e-Tech Racing's Inverter Firmware

v0

Generated by Doxygen 1.10.0

1 Data Structure Index 1

1.1 Data Structures . . . 1

2 File Index 3

2.1 File List . . . 3

3 Data Structure Documentation 5

3.1 Analog Struct Reference . . . 5

3.1.1 Detailed Description . . . 5

3.1.2 Field Documentation . . . 5