 0.67, 0.68,
0.69, 0.69, 0.70, 0.71, 0.72, 0.72, 0.73, 0.74, 0.75, 0.75, 0.76, 0.77, 0.77, 0.78, 0.79, 0.↩
80, 0.80, 0.81, 0.82, 0.83, 0.83, 0.84, 0.85, 0.85, 0.86, 0.87, 0.88, 0.88, 0.89, 0.90, 0.91,
0.91, 0.92, 0.93, 0.94, 0.94, 0.95, 0.96, 0.96, 0.97, 0.98, 0.99, 0.99, 1.00, 1.01, 1.02, 1.↩
02, 1.03, 1.04, 1.05, 1.05, 1.06, 1.07, 1.08, 1.08, 1.09, 1.10, 1.10, 1.11, 1.12, 1.13, 1.13,
1.14, 1.15, 1.16, 1.16, 1.17, 1.18, 1.19, 1.19, 1.20, 1.21, 1.22, 1.22, 1.23, 1.24, 1.25, 1.↩
25, 1.26, 1.27, 1.28, 1.28, 1.29, 1.30, 1.31, 1.31, 1.32, 1.33, 1.34, 1.34, 1.35, 1.36, 1.37,
1.37, 1.38, 1.39, 1.40, 1.40, 1.41, 1.42, 1.43, 1.43, 1.44, 1.45, 1.46, 1.46, 1.47, 1.48, 1.↩
49, 1.49, 1.50, 1.51, 1.52, 1.52, 1.53, 1.54, 1.55, 1.55, 1.56, 1.57, 1.58, 1.58, 1.59, 1.60,
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72, 1.73, 1.74, 1.74, 1.75, 1.76, 1.77, 1.77, 1.78, 1.79, 1.80, 1.80, 1.81, 1.82, 1.83, 1.84,
1.84, 1.85, 1.86, 1.87, 1.87, 1.88, 1.89, 1.90, 1.90, 1.91, 1.92, 1.93, 1.93, 1.94, 1.95, 1.↩
96, 1.97, 1.97, 1.98, 1.99, 2.00, 2.00, 2.01, 2.02, 2.03, 2.04, 2.04, 2.05, 2.06, 2.07, 2.07,
2.08, 2.09, 2.10, 2.10, 2.11, 2.12, 2.13, 2.14, 2.14, 2.15, 2.16, 2.17, 2.17, 2.18, 2.19, 2.↩
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2.32, 2.33, 2.34, 2.35, 2.35, 2.36, 2.37, 2.38, 2.39, 2.39, 2.40, 2.41, 2.42, 2.43, 2.43, 2.↩
44, 2.45, 2.46, 2.46, 2.47, 2.48, 2.49, 2.50, 2.50, 2.51, 2.52, 2.53, 2.54, 2.54, 2.55, 2.56,
2.57, 2.58, 2.58, 2.59, 2.60, 2.61, 2.62, 2.62, 2.63, 2.64, 2.65, 2.66, 2.66, 2.67, 2.68, 2.↩
69, 2.70, 2.70, 2.71, 2.72, 2.73, 2.74, 2.74, 2.75, 2.76, 2.77, 2.78, 2.78, 2.79, 2.80, 2.81,
2.82, 2.82, 2.83, 2.84, 2.85, 2.86, 2.86, 2.87, 2.88, 2.89, 2.90, 2.90, 2.91, 2.92, 2.93, 2.↩
94, 2.94, 2.95, 2.96, 2.97, 2.98, 2.98, 2.99, 3.00, 3.01, 3.02, 3.02, 3.03, 3.04, 3.05, 3.06,
3.07, 3.07, 3.08, 3.09, 3.10, 3.11, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.16, 3.17, 3.18, 3.↩
```

```
19, 3.20, 3.20, 3.21, 3.22, 3.23, 3.24, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29, 3.29, 3.30, 3.31,
3.32, 3.33, 3.34, 3.34, 3.35, 3.36, 3.37, 3.38, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, 3.43, 3.↩
44, 3.45, 3.46, 3.47, 3.48, 3.48, 3.49, 3.50, 3.51, 3.52, 3.53, 3.53, 3.54, 3.55, 3.56, 3.57,
3.58, 3.58, 3.59, 3.60, 3.61, 3.62, 3.63, 3.63, 3.64, 3.65, 3.66, 3.67, 3.68, 3.68, 3.69, 3.↩
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5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.↩
32, 5.33, 5.34, 5.34, 5.35, 5.36, 5.37, 5.38, 5.39, 5.40, 5.41, 5.42, 5.43, 5.43, 5.44, 5.45,
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64, 8.65, 8.66, 8.67, 8.68, 8.69, 8.70, 8.71, 8.72, 8.74, 8.75, 8.76, 8.77, 8.78, 8.79, 8.80,
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97, 8.98, 8.99, 9.00, 9.01, 9.02, 9.03, 9.04, 9.06, 9.07, 9.08, 9.09, 9.10, 9.11, 9.12, 9.13,
9.14, 9.15, 9.16, 9.17, 9.18, 9.20, 9.21, 9.22, 9.23, 9.24, 9.25, 9.26, 9.27, 9.28, 9.29, 9.↩
30, 9.31, 9.33, 9.34, 9.35, 9.36, 9.37, 9.38, 9.39, 9.40, 9.41, 9.42, 9.43, 9.45, 9.46, 9.47,
9.48, 9.49, 9.50, 9.51, 9.52, 9.53, 9.54, 9.55, 9.57, 9.58, 9.59, 9.60, 9.61, 9.62, 9.63, 9.↩
64, 9.65, 9.66, 9.68, 9.69, 9.70, 9.71, 9.72, 9.73, 9.74, 9.75, 9.76, 9.78, 9.79, 9.80, 9.81,
9.82, 9.83, 9.84, 9.85, 9.86, 9.88, 9.89, 9.90, 9.91, 9.92, 9.93, 9.94, 9.95, 9.96, 9.98, 9.↩
99, 10.00, 10.01, 10.02, 10.03, 10.04, 10.05, 10.07, 10.08, 10.09, 10.10, 10.11, 10.12, 10.↩
13, 10.14, 10.16, 10.17, 10.18, 10.19, 10.20, 10.21, 10.22, 10.24, 10.25, 10.26, 10.27, 10.↩
28, 10.29, 10.30, 10.31, 10.33, 10.34, 10.35, 10.36, 10.37, 10.38, 10.39, 10.41, 10.42, 10.↩
43, 10.44, 10.45, 10.46, 10.47, 10.49, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.57, 10.↩
58, 10.59, 10.60, 10.61, 10.62, 10.64, 10.65, 10.66, 10.67, 10.68, 10.69, 10.70, 10.72, 10.↩
73, 10.74, 10.75, 10.76, 10.77, 10.79, 10.80, 10.81, 10.82, 10.83, 10.84, 10.86, 10.87, 10.↩
88, 10.89, 10.90, 10.91, 10.93, 10.94, 10.95, 10.96, 10.97, 10.98, 11.00, 11.01, 11.02, 11.↩
03, 11.04, 11.05, 11.07, 11.08, 11.09, 11.10, 11.11, 11.13, 11.14, 11.15, 11.16, 11.17, 11.↩
18, 11.20, 11.21, 11.22, 11.23, 11.24, 11.26, 11.27, 11.28, 11.29, 11.30, 11.32, 11.33, 11.↩
34, 11.35, 11.36, 11.37, 11.39, 11.40, 11.41, 11.42, 11.43, 11.45, 11.46, 11.47, 11.48, 11.↩
49, 11.51, 11.52, 11.53, 11.54, 11.55, 11.57, 11.58, 11.59, 11.60, 11.61, 11.63, 11.64, 11.↩
65, 11.66, 11.68, 11.69, 11.70, 11.71, 11.72, 11.74, 11.75, 11.76, 11.77, 11.78, 11.80, 11.↩
```

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81, 11.82, 11.83, 11.85, 11.86, 11.87, 11.88, 11.89, 11.91, 11.92, 11.93, 11.94, 11.96, 11.↩
97, 11.98, 11.99, 12.00, 12.02, 12.03, 12.04, 12.05, 12.07, 12.08, 12.09, 12.10, 12.11, 12.↩
13, 12.14, 12.15, 12.16, 12.18, 12.19, 12.20, 12.21, 12.23, 12.24, 12.25, 12.26, 12.28, 12.↩
29, 12.30, 12.31, 12.33, 12.34, 12.35, 12.36, 12.38, 12.39, 12.40, 12.41, 12.43, 12.44, 12.↩
45, 12.46, 12.48, 12.49, 12.50, 12.51, 12.53, 12.54, 12.55, 12.56, 12.58, 12.59, 12.60, 12.↩
61, 12.63, 12.64, 12.65, 12.66, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.77, 12.↩
78, 12.79, 12.80, 12.82, 12.83, 12.84, 12.86, 12.87, 12.88, 12.89, 12.91, 12.92, 12.93, 12.↩
94, 12.96, 12.97, 12.98, 13.00, 13.01, 13.02, 13.03, 13.05, 13.06, 13.07, 13.09, 13.10, 13.↩
11, 13.12, 13.14, 13.15, 13.16, 13.18, 13.19, 13.20, 13.22, 13.23, 13.24, 13.25, 13.27, 13.↩
28, 13.29, 13.31, 13.32, 13.33, 13.35, 13.36, 13.37, 13.38, 13.40, 13.41, 13.42, 13.44, 13.↩
45, 13.46, 13.48, 13.49, 13.50, 13.52, 13.53, 13.54, 13.55, 13.57, 13.58, 13.59, 13.61, 13.↩
62, 13.63, 13.65, 13.66, 13.67, 13.69, 13.70, 13.71, 13.73, 13.74, 13.75, 13.77, 13.78, 13.↩
79, 13.81, 13.82, 13.83, 13.85, 13.86, 13.87, 13.89, 13.90, 13.91, 13.93, 13.94, 13.95, 13.↩
97, 13.98, 13.99, 14.01, 14.02, 14.03, 14.05, 14.06, 14.07, 14.09, 14.10, 14.11, 14.13, 14.↩
14, 14.16, 14.17, 14.18, 14.20, 14.21, 14.22, 14.24, 14.25, 14.26, 14.28, 14.29, 14.30, 14.↩
32, 14.33, 14.35, 14.36, 14.37, 14.39, 14.40, 14.41, 14.43, 14.44, 14.45, 14.47, 14.48, 14.↩
50, 14.51, 14.52, 14.54, 14.55, 14.56, 14.58, 14.59, 14.61, 14.62, 14.63, 14.65, 14.66, 14.↩
67, 14.69, 14.70, 14.72, 14.73, 14.74, 14.76, 14.77, 14.79, 14.80, 14.81, 14.83, 14.84, 14.↩
86, 14.87, 14.88, 14.90, 14.91, 14.93, 14.94, 14.95, 14.97, 14.98, 15.00, 15.01, 15.02, 15.↩
04, 15.05, 15.07, 15.08, 15.09, 15.11, 15.12, 15.14, 15.15, 15.16, 15.18, 15.19, 15.21, 15.↩
22, 15.24, 15.25, 15.26, 15.28, 15.29, 15.31, 15.32, 15.33, 15.35, 15.36, 15.38, 15.39, 15.↩
41, 15.42, 15.43, 15.45, 15.46, 15.48, 15.49, 15.51, 15.52, 15.54, 15.55, 15.56, 15.58, 15.↩
59, 15.61, 15.62, 15.64, 15.65, 15.66, 15.68, 15.69, 15.71, 15.72, 15.74, 15.75, 15.77, 15.↩
78, 15.80, 15.81, 15.82, 15.84, 15.85, 15.87, 15.88, 15.90, 15.91, 15.93, 15.94, 15.96, 15.↩
97, 15.99, 16.00, 16.01, 16.03, 16.04, 16.06, 16.07, 16.09, 16.10, 16.12, 16.13, 16.15, 16.↩
16, 16.18, 16.19, 16.21, 16.22, 16.24, 16.25, 16.27, 16.28, 16.30, 16.31, 16.33, 16.34, 16.↩
35, 16.37, 16.38, 16.40, 16.41, 16.43, 16.44, 16.46, 16.47, 16.49, 16.50, 16.52, 16.53, 16.↩
55, 16.56, 16.58, 16.59, 16.61, 16.62, 16.64, 16.66, 16.67, 16.69, 16.70, 16.72, 16.73, 16.↩
75, 16.76, 16.78, 16.79, 16.81, 16.82, 16.84, 16.85, 16.87, 16.88, 16.90, 16.91, 16.93, 16.↩
94, 16.96, 16.97, 16.99, 17.01, 17.02, 17.04, 17.05, 17.07, 17.08, 17.10, 17.11, 17.13, 17.↩
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96, 17.98, 17.99, 18.01, 18.02, 18.04, 18.06, 18.07, 18.09, 18.11, 18.12, 18.14, 18.15, 18.↩
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38, 18.40, 18.41, 18.43, 18.45, 18.46, 18.48, 18.49, 18.51, 18.53, 18.54, 18.56, 18.58, 18.↩
59, 18.61, 18.63, 18.64, 18.66, 18.68, 18.69, 18.71, 18.73, 18.74, 18.76, 18.77, 18.79, 18.↩
81, 18.82, 18.84, 18.86, 18.87, 18.89, 18.91, 18.92, 18.94, 18.96, 18.97, 18.99, 19.01, 19.↩
02, 19.04, 19.06, 19.08, 19.09, 19.11, 19.13, 19.14, 19.16, 19.18, 19.19, 19.21, 19.23, 19.↩
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06, 23.08, 23.10, 23.12, 23.14, 23.16, 23.18, 23.20, 23.22, 23.24, 23.26, 23.28, 23.30, 23.↩
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39, 24.41, 24.43, 24.46, 24.48, 24.50, 24.52, 24.54, 24.56, 24.58, 24.60, 24.63, 24.65, 24.↩
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69, 26.72, 26.74, 26.76, 26.79, 26.81, 26.83, 26.86, 26.88, 26.90, 26.93, 26.95, 26.98, 27.↩
00, 27.02, 27.05, 27.07, 27.09, 27.12, 27.14, 27.16, 27.19, 27.21, 27.24, 27.26, 27.28, 27.↩
31, 27.33, 27.35, 27.38, 27.40, 27.43, 27.45, 27.47, 27.50, 27.52, 27.55, 27.57, 27.59, 27.↩
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09, 32.12, 32.15, 32.18, 32.21, 32.24, 32.27, 32.29, 32.32, 32.35, 32.38, 32.41, 32.44, 32.↩
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31, 35.35, 35.38, 35.41, 35.44, 35.48, 35.51, 35.54, 35.58, 35.61, 35.65, 35.68, 35.71, 35.↩
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19, 36.22, 36.26, 36.29, 36.33, 36.36, 36.39, 36.43, 36.46, 36.50, 36.53, 36.57, 36.60, 36.↩
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19, 42.24, 42.28, 42.32, 42.37, 42.41, 42.46, 42.50, 42.54, 42.59, 42.63, 42.68, 42.72, 42.↩
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18, 45.23, 45.28, 45.33, 45.38, 45.43, 45.48, 45.53, 45.57, 45.62, 45.67, 45.72, 45.77, 45.↩
82, 45.87, 45.92, 45.97, 46.02, 46.07, 46.12, 46.17, 46.23, 46.28, 46.33, 46.38, 46.43, 46.↩
48, 46.53, 46.58, 46.63, 46.69, 46.74, 46.79, 46.84, 46.89, 46.95, 47.00, 47.05, 47.10, 47.↩
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15, 82.33, 82.51, 82.70, 82.88, 83.07, 83.25, 83.44, 83.63, 83.82, 84.01, 84.20, 84.40, 84.↩
59, 84.79, 84.98, 85.18, 85.38, 85.58, 85.79, 85.99, 86.20, 86.40, 86.61, 86.82, 87.03, 87.↩
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92, 115.42, 115.93, 116.44, 116.97, 117.50, 118.04, 118.59, 119.14, 119.71, 120.29, 120.87,
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138.93, 139.92, 140.93, 141.97, 143.05, 144.15, 145.29, 146.46, 147.67, 148.92, 150.22, 151.↩
55, 152.94, 154.38, 155.87, 157.42, 159.04, 160.72, 162.48, 164.33, 166.26, 168.29, 170.42,
172.68, 175.07, 177.60, 180.30, 183.19, 186.29, 189.63, 193.26, 197.23, 201.59, 206.43, 211.↩
86, 218.04, 225.19, 233.64, 243.93, 257.02, 274.82, 302.24, 360.00, 421.98, 421.98, 421.98,
421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.↩
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421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.↩
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421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.↩
98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98,
421.98}
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4.33.3.5 tempMotorLUT

```
const float tempMotorLUT[] = {-2.45, -2.44, -2.44, -2.43, -2.42, -2.42, -2.41, -2.41, -2.↩
40, -2.39, -2.39, -2.38, -2.37, -2.37, -2.36, -2.36, -2.35, -2.34, -2.34, -2.33, -2.32, -2.↩
32, -2.31, -2.31, -2.30, -2.29, -2.29, -2.28, -2.27, -2.27, -2.26, -2.26, -2.25, -2.24, -2.↩
24, -2.23, -2.22, -2.22, -2.21, -2.20, -2.20, -2.19, -2.19, -2.18, -2.17, -2.17, -2.16, -2.↩
15, -2.15, -2.14, -2.14, -2.13, -2.12, -2.12, -2.11, -2.10, -2.10, -2.09, -2.08, -2.08, -2.↩
07, -2.07, -2.06, -2.05, -2.05, -2.04, -2.03, -2.03, -2.02, -2.01, -2.01, -2.00, -2.00, -1.↩
99, -1.98, -1.98, -1.97, -1.96, -1.96, -1.95, -1.94, -1.94, -1.93, -1.93, -1.92, -1.91, -1.↩
91, -1.90, -1.89, -1.89, -1.88, -1.87, -1.87, -1.86, -1.86, -1.85, -1.84, -1.84, -1.83, -1.↩
82, -1.82, -1.81, -1.80, -1.80, -1.79, -1.78, -1.78, -1.77, -1.77, -1.76, -1.75, -1.75, -1.↩
74, -1.73, -1.73, -1.72, -1.71, -1.71, -1.70, -1.69, -1.69, -1.68, -1.67, -1.67, -1.66, -1.↩
66, -1.65, -1.64, -1.64, -1.63, -1.62, -1.62, -1.61, -1.60, -1.60, -1.59, -1.58, -1.58, -1.↩
57, -1.56, -1.56, -1.55, -1.54, -1.54, -1.53, -1.53, -1.52, -1.51, -1.51, -1.50, -1.49, -1.↩
49, -1.48, -1.47, -1.47, -1.46, -1.45, -1.45, -1.44, -1.43, -1.43, -1.42, -1.41, -1.41, -1.↩
40, -1.39, -1.39, -1.38, -1.37, -1.37, -1.36, -1.36, -1.35, -1.34, -1.34, -1.33, -1.32, -1.↩
32, -1.31, -1.30, -1.30, -1.29, -1.28, -1.28, -1.27, -1.26, -1.26, -1.25, -1.24, -1.24, -1.↩
23, -1.22, -1.22, -1.21, -1.20, -1.20, -1.19, -1.18, -1.18, -1.17, -1.16, -1.16, -1.15, -1.↩
14, -1.14, -1.13, -1.12, -1.12, -1.11, -1.10, -1.10, -1.09, -1.08, -1.08, -1.07, -1.06, -1.↩
06, -1.05, -1.04, -1.04, -1.03, -1.02, -1.02, -1.01, -1.00, -1.00, -0.99, -0.98, -0.98, -0.↩
97, -0.96, -0.96, -0.95, -0.94, -0.94, -0.93, -0.92, -0.92, -0.91, -0.90, -0.90, -0.89, -0.↩
88, -0.88, -0.87, -0.86, -0.86, -0.85, -0.84, -0.84, -0.83, -0.82, -0.82, -0.81, -0.80, -0.↩
80, -0.79, -0.78, -0.78, -0.77, -0.76, -0.76, -0.75, -0.74, -0.73, -0.73, -0.72, -0.71, -0.↩
71, -0.70, -0.69, -0.69, -0.68, -0.67, -0.67, -0.66, -0.65, -0.65, -0.64, -0.63, -0.63, -0.↩
62, -0.61, -0.61, -0.60, -0.59, -0.59, -0.58, -0.57, -0.56, -0.56, -0.55, -0.54, -0.54, -0.↩
53, -0.52, -0.52, -0.51, -0.50, -0.50, -0.49, -0.48, -0.48, -0.47, -0.46, -0.46, -0.45, -0.↩
44, -0.43, -0.43, -0.42, -0.41, -0.41, -0.40, -0.39, -0.39, -0.38, -0.37, -0.37, -0.36, -0.↩
35, -0.35, -0.34, -0.33, -0.32, -0.32, -0.31, -0.30, -0.30, -0.29, -0.28, -0.28, -0.27, -0.↩
26, -0.26, -0.25, -0.24, -0.23, -0.23, -0.22, -0.21, -0.21, -0.20, -0.19, -0.19, -0.18, -0.↩
17, -0.17, -0.16, -0.15, -0.14, -0.14, -0.13, -0.12, -0.12, -0.11, -0.10, -0.10, -0.09, -0.08,
-0.07, -0.07, -0.06, -0.05, -0.05, -0.04, -0.03, -0.03, -0.02, -0.01, -0.00, 0.00, 0.01, 0.02,
0.02, 0.03, 0.04, 0.04, 0.05, 0.06, 0.07, 0.07, 0.08, 0.09, 0.09, 0.10, 0.11, 0.12, 0.12, 0.↩
13, 0.14, 0.14, 0.15, 0.16, 0.16, 0.17, 0.18, 0.19, 0.19, 0.20, 0.21, 0.21, 0.22, 0.23, 0.24,
0.24, 0.25, 0.26, 0.26, 0.27, 0.28, 0.29, 0.29, 0.30, 0.31, 0.31, 0.32, 0.33, 0.34, 0.34, 0.↩
35, 0.36, 0.36, 0.37, 0.38, 0.39, 0.39, 0.40, 0.41, 0.41, 0.42, 0.43, 0.44, 0.44, 0.45, 0.46,
0.46, 0.47, 0.48, 0.49, 0.49, 0.50, 0.51, 0.51, 0.52, 0.53, 0.54, 0.54, 0.55, 0.56, 0.56, 0.↩
57, 0.58, 0.59, 0.59, 0.60, 0.61, 0.61, 0.62, 0.63, 0.64, 0.64, 0.65, 0.66, 0.67, 0.67, 0.68,
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0.69, 0.69, 0.70, 0.71, 0.72, 0.72, 0.73, 0.74, 0.75, 0.75, 0.76, 0.77, 0.77, 0.78, 0.79, 0.↩
80, 0.80, 0.81, 0.82, 0.83, 0.83, 0.84, 0.85, 0.85, 0.86, 0.87, 0.88, 0.88, 0.89, 0.90, 0.91,
0.91, 0.92, 0.93, 0.94, 0.94, 0.95, 0.96, 0.96, 0.97, 0.98, 0.99, 0.99, 1.00, 1.01, 1.02, 1.↩
02, 1.03, 1.04, 1.05, 1.05, 1.06, 1.07, 1.08, 1.08, 1.09, 1.10, 1.10, 1.11, 1.12, 1.13, 1.13,
1.14, 1.15, 1.16, 1.16, 1.17, 1.18, 1.19, 1.19, 1.20, 1.21, 1.22, 1.22, 1.23, 1.24, 1.25, 1.↩
25, 1.26, 1.27, 1.28, 1.28, 1.29, 1.30, 1.31, 1.31, 1.32, 1.33, 1.34, 1.34, 1.35, 1.36, 1.37,
1.37, 1.38, 1.39, 1.40, 1.40, 1.41, 1.42, 1.43, 1.43, 1.44, 1.45, 1.46, 1.46, 1.47, 1.48, 1.↩
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1.61, 1.61, 1.62, 1.63, 1.64, 1.64, 1.65, 1.66, 1.67, 1.67, 1.68, 1.69, 1.70, 1.71, 1.71, 1.↩
72, 1.73, 1.74, 1.74, 1.75, 1.76, 1.77, 1.77, 1.78, 1.79, 1.80, 1.80, 1.81, 1.82, 1.83, 1.84,
1.84, 1.85, 1.86, 1.87, 1.87, 1.88, 1.89, 1.90, 1.90, 1.91, 1.92, 1.93, 1.93, 1.94, 1.95, 1.↩
96, 1.97, 1.97, 1.98, 1.99, 2.00, 2.00, 2.01, 2.02, 2.03, 2.04, 2.04, 2.05, 2.06, 2.07, 2.07,
2.08, 2.09, 2.10, 2.10, 2.11, 2.12, 2.13, 2.14, 2.14, 2.15, 2.16, 2.17, 2.17, 2.18, 2.19, 2.↩
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2.32, 2.33, 2.34, 2.35, 2.35, 2.36, 2.37, 2.38, 2.39, 2.39, 2.40, 2.41, 2.42, 2.43, 2.43, 2.↩
44, 2.45, 2.46, 2.46, 2.47, 2.48, 2.49, 2.50, 2.50, 2.51, 2.52, 2.53, 2.54, 2.54, 2.55, 2.56,
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69, 2.70, 2.70, 2.71, 2.72, 2.73, 2.74, 2.74, 2.75, 2.76, 2.77, 2.78, 2.78, 2.79, 2.80, 2.81,
2.82, 2.82, 2.83, 2.84, 2.85, 2.86, 2.86, 2.87, 2.88, 2.89, 2.90, 2.90, 2.91, 2.92, 2.93, 2.↩
94, 2.94, 2.95, 2.96, 2.97, 2.98, 2.98, 2.99, 3.00, 3.01, 3.02, 3.02, 3.03, 3.04, 3.05, 3.06,
3.07, 3.07, 3.08, 3.09, 3.10, 3.11, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.16, 3.17, 3.18, 3.↩
19, 3.20, 3.20, 3.21, 3.22, 3.23, 3.24, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29, 3.29, 3.30, 3.31,
3.32, 3.33, 3.34, 3.34, 3.35, 3.36, 3.37, 3.38, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, 3.43, 3.↩
44, 3.45, 3.46, 3.47, 3.48, 3.48, 3.49, 3.50, 3.51, 3.52, 3.53, 3.53, 3.54, 3.55, 3.56, 3.57,
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3.83, 3.84, 3.85, 3.86, 3.87, 3.88, 3.89, 3.89, 3.90, 3.91, 3.92, 3.93, 3.94, 3.94, 3.95, 3.↩
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4.36, 4.37, 4.38, 4.39, 4.40, 4.41, 4.42, 4.42, 4.43, 4.44, 4.45, 4.46, 4.47, 4.48, 4.48, 4.↩
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4.63, 4.64, 4.65, 4.66, 4.67, 4.68, 4.69, 4.69, 4.70, 4.71, 4.72, 4.73, 4.74, 4.75, 4.76, 4.↩
76, 4.77, 4.78, 4.79, 4.80, 4.81, 4.82, 4.83, 4.83, 4.84, 4.85, 4.86, 4.87, 4.88, 4.89, 4.90,
4.91, 4.91, 4.92, 4.93, 4.94, 4.95, 4.96, 4.97, 4.98, 4.99, 4.99, 5.00, 5.01, 5.02, 5.03, 5.↩
04, 5.05, 5.06, 5.07, 5.07, 5.08, 5.09, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.16, 5.17,
5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.↩
32, 5.33, 5.34, 5.34, 5.35, 5.36, 5.37, 5.38, 5.39, 5.40, 5.41, 5.42, 5.43, 5.43, 5.44, 5.45,
5.46, 5.47, 5.48, 5.49, 5.50, 5.51, 5.52, 5.53, 5.53, 5.54, 5.55, 5.56, 5.57, 5.58, 5.59, 5.↩
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5.75, 5.75, 5.76, 5.77, 5.78, 5.79, 5.80, 5.81, 5.82, 5.83, 5.84, 5.85, 5.86, 5.87, 5.88, 5.↩
88, 5.89, 5.90, 5.91, 5.92, 5.93, 5.94, 5.95, 5.96, 5.97, 5.98, 5.99, 6.00, 6.01, 6.01, 6.02,
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7.84, 7.85, 7.86, 7.87, 7.88, 7.89, 7.91, 7.92, 7.93, 7.94, 7.95, 7.96, 7.97, 7.98, 7.99, 8.↩
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8.16, 8.17, 8.18, 8.19, 8.20, 8.21, 8.22, 8.23, 8.24, 8.25, 8.26, 8.27, 8.29, 8.30, 8.31, 8.↩
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8.81, 8.82, 8.83, 8.84, 8.85, 8.86, 8.87, 8.88, 8.89, 8.91, 8.92, 8.93, 8.94, 8.95, 8.96, 8.↩
97, 8.98, 8.99, 9.00, 9.01, 9.02, 9.03, 9.04, 9.06, 9.07, 9.08, 9.09, 9.10, 9.11, 9.12, 9.13,
9.14, 9.15, 9.16, 9.17, 9.18, 9.20, 9.21, 9.22, 9.23, 9.24, 9.25, 9.26, 9.27, 9.28, 9.29, 9.↩
30, 9.31, 9.33, 9.34, 9.35, 9.36, 9.37, 9.38, 9.39, 9.40, 9.41, 9.42, 9.43, 9.45, 9.46, 9.47,
9.48, 9.49, 9.50, 9.51, 9.52, 9.53, 9.54, 9.55, 9.57, 9.58, 9.59, 9.60, 9.61, 9.62, 9.63, 9.↩
64, 9.65, 9.66, 9.68, 9.69, 9.70, 9.71, 9.72, 9.73, 9.74, 9.75, 9.76, 9.78, 9.79, 9.80, 9.81,
9.82, 9.83, 9.84, 9.85, 9.86, 9.88, 9.89, 9.90, 9.91, 9.92, 9.93, 9.94, 9.95, 9.96, 9.98, 9.↩
99, 10.00, 10.01, 10.02, 10.03, 10.04, 10.05, 10.07, 10.08, 10.09, 10.10, 10.11, 10.12, 10.↩
13, 10.14, 10.16, 10.17, 10.18, 10.19, 10.20, 10.21, 10.22, 10.24, 10.25, 10.26, 10.27, 10.↩
28, 10.29, 10.30, 10.31, 10.33, 10.34, 10.35, 10.36, 10.37, 10.38, 10.39, 10.41, 10.42, 10.↩
43, 10.44, 10.45, 10.46, 10.47, 10.49, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.57, 10.↩
58, 10.59, 10.60, 10.61, 10.62, 10.64, 10.65, 10.66, 10.67, 10.68, 10.69, 10.70, 10.72, 10.↩
73, 10.74, 10.75, 10.76, 10.77, 10.79, 10.80, 10.81, 10.82, 10.83, 10.84, 10.86, 10.87, 10.↩
88, 10.89, 10.90, 10.91, 10.93, 10.94, 10.95, 10.96, 10.97, 10.98, 11.00, 11.01, 11.02, 11.↩
03, 11.04, 11.05, 11.07, 11.08, 11.09, 11.10, 11.11, 11.13, 11.14, 11.15, 11.16, 11.17, 11.↩
18, 11.20, 11.21, 11.22, 11.23, 11.24, 11.26, 11.27, 11.28, 11.29, 11.30, 11.32, 11.33, 11.↩
34, 11.35, 11.36, 11.37, 11.39, 11.40, 11.41, 11.42, 11.43, 11.45, 11.46, 11.47, 11.48, 11.↩
49, 11.51, 11.52, 11.53, 11.54, 11.55, 11.57, 11.58, 11.59, 11.60, 11.61, 11.63, 11.64, 11.↩
65, 11.66, 11.68, 11.69, 11.70, 11.71, 11.72, 11.74, 11.75, 11.76, 11.77, 11.78, 11.80, 11.↩
81, 11.82, 11.83, 11.85, 11.86, 11.87, 11.88, 11.89, 11.91, 11.92, 11.93, 11.94, 11.96, 11.↩
97, 11.98, 11.99, 12.00, 12.02, 12.03, 12.04, 12.05, 12.07, 12.08, 12.09, 12.10, 12.11, 12.↩
13, 12.14, 12.15, 12.16, 12.18, 12.19, 12.20, 12.21, 12.23, 12.24, 12.25, 12.26, 12.28, 12.↩
29, 12.30, 12.31, 12.33, 12.34, 12.35, 12.36, 12.38, 12.39, 12.40, 12.41, 12.43, 12.44, 12.↩
45, 12.46, 12.48, 12.49, 12.50, 12.51, 12.53, 12.54, 12.55, 12.56, 12.58, 12.59, 12.60, 12.↩
61, 12.63, 12.64, 12.65, 12.66, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.77, 12.↩
78, 12.79, 12.80, 12.82, 12.83, 12.84, 12.86, 12.87, 12.88, 12.89, 12.91, 12.92, 12.93, 12.↩
94, 12.96, 12.97, 12.98, 13.00, 13.01, 13.02, 13.03, 13.05, 13.06, 13.07, 13.09, 13.10, 13.↩
11, 13.12, 13.14, 13.15, 13.16, 13.18, 13.19, 13.20, 13.22, 13.23, 13.24, 13.25, 13.27, 13.↩
28, 13.29, 13.31, 13.32, 13.33, 13.35, 13.36, 13.37, 13.38, 13.40, 13.41, 13.42, 13.44, 13.↩
45, 13.46, 13.48, 13.49, 13.50, 13.52, 13.53, 13.54, 13.55, 13.57, 13.58, 13.59, 13.61, 13.↩
62, 13.63, 13.65, 13.66, 13.67, 13.69, 13.70, 13.71, 13.73, 13.74, 13.75, 13.77, 13.78, 13.↩
79, 13.81, 13.82, 13.83, 13.85, 13.86, 13.87, 13.89, 13.90, 13.91, 13.93, 13.94, 13.95, 13.↩
97, 13.98, 13.99, 14.01, 14.02, 14.03, 14.05, 14.06, 14.07, 14.09, 14.10, 14.11, 14.13, 14.↩
14, 14.16, 14.17, 14.18, 14.20, 14.21, 14.22, 14.24, 14.25, 14.26, 14.28, 14.29, 14.30, 14.↩
32, 14.33, 14.35, 14.36, 14.37, 14.39, 14.40, 14.41, 14.43, 14.44, 14.45, 14.47, 14.48, 14.↩
50, 14.51, 14.52, 14.54, 14.55, 14.56, 14.58, 14.59, 14.61, 14.62, 14.63, 14.65, 14.66, 14.↩
67, 14.69, 14.70, 14.72, 14.73, 14.74, 14.76, 14.77, 14.79, 14.80, 14.81, 14.83, 14.84, 14.↩
86, 14.87, 14.88, 14.90, 14.91, 14.93, 14.94, 14.95, 14.97, 14.98, 15.00, 15.01, 15.02, 15.↩
04, 15.05, 15.07, 15.08, 15.09, 15.11, 15.12, 15.14, 15.15, 15.16, 15.18, 15.19, 15.21, 15.↩
22, 15.24, 15.25, 15.26, 15.28, 15.29, 15.31, 15.32, 15.33, 15.35, 15.36, 15.38, 15.39, 15.↩
41, 15.42, 15.43, 15.45, 15.46, 15.48, 15.49, 15.51, 15.52, 15.54, 15.55, 15.56, 15.58, 15.↩
59, 15.61, 15.62, 15.64, 15.65, 15.66, 15.68, 15.69, 15.71, 15.72, 15.74, 15.75, 15.77, 15.↩
78, 15.80, 15.81, 15.82, 15.84, 15.85, 15.87, 15.88, 15.90, 15.91, 15.93, 15.94, 15.96, 15.↩
97, 15.99, 16.00, 16.01, 16.03, 16.04, 16.06, 16.07, 16.09, 16.10, 16.12, 16.13, 16.15, 16.↩
16, 16.18, 16.19, 16.21, 16.22, 16.24, 16.25, 16.27, 16.28, 16.30, 16.31, 16.33, 16.34, 16.↩
35, 16.37, 16.38, 16.40, 16.41, 16.43, 16.44, 16.46, 16.47, 16.49, 16.50, 16.52, 16.53, 16.↩
55, 16.56, 16.58, 16.59, 16.61, 16.62, 16.64, 16.66, 16.67, 16.69, 16.70, 16.72, 16.73, 16.↩
75, 16.76, 16.78, 16.79, 16.81, 16.82, 16.84, 16.85, 16.87, 16.88, 16.90, 16.91, 16.93, 16.↩
94, 16.96, 16.97, 16.99, 17.01, 17.02, 17.04, 17.05, 17.07, 17.08, 17.10, 17.11, 17.13, 17.↩
14, 17.16, 17.17, 17.19, 17.21, 17.22, 17.24, 17.25, 17.27, 17.28, 17.30, 17.31, 17.33, 17.↩
35, 17.36, 17.38, 17.39, 17.41, 17.42, 17.44, 17.45, 17.47, 17.49, 17.50, 17.52, 17.53, 17.↩
55, 17.56, 17.58, 17.60, 17.61, 17.63, 17.64, 17.66, 17.67, 17.69, 17.71, 17.72, 17.74, 17.↩
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96, 17.98, 17.99, 18.01, 18.02, 18.04, 18.06, 18.07, 18.09, 18.11, 18.12, 18.14, 18.15, 18.↩
17, 18.19, 18.20, 18.22, 18.23, 18.25, 18.27, 18.28, 18.30, 18.32, 18.33, 18.35, 18.36, 18.↩
38, 18.40, 18.41, 18.43, 18.45, 18.46, 18.48, 18.49, 18.51, 18.53, 18.54, 18.56, 18.58, 18.↩
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81, 18.82, 18.84, 18.86, 18.87, 18.89, 18.91, 18.92, 18.94, 18.96, 18.97, 18.99, 19.01, 19.↩
02, 19.04, 19.06, 19.08, 19.09, 19.11, 19.13, 19.14, 19.16, 19.18, 19.19, 19.21, 19.23, 19.↩
24, 19.26, 19.28, 19.29, 19.31, 19.33, 19.35, 19.36, 19.38, 19.40, 19.41, 19.43, 19.45, 19.↩
46, 19.48, 19.50, 19.52, 19.53, 19.55, 19.57, 19.58, 19.60, 19.62, 19.64, 19.65, 19.67, 19.↩
69, 19.70, 19.72, 19.74, 19.76, 19.77, 19.79, 19.81, 19.83, 19.84, 19.86, 19.88, 19.90, 19.↩
91, 19.93, 19.95, 19.97, 19.98, 20.00, 20.02, 20.04, 20.05, 20.07, 20.09, 20.11, 20.12, 20.↩
14, 20.16, 20.18, 20.19, 20.21, 20.23, 20.25, 20.26, 20.28, 20.30, 20.32, 20.33, 20.35, 20.↩
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84, 20.85, 20.87, 20.89, 20.91, 20.93, 20.95, 20.96, 20.98, 21.00, 21.02, 21.04, 21.06, 21.↩
07, 21.09, 21.11, 21.13, 21.15, 21.17, 21.18, 21.20, 21.22, 21.24, 21.26, 21.28, 21.29, 21.↩
31, 21.33, 21.35, 21.37, 21.39, 21.41, 21.42, 21.44, 21.46, 21.48, 21.50, 21.52, 21.54, 21.↩
55, 21.57, 21.59, 21.61, 21.63, 21.65, 21.67, 21.69, 21.70, 21.72, 21.74, 21.76, 21.78, 21.↩
80, 21.82, 21.84, 21.86, 21.87, 21.89, 21.91, 21.93, 21.95, 21.97, 21.99, 22.01, 22.03, 22.↩
05, 22.06, 22.08, 22.10, 22.12, 22.14, 22.16, 22.18, 22.20, 22.22, 22.24, 22.26, 22.28, 22.↩
30, 22.31, 22.33, 22.35, 22.37, 22.39, 22.41, 22.43, 22.45, 22.47, 22.49, 22.51, 22.53, 22.↩
55, 22.57, 22.59, 22.61, 22.63, 22.64, 22.66, 22.68, 22.70, 22.72, 22.74, 22.76, 22.78, 22.↩
80, 22.82, 22.84, 22.86, 22.88, 22.90, 22.92, 22.94, 22.96, 22.98, 23.00, 23.02, 23.04, 23.↩
06, 23.08, 23.10, 23.12, 23.14, 23.16, 23.18, 23.20, 23.22, 23.24, 23.26, 23.28, 23.30, 23.↩
32, 23.34, 23.36, 23.38, 23.40, 23.42, 23.44, 23.46, 23.48, 23.50, 23.52, 23.54, 23.56, 23.↩
58, 23.60, 23.62, 23.65, 23.67, 23.69, 23.71, 23.73, 23.75, 23.77, 23.79, 23.81, 23.83, 23.↩
85, 23.87, 23.89, 23.91, 23.93, 23.95, 23.97, 24.00, 24.02, 24.04, 24.06, 24.08, 24.10, 24.↩
12, 24.14, 24.16, 24.18, 24.20, 24.22, 24.25, 24.27, 24.29, 24.31, 24.33, 24.35, 24.37, 24.↩
39, 24.41, 24.43, 24.46, 24.48, 24.50, 24.52, 24.54, 24.56, 24.58, 24.60, 24.63, 24.65, 24.↩
67, 24.69, 24.71, 24.73, 24.75, 24.78, 24.80, 24.82, 24.84, 24.86, 24.88, 24.90, 24.93, 24.↩
95, 24.97, 24.99, 25.01, 25.03, 25.06, 25.08, 25.10, 25.12, 25.14, 25.16, 25.19, 25.21, 25.↩
23, 25.25, 25.27, 25.30, 25.32, 25.34, 25.36, 25.38, 25.41, 25.43, 25.45, 25.47, 25.49, 25.↩
52, 25.54, 25.56, 25.58, 25.60, 25.63, 25.65, 25.67, 25.69, 25.72, 25.74, 25.76, 25.78, 25.↩
81, 25.83, 25.85, 25.87, 25.89, 25.92, 25.94, 25.96, 25.98, 26.01, 26.03, 26.05, 26.08, 26.↩
10, 26.12, 26.14, 26.17, 26.19, 26.21, 26.23, 26.26, 26.28, 26.30, 26.33, 26.35, 26.37, 26.↩
39, 26.42, 26.44, 26.46, 26.49, 26.51, 26.53, 26.56, 26.58, 26.60, 26.63, 26.65, 26.67, 26.↩
69, 26.72, 26.74, 26.76, 26.79, 26.81, 26.83, 26.86, 26.88, 26.90, 26.93, 26.95, 26.98, 27.↩
00, 27.02, 27.05, 27.07, 27.09, 27.12, 27.14, 27.16, 27.19, 27.21, 27.24, 27.26, 27.28, 27.↩
31, 27.33, 27.35, 27.38, 27.40, 27.43, 27.45, 27.47, 27.50, 27.52, 27.55, 27.57, 27.59, 27.↩
62, 27.64, 27.67, 27.69, 27.72, 27.74, 27.76, 27.79, 27.81, 27.84, 27.86, 27.89, 27.91, 27.↩
93, 27.96, 27.98, 28.01, 28.03, 28.06, 28.08, 28.11, 28.13, 28.16, 28.18, 28.21, 28.23, 28.↩
26, 28.28, 28.30, 28.33, 28.35, 28.38, 28.40, 28.43, 28.45, 28.48, 28.50, 28.53, 28.55, 28.↩
58, 28.60, 28.63, 28.66, 28.68, 28.71, 28.73, 28.76, 28.78, 28.81, 28.83, 28.86, 28.88, 28.↩
91, 28.93, 28.96, 28.99, 29.01, 29.04, 29.06, 29.09, 29.11, 29.14, 29.17, 29.19, 29.22, 29.↩
24, 29.27, 29.29, 29.32, 29.35, 29.37, 29.40, 29.42, 29.45, 29.48, 29.50, 29.53, 29.55, 29.↩
58, 29.61, 29.63, 29.66, 29.69, 29.71, 29.74, 29.76, 29.79, 29.82, 29.84, 29.87, 29.90, 29.↩
92, 29.95, 29.98, 30.00, 30.03, 30.06, 30.08, 30.11, 30.14, 30.16, 30.19, 30.22, 30.24, 30.↩
27, 30.30, 30.33, 30.35, 30.38, 30.41, 30.43, 30.46, 30.49, 30.52, 30.54, 30.57, 30.60, 30.↩
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98, 31.01, 31.04, 31.07, 31.09, 31.12, 31.15, 31.18, 31.21, 31.23, 31.26, 31.29, 31.32, 31.↩
35, 31.37, 31.40, 31.43, 31.46, 31.49, 31.52, 31.54, 31.57, 31.60, 31.63, 31.66, 31.69, 31.↩
72, 31.74, 31.77, 31.80, 31.83, 31.86, 31.89, 31.92, 31.95, 31.97, 32.00, 32.03, 32.06, 32.↩
09, 32.12, 32.15, 32.18, 32.21, 32.24, 32.27, 32.29, 32.32, 32.35, 32.38, 32.41, 32.44, 32.↩
47, 32.50, 32.53, 32.56, 32.59, 32.62, 32.65, 32.68, 32.71, 32.74, 32.77, 32.80, 32.83, 32.↩
86, 32.89, 32.92, 32.95, 32.98, 33.01, 33.04, 33.07, 33.10, 33.13, 33.16, 33.19, 33.22, 33.↩
25, 33.28, 33.31, 33.34, 33.37, 33.40, 33.43, 33.46, 33.49, 33.53, 33.56, 33.59, 33.62, 33.↩
65, 33.68, 33.71, 33.74, 33.77, 33.80, 33.84, 33.87, 33.90, 33.93, 33.96, 33.99, 34.02, 34.↩
05, 34.09, 34.12, 34.15, 34.18, 34.21, 34.24, 34.28, 34.31, 34.34, 34.37, 34.40, 34.43, 34.↩
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89, 34.92, 34.95, 34.98, 35.02, 35.05, 35.08, 35.11, 35.15, 35.18, 35.21, 35.25, 35.28, 35.↩
31, 35.35, 35.38, 35.41, 35.44, 35.48, 35.51, 35.54, 35.58, 35.61, 35.65, 35.68, 35.71, 35.↩
75, 35.78, 35.81, 35.85, 35.88, 35.91, 35.95, 35.98, 36.02, 36.05, 36.08, 36.12, 36.15, 36.↩
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19, 36.22, 36.26, 36.29, 36.33, 36.36, 36.39, 36.43, 36.46, 36.50, 36.53, 36.57, 36.60, 36.↩
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09, 37.13, 37.17, 37.20, 37.24, 37.27, 37.31, 37.34, 37.38, 37.42, 37.45, 37.49, 37.52, 37.↩
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19, 42.24, 42.28, 42.32, 42.37, 42.41, 42.46, 42.50, 42.54, 42.59, 42.63, 42.68, 42.72, 42.↩
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35, 43.39, 43.44, 43.48, 43.53, 43.58, 43.62, 43.67, 43.71, 43.76, 43.81, 43.85, 43.90, 43.↩
94, 43.99, 44.04, 44.08, 44.13, 44.18, 44.23, 44.27, 44.32, 44.37, 44.41, 44.46, 44.51, 44.↩
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15, 47.21, 47.26, 47.31, 47.37, 47.42, 47.47, 47.52, 47.58, 47.63, 47.69, 47.74, 47.79, 47.↩
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04, 50.10, 50.16, 50.21, 50.27, 50.33, 50.39, 50.45, 50.51, 50.57, 50.63, 50.69, 50.75, 50.↩
81, 50.87, 50.93, 50.99, 51.05, 51.11, 51.17, 51.24, 51.30, 51.36, 51.42, 51.48, 51.54, 51.↩
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43, 52.49, 52.55, 52.62, 52.68, 52.75, 52.81, 52.88, 52.94, 53.01, 53.07, 53.14, 53.21, 53.↩
27, 53.34, 53.40, 53.47, 53.54, 53.60, 53.67, 53.74, 53.80, 53.87, 53.94, 54.01, 54.08, 54.↩
14, 54.21, 54.28, 54.35, 54.42, 54.49, 54.56, 54.63, 54.70, 54.76, 54.83, 54.90, 54.98, 55.↩
05, 55.12, 55.19, 55.26, 55.33, 55.40, 55.47, 55.54, 55.62, 55.69, 55.76, 55.83, 55.91, 55.↩
98, 56.05, 56.12, 56.20, 56.27, 56.35, 56.42, 56.49, 56.57, 56.64, 56.72, 56.79, 56.87, 56.↩
94, 57.02, 57.10, 57.17, 57.25, 57.32, 57.40, 57.48, 57.56, 57.63, 57.71, 57.79, 57.87, 57.↩
94, 58.02, 58.10, 58.18, 58.26, 58.34, 58.42, 58.50, 58.58, 58.66, 58.74, 58.82, 58.90, 58.↩
98, 59.06, 59.15, 59.23, 59.31, 59.39, 59.48, 59.56, 59.64, 59.72, 59.81, 59.89, 59.98, 60.↩
06, 60.15, 60.23, 60.32, 60.40, 60.49, 60.57, 60.66, 60.75, 60.83, 60.92, 61.01, 61.10, 61.↩
18, 61.27, 61.36, 61.45, 61.54, 61.63, 61.72, 61.81, 61.90, 61.99, 62.08, 62.17, 62.26, 62.↩
35, 62.44, 62.54, 62.63, 62.72, 62.82, 62.91, 63.00, 63.10, 63.19, 63.29, 63.38, 63.48, 63.↩
57, 63.67, 63.76, 63.86, 63.96, 64.06, 64.15, 64.25, 64.35, 64.45, 64.55, 64.65, 64.75, 64.↩
85, 64.95, 65.05, 65.15, 65.25, 65.35, 65.46, 65.56, 65.66, 65.76, 65.87, 65.97, 66.08, 66.↩
18, 66.29, 66.39, 66.50, 66.61, 66.71, 66.82, 66.93, 67.03, 67.14, 67.25, 67.36, 67.47, 67.↩
58, 67.69, 67.80, 67.91, 68.03, 68.14, 68.25, 68.36, 68.48, 68.59, 68.71, 68.82, 68.94, 69.↩
05, 69.17, 69.29, 69.40, 69.52, 69.64, 69.76, 69.88, 70.00, 70.12, 70.24, 70.36, 70.48, 70.↩
60, 70.73, 70.85, 70.97, 71.10, 71.22, 71.35, 71.47, 71.60, 71.73, 71.86, 71.98, 72.11, 72.↩
24, 72.37, 72.50, 72.63, 72.76, 72.90, 73.03, 73.16, 73.30, 73.43, 73.57, 73.70, 73.84, 73.↩
98, 74.11, 74.25, 74.39, 74.53, 74.67, 74.81, 74.95, 75.10, 75.24, 75.38, 75.53, 75.67, 75.↩
82, 75.97, 76.11, 76.26, 76.41, 76.56, 76.71, 76.86, 77.01, 77.17, 77.32, 77.47, 77.63, 77.↩
78, 77.94, 78.10, 78.26, 78.42, 78.58, 78.74, 78.90, 79.06, 79.23, 79.39, 79.55, 79.72, 79.↩
89, 80.06, 80.23, 80.40, 80.57, 80.74, 80.91, 81.08, 81.26, 81.44, 81.61, 81.79, 81.97, 82.↩
15, 82.33, 82.51, 82.70, 82.88, 83.07, 83.25, 83.44, 83.63, 83.82, 84.01, 84.20, 84.40, 84.↩
59, 84.79, 84.98, 85.18, 85.38, 85.58, 85.79, 85.99, 86.20, 86.40, 86.61, 86.82, 87.03, 87.↩
24, 87.46, 87.67, 87.89, 88.11, 88.33, 88.55, 88.77, 89.00, 89.22, 89.45, 89.68, 89.91, 90.↩
14, 90.38, 90.62, 90.85, 91.09, 91.34, 91.58, 91.82, 92.07, 92.32, 92.57, 92.83, 93.08, 93.↩
34, 93.60, 93.86, 94.13, 94.39, 94.66, 94.93, 95.20, 95.48, 95.76, 96.04, 96.32, 96.61, 96.89,
97.18, 97.48, 97.77, 98.07, 98.37, 98.68, 98.98, 99.29, 99.61, 99.92, 100.24, 100.56, 100.89,
101.22, 101.55, 101.88, 102.22, 102.56, 102.91, 103.26, 103.61, 103.97, 104.33, 104.70, 105.↩
07, 105.44, 105.82, 106.20, 106.58, 106.98, 107.37, 107.77, 108.18, 108.59, 109.00, 109.42,
109.85, 110.28, 110.71, 111.16, 111.60, 112.06, 112.52, 112.99, 113.46, 113.94, 114.43, 114.↩
```

```
92, 115.42, 115.93, 116.44, 116.97, 117.50, 118.04, 118.59, 119.14, 119.71, 120.29, 120.87,
121.47, 122.07, 122.69, 123.32, 123.95, 124.61, 125.27, 125.94, 126.63, 127.33, 128.05, 128.←↩
78, 129.52, 130.29, 131.06, 131.86, 132.67, 133.50, 134.35, 135.22, 136.12, 137.03, 137.97,
138.93, 139.92, 140.93, 141.97, 143.05, 144.15, 145.29, 146.46, 147.67, 148.92, 150.22, 151.←↩
55, 152.94, 154.38, 155.87, 157.42, 159.04, 160.72, 162.48, 164.33, 166.26, 168.29, 170.42,
172.68, 175.07, 177.60, 180.30, 183.19, 186.29, 189.63, 193.26, 197.23, 201.59, 206.43, 211.←↩
86, 218.04, 225.19, 233.64, 243.93, 257.02, 274.82, 302.24, 360.00, 421.98, 421.98, 421.98,
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98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98,
421.98}
```
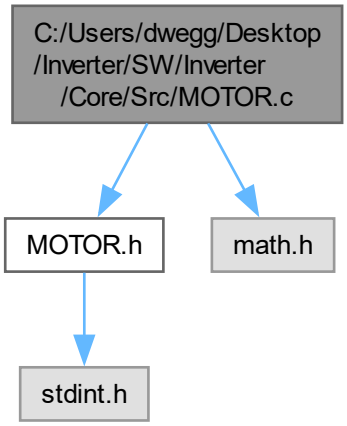

4.34 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MOTOR.c File Reference

Source file for motor parameters.

```
#include "MOTOR.h"
#include <math.h>
```

Include dependency graph for MOTOR.c:



Functions

- void precalculate_motor_constants (MotorParameters *motor)

  Precomputes the constants for a motor and updates the MotorParameters structure.
- int check_motor_parameters (MotorParameters *motor, float Ts)

  Perform a parameter check and correct possible errors.

Variables

- MotorParameters motor_left

  Left motor parameters.
- MotorParameters motor_right

  Right motor parameters.

4.34.1 Detailed Description

Source file for motor parameters.

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4.34.2 Function Documentation

4.34.2.1 check_motor_parameters()

```
int check_motor_parameters (
            MotorParameters * motor,
            float Ts )
```

Perform a parameter check and correct possible errors.

Parameters

in	*motor*	Pointer to the MotorParameters struct.

Return values

OK	0 if an error occurred, 1 if successful.

Here is the caller graph for this function:

4.34.2.2 precalculate_motor_constants()

```
void precalculate_motor_constants (
            MotorParameters * motor )
```

Precomputes the constants for a motor and updates the MotorParameters structure.

Parameters

motor	[in, out] Pointer to the motor parameters structure

Here is the caller graph for this function:

4.34.3 Variable Documentation

4.34.3.1 motor_left

```
MotorParameters motor_left
```

Initial value:

```
= {
    .Ld = 0.00291F,
    .Lq = 0.00291F,
    .Rs = 1.95F,
    .lambda = 0.13391F,
    .pp = 4,
    .J = 0.00093F,
    .b = 0.632653F,
    .torqueMax = 10.0F,
    .dTorqueMax = 1.0F,
    .speedMax_RPM = 8500.0F,
    .iMax = 60.0F,
    .vDCMax = 450.0F
}
```

Left motor parameters.

4.34.3.2 motor_right

```
MotorParameters motor_right
```

Initial value:

```
= {
    .Ld = 0.00291F,
    .Lq = 0.00291F,
    .Rs = 1.95F,
    .lambda = 0.13391F,
    .pp = 4,
    .J = 0.00093F,
    .b = 0.632653F,
    .torqueMax = 10.0F,
    .dTorqueMax = 1.0F,
    .speedMax_RPM = 8500.0F,
    .iMax = 60.0F,
    .vDCMax = 450.0F
}
```

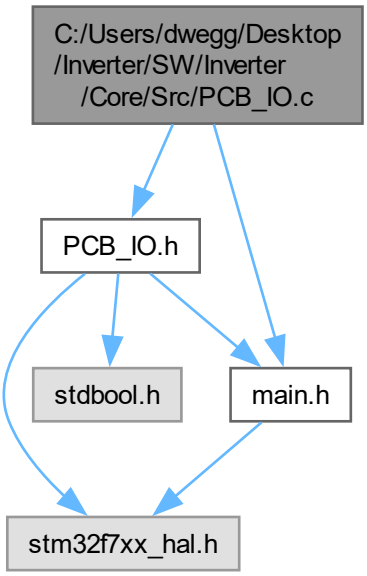
Right motor parameters.

4.35 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PCB_IO.c File Reference

This file provides functions for handling GPIOs.

```
#include "PCB_IO.h"
#include "main.h"
```

Include dependency graph for PCB_IO.c:



Functions

- void handle_LED (LED *led, uint32_t ms_counter)

  LED handler function.
- void handle_direction (volatile int8_t *dir_left, volatile int8_t *dir_right)

  Handles the direction of the motors.
- void enable_inverters (volatile bool enableSW_left, volatile bool enableSW_right, volatile bool *enable_left, volatile bool *enable_right)

  Handles the direction of the motors and enables/disables the inverters.

Variables

- LED led_left = { .port = LED_LEFT_GPIO_Port, .pin = LED_LEFT_Pin, .mode = LED_MODE_OFF }
- LED led_right = { .port = LED_RIGHT_GPIO_Port, .pin = LED_RIGHT_Pin, .mode = LED_MODE_OFF }
- LED ledError = { .port = LED_ERR_GPIO_Port, .pin = LED_ERR_Pin, .mode = LED_MODE_OFF }

4.35.1 Detailed Description

This file provides functions for handling GPIOs.

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4.35.2 Function Documentation

4.35.2.1 enable_inverters()

```
void enable_inverters (
            volatile bool enableSW_left,
            volatile bool enableSW_right,
            volatile bool * enable_left,
            volatile bool * enable_right )
```

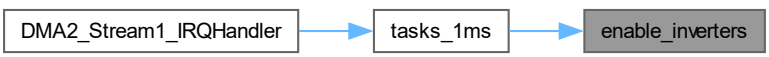
Handles the direction of the motors and enables/disables the inverters.

This function reads the state of the shutdown chain (SC or SDC) and enables/disables the inverters based on that and an external software enable bool.

Parameters

in	*enableSW_left*	The software enable state for the left inverter.
in	*enableSW_right*	The software enable state for the right inverter.
out	*enable_left*	Output parameter for the left inverter's enable state.
out	*enable_right*	Output parameter for the right inverter's enable state.

Here is the caller graph for this function:



4.35.2.2 handle_direction()

```
void handle_direction (
            volatile int8_t * dir_left,
            volatile int8_t * dir_right )
```

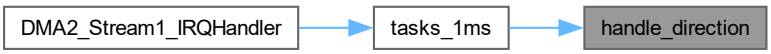
Handles the direction of the motors.

This function reads the state of the DIR switch and updates the directions of both the left and right motors. If one motor is set to rotate clockwise (CW), the other one is set to rotate counterclockwise (CCW), and vice versa.

Parameters

dir_left	Pointer to the direction parameter in the left inverter structure.
dir_right	Pointer to the direction parameter in the right inverter structure.

Here is the caller graph for this function:



4.35.2.3 handle_LED()

```
void handle_LED (
            LED * led,
            uint32_t ms_counter )
```

LED handler function.

This function handles the LED blinking modes based on the LED mode and current millisecond counter.

Parameters

led	Pointer to the LED structure.
ms_counter	Current millisecond counter.

Here is the caller graph for this function:

4.35.3 Variable Documentation

4.35.3.1 led_left

```
LED led_left = { .port = LED_LEFT_GPIO_Port, .pin = LED_LEFT_Pin, .mode = LED_MODE_OFF }
```

4.35.3.2 led_right

```
LED led_right = { .port = LED_RIGHT_GPIO_Port, .pin = LED_RIGHT_Pin, .mode = LED_MODE_OFF }
```

4.35.3.3 ledError

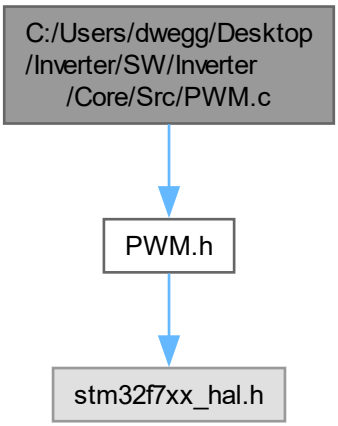
```
LED ledError = { .port = LED_ERR_GPIO_Port, .pin = LED_ERR_Pin, .mode = LED_MODE_OFF }
```

4.36 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PWM.c File Reference

This file provides functions for controlling PWM output.

```
#include "PWM.h"
```

Include dependency graph for PWM.c:



Functions

- void enable_PWM (TIM_HandleTypeDef *htim)

  Enable PWM output.
- void disable_PWM (TIM_HandleTypeDef *htim)

  Disable PWM output.
- void update_PWM (TIM_HandleTypeDef *htim, Duties duties)

  Set PWM duty cycles.

4.36.1 Detailed Description

This file provides functions for controlling PWM output.

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4.36.2 Function Documentation

4.36.2.1 disable_PWM()

```
void disable_PWM (
            TIM_HandleTypeDef * htim )
```

Disable PWM output.

This function disables PWM output for the specified timer.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.

4.36.2.2 enable_PWM()

```
void enable_PWM (
            TIM_HandleTypeDef * htim )
```

Enable PWM output.

This function enables PWM output for the specified timer.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.

4.36.2.3 update_PWM()

```
void update_PWM (
            TIM_HandleTypeDef * htim,
            Duties duties )
```

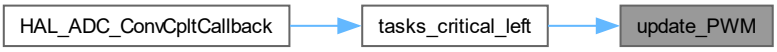
Set PWM duty cycles.

This function sets the duty cycles for the PWM channels.

Parameters

htim	Pointer to the TIM_HandleTypeDef structure.
duties	Duties structure containing duty cycle values.

Here is the caller graph for this function:

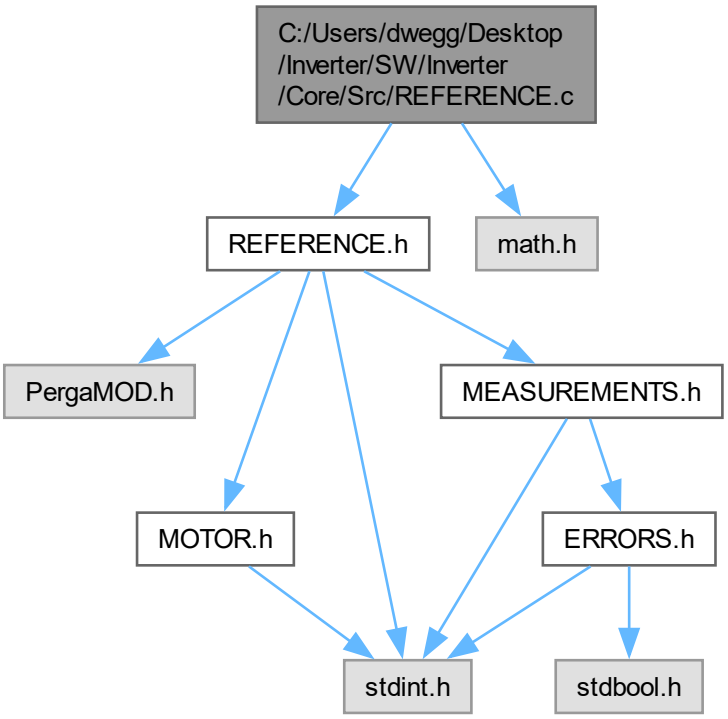


4.37 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/↩ REFERENCE.c File Reference

Source file for torque reference handling.

```
#include "REFERENCE.h"
#include <math.h>
```

Include dependency graph for REFERENCE.c:



Functions

- float handle_torqueRef (float torqueRefIn, int8_t direction, float torqueMax, float speedMaxRPM, float speedMeas, volatile pi_struct *loopSpeed)

  Handles torque control based on the reference torque, direction, maximum torque, maximum speed, measured speed, maximum torque rate of change, speed control loop parameters, and sampling time.
- float set_torque_direction (float torqueRefIn, int8_t direction)

  Set torque direction based on inverter direction.
- float saturate_symmetric (float ref, float max)

  Symmetrically saturate a reference value.
- float limit_torque_to_prevent_overspeed (float speedMaxRPM, float speedMeas, float torqueRefIn, volatile pi_struct *loopSpeed)

  Speed loop acts as a torque saturation, reducing torque in order to limit the maximum speed.
- float calculate_derated_current (float temperature, float tempStart, float tempMax, float iMax)

  Calculate derated current based on temperature thresholds. It implements a simple linear derating from tempStart to tempMax.
- float derate_current_reference (float tempMotor, float tempInverter, float iMax)

  Derate the current reference based on both motor and inverter temperatures.

Variables

- float torqueRefIn_left = 0.0F
- float torqueRefIn_right = 0.0F

4.37.1 Detailed Description

Source file for torque reference handling.

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4.37.2 Function Documentation

4.37.2.1 calculate_derated_current()

```
float calculate_derated_current (
            float temperature,
            float tempStart,
            float tempMax,
            float iMax )
```

Calculate derated current based on temperature thresholds. It implements a simple linear derating from tempStart to tempMax.

Parameters

in	*temperature*	The current temperature.
in	*tempStart*	The temperature at which derating starts.
in	*tempMax*	The temperature at which the current is fully derated to 0.
in	*iMax*	The maximum current.

Returns

The derated current.

Here is the caller graph for this function:

4.37.2.2 derate_current_reference()

```
float derate_current_reference (
            float tempMotor,
```

```
            float tempInverter,
            float iMax )
```

Derate the current reference based on both motor and inverter temperatures.

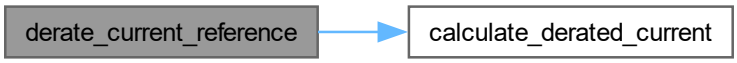
Parameters

in	*tempMotor*	The motor temperature.
in	*tempInverter*	The inverter temperature.
in	*iMax*	The maximum current.

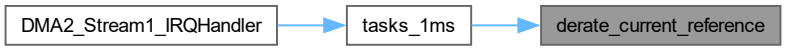
Returns

The derated current reference.

Here is the call graph for this function:



Here is the caller graph for this function:



4.37.2.3 handle_torqueRef()

```
float handle_torqueRef (
            float torqueRefIn,
            int8_t direction,
            float torqueMax,
            float speedMaxRPM,
            float speedMeas,
            volatile pi_struct * loopSpeed )
```

Handles torque control based on the reference torque, direction, maximum torque, maximum speed, measured speed, maximum torque rate of change, speed control loop parameters, and sampling time.

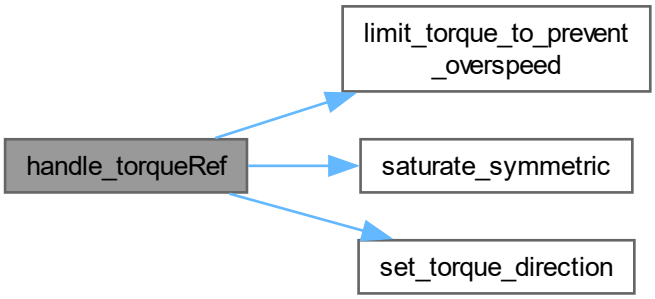
Parameters

torqueRefIn	Input reference torque.
direction	Direction of torque (1 for positive torque, -1 for negative torque).
torqueMax	Maximum allowable torque.
speedMaxRPM	Maximum allowable speed in RPM.
speedMeas	Measured speed.
loopSpeed	Speed control loop parameters.

Returns

The output torque after handling direction, saturation, and rate limiting.

Here is the call graph for this function:



Here is the caller graph for this function:

4.37.2.4 limit_torque_to_prevent_overspeed()

```
float limit_torque_to_prevent_overspeed (
            float speedMaxRPM,
            float speedMeas,
            float torqueRefIn,
            volatile pi_struct * loopSpeed )
```

Speed loop acts as a torque saturation, reducing torque in order to limit the maximum speed.

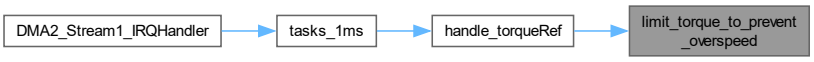
Parameters

in	*speedMaxRPM*	The maximum speed value in RPM.
in	*speedMeas*	The measured speed value in RPM.
in	*torqueRefIn*	The torque reference value before this saturation.
in	*loopSpeed*	Pointer to the speed PI controller structure.

Returns

torqueRefOut The limited torque reference value after this saturation.

Here is the caller graph for this function:



4.37.2.5 saturate_symmetric()

```
float saturate_symmetric (
            float ref,
            float max )
```

Symmetrically saturate a reference value.

This function symmetrically saturates a reference value based on the maximum allowed value. If the reference value exceeds the maximum allowed value, it is saturated to the maximum value. If the reference value is less than the negative of the maximum allowed value, it is saturated to the negative of the maximum value.

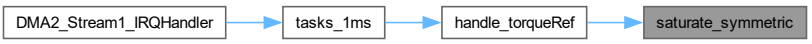
Parameters

in	*ref*	The reference value to saturate.
in	*max*	The maximum allowed value for saturation.

Returns

The saturated reference value.

Here is the caller graph for this function:



4.37.2.6 set_torque_direction()

```
float set_torque_direction (
            float torqueRefIn,
            int8_t direction )
```

Set torque direction based on inverter direction.

This function adjusts the torque reference based on the desired direction. If the motor is set to rotate counterclockwise (CCW), positive torque represents traction, negative is braking. If the motor is set to rotate clockwise (CW), negative torque represents traction, positive is braking.

Parameters

in	*torque↩ RefIn*	The torque reference value to adjust.
in	*direction*	Pointer to the direction of the inverter (1 for CW, -1 for CCW).

Returns

torqueRefOut The adjusted torque reference value.

Here is the caller graph for this function:

4.37.3 Variable Documentation

4.37.3.1 torqueRefIn_left

```
float torqueRefIn_left = 0.0F
```

4.37.3.2 torqueRefIn_right

```
float torqueRefIn_right = 0.0F
```

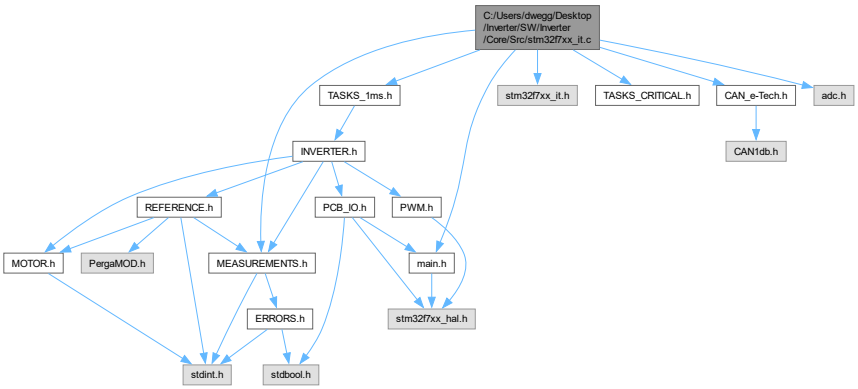
4.38 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/stm32f7xx↩ _it.c File Reference

Interrupt Service Routines.

```
#include "main.h"
#include "stm32f7xx_it.h"
```

```
#include "TASKS_1ms.h"
#include "TASKS_CRITICAL.h"
#include "CAN_e-Tech.h"
#include "adc.h"
#include "MEASUREMENTS.h"
```

Include dependency graph for stm32f7xx_it.c:



Functions

- void NMI_Handler (void)

  This function handles Non maskable interrupt.
- void HardFault_Handler (void)

  This function handles Hard fault interrupt.
- void MemManage_Handler (void)

  This function handles Memory management fault.
- void BusFault_Handler (void)

  This function handles Pre-fetch fault, memory access fault.
- void UsageFault_Handler (void)

  This function handles Undefined instruction or illegal state.
- void SVC_Handler (void)

  This function handles System service call via SWI instruction.
- void DebugMon_Handler (void)

  This function handles Debug monitor.
- void PendSV_Handler (void)

  This function handles Pendable request for system service.
- void SysTick_Handler (void)

  This function handles System tick timer.
- void CAN1_RX0_IRQHandler (void)

  This function handles CAN1 RX0 interrupts.
- void TIM1_UP_TIM10_IRQHandler (void)

  This function handles TIM1 update interrupt and TIM10 global interrupt.
- void TIM6_DAC_IRQHandler (void)

  This function handles TIM6 global interrupt, DAC1 and DAC2 underrun error interrupts.
- void DMA2_Stream0_IRQHandler (void)

  This function handles DMA2 stream0 global interrupt.
- void DMA2_Stream1_IRQHandler (void)

  This function handles DMA2 stream1 global interrupt.
- void DMA2_Stream2_IRQHandler (void)

  This function handles DMA2 stream2 global interrupt.
- void HAL_ADC_ConvCpltCallback (ADC_HandleTypeDef *hadc)

Variables

- DMA_HandleTypeDef hdma_adc1
- DMA_HandleTypeDef hdma_adc2
- DMA_HandleTypeDef hdma_adc3
- CAN_HandleTypeDef hcan1
- DAC_HandleTypeDef hdac
- TIM_HandleTypeDef htim1
- TIM_HandleTypeDef htim6

4.38.1 Detailed Description

Interrupt Service Routines.

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4.38.2 Function Documentation

4.38.2.1 BusFault_Handler()

```
void BusFault_Handler (
             void  )
```

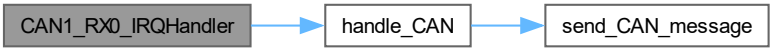
This function handles Pre-fetch fault, memory access fault.

4.38.2.2 CAN1_RX0_IRQHandler()

```
void CAN1_RX0_IRQHandler (
             void  )
```

This function handles CAN1 RX0 interrupts.

Here is the call graph for this function:



4.38.2.3 DebugMon_Handler()

```
void DebugMon_Handler (
            void  )
```

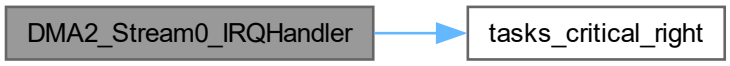
This function handles Debug monitor.

4.38.2.4 DMA2_Stream0_IRQHandler()

```
void DMA2_Stream0_IRQHandler (
            void  )
```

This function handles DMA2 stream0 global interrupt.

Here is the call graph for this function:

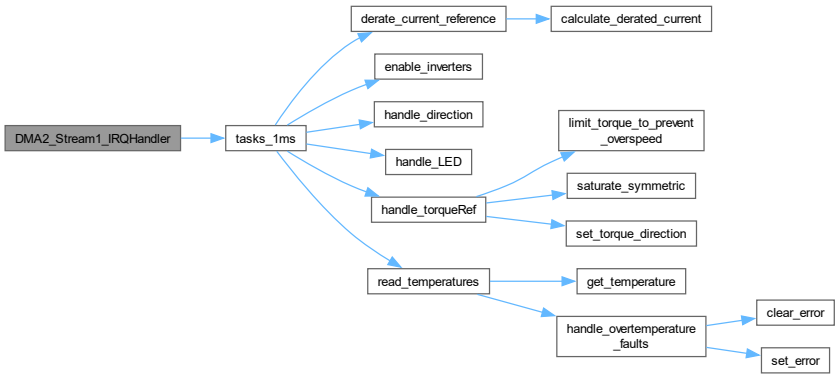


4.38.2.5 DMA2_Stream1_IRQHandler()

```
void DMA2_Stream1_IRQHandler (
            void  )
```

This function handles DMA2 stream1 global interrupt.

Here is the call graph for this function:



4.38.2.6 DMA2_Stream2_IRQHandler()

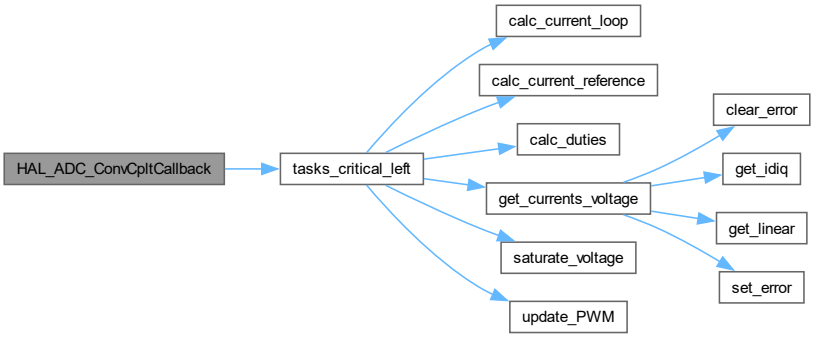
```
void DMA2_Stream2_IRQHandler (
            void  )
```

This function handles DMA2 stream2 global interrupt.

4.38.2.7 HAL_ADC_ConvCpltCallback()

```
void HAL_ADC_ConvCpltCallback (
            ADC_HandleTypeDef * hadc )
```

Here is the call graph for this function:



4.38.2.8 HardFault_Handler()

```
void HardFault_Handler (
            void  )
```

This function handles Hard fault interrupt.

4.38.2.9 MemManage_Handler()

```
void MemManage_Handler (
            void  )
```

This function handles Memory management fault.

4.38.2.10 NMI_Handler()

```
void NMI_Handler (
            void  )
```

This function handles Non maskable interrupt.

4.38.2.11 PendSV_Handler()

```
void PendSV_Handler (
             void  )
```

This function handles Pendable request for system service.

4.38.2.12 SVC_Handler()

```
void SVC_Handler (
             void  )
```

This function handles System service call via SWI instruction.

4.38.2.13 SysTick_Handler()

```
void SysTick_Handler (
             void  )
```

This function handles System tick timer.

4.38.2.14 TIM1_UP_TIM10_IRQHandler()

```
void TIM1_UP_TIM10_IRQHandler (
             void  )
```

This function handles TIM1 update interrupt and TIM10 global interrupt.

4.38.2.15 TIM6_DAC_IRQHandler()

```
void TIM6_DAC_IRQHandler (
             void  )
```

This function handles TIM6 global interrupt, DAC1 and DAC2 underrun error interrupts.

4.38.2.16 UsageFault_Handler()

```
void UsageFault_Handler (
             void  )
```

This function handles Undefined instruction or illegal state.

4.38.3 Variable Documentation

4.38.3.1 hcan1

```
CAN_HandleTypeDef hcan1  [extern]
```

4.38.3.2 hdac

```
DAC_HandleTypeDef hdac  [extern]
```

4.38.3.3 hdma_adc1

```
DMA_HandleTypeDef hdma_adc1  [extern]
```

4.38.3.4 hdma_adc2

```
DMA_HandleTypeDef hdma_adc2  [extern]
```

4.38.3.5 hdma_adc3

```
DMA_HandleTypeDef hdma_adc3  [extern]
```

4.38.3.6 htim1

```
TIM_HandleTypeDef htim1  [extern]
```

4.38.3.7 htim6

```
TIM_HandleTypeDef htim6  [extern]
```

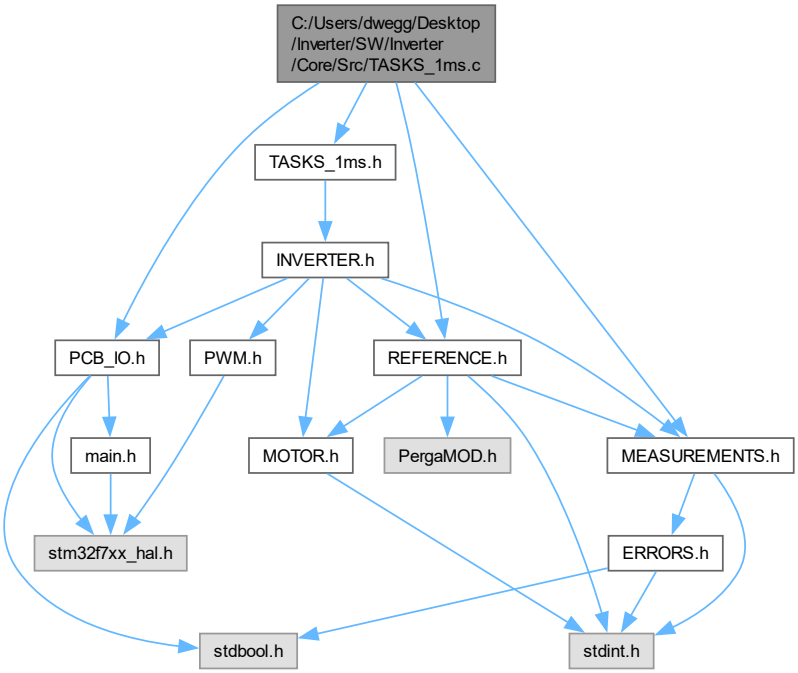
4.39 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_↩ 1ms.c File Reference

This file contains functions to execute tasks every 1ms.

```
#include "TASKS_1ms.h"
#include "PCB_IO.h"
#include "MEASUREMENTS.h"
```

```
#include "REFERENCE.h"
```

Include dependency graph for TASKS_1ms.c:



Functions

- void tasks_1ms (void)

  Function to be executed every 1ms.
- void read_temperatures (void)

  Function to read temperatures and handle overtemperature faults.
- void handle_overtemperature_faults (volatile InverterStruct *inv)

  Function to handle overtemperature faults.

4.39.1 Detailed Description

This file contains functions to execute tasks every 1ms.

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4.39.2 Function Documentation

4.39.2.1 handle_overtemperature_faults()

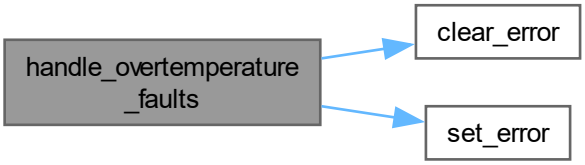
```
void handle_overtemperature_faults (
            volatile InverterStruct * inv )
```

Function to handle overtemperature faults.

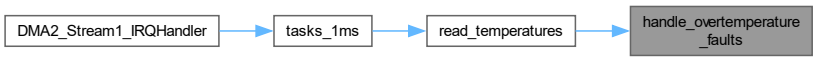
Parameters

in,out	*inv*	Pointer to the InverterStruct structure.

Here is the call graph for this function:



Here is the caller graph for this function:

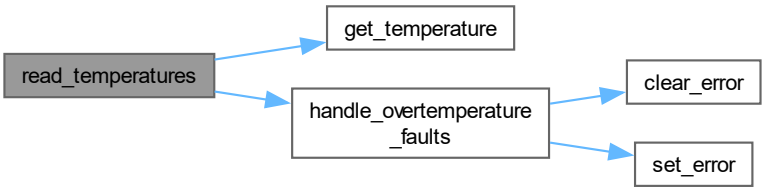


4.39.2.2 read_temperatures()

```
void read_temperatures (
            void  )
```

Function to read temperatures and handle overtemperature faults.

Here is the call graph for this function:



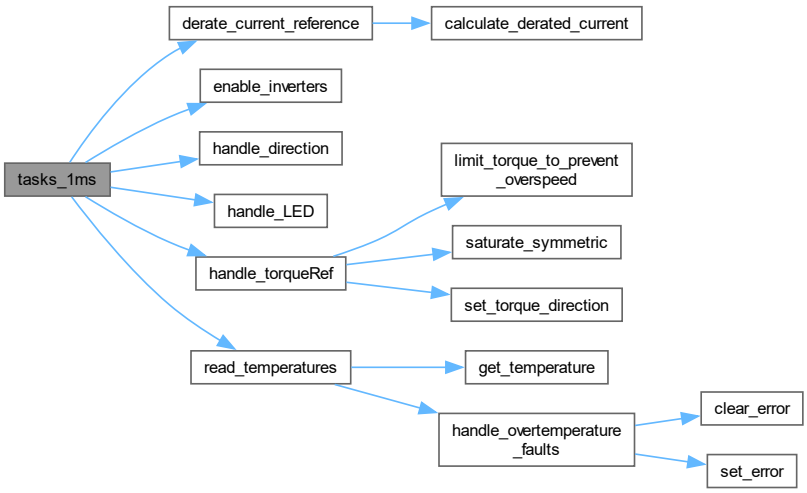
Here is the caller graph for this function:

4.39.2.3 tasks_1ms()

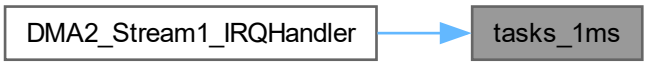
```
void tasks_1ms (
            void  )
```

Function to be executed every 1ms.

This function is called by the TIM6 IRQ handler every millisecond. It increments the millisecond counter and executes all the low priority tasks. Here is the call graph for this function:



Here is the caller graph for this function:

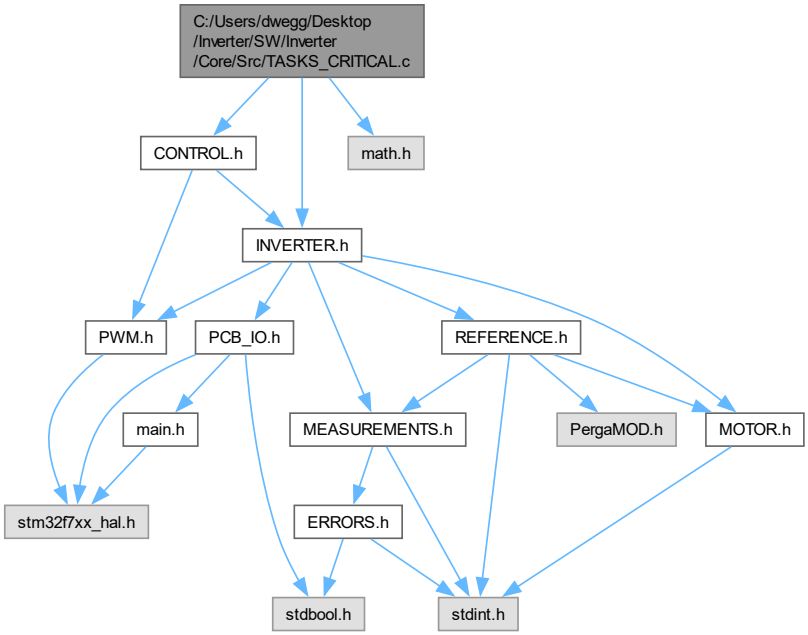


4.40 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_CRITICAL.c File Reference

This file contains functions executed in each PWM timer interruption.

```
#include "CONTROL.h"
#include "INVERTER.h"
#include <math.h>
```

Include dependency graph for TASKS_CRITICAL.c:



Functions

- void tasks_critical_left (void)

  Function to be executed every TS.
- void tasks_critical_right (void)

  Function to be executed every TS.

Variables

- uint32_t start_ticks = 0
- uint32_t elapsed_ticks = 0
- angle_struct angle_left
- rampa_struct freqRamp_left

4.40.1 Detailed Description

This file contains functions executed in each PWM timer interruption.

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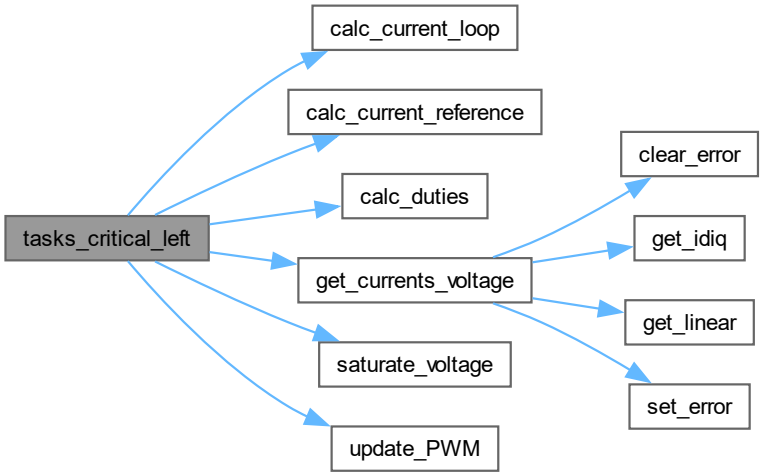
4.40.2 Function Documentation

4.40.2.1 tasks_critical_left()

```
void tasks_critical_left (
            void  )
```

Function to be executed every TS.

This function is called by the TIM1 trigger handler every TS. Here is the call graph for this function:



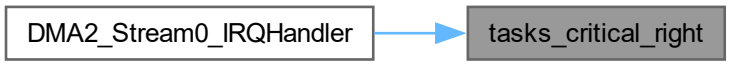
Here is the caller graph for this function:

4.40.2.2 tasks_critical_right()

```
void tasks_critical_right (
            void  )
```

Function to be executed every TS.

This function is called by the TIM8 trigger handler every TS. Here is the caller graph for this function:



4.40.3 Variable Documentation

4.40.3.1 angle_left

```
angle_struct angle_left
```

Initial value:

```
= {
    .freq = 0.0F,
    .Ts = TS,
}
```

4.40.3.2 elapsed_ticks

```
uint32_t elapsed_ticks = 0
```

4.40.3.3 freqRamp_left

```
rampa_struct freqRamp_left
```

Initial value:

```
= {
        .in = 5.0F,
        .Incr = TS*1000,
}
```

4.40.3.4 start_ticks

```
uint32_t start_ticks = 0
```

Index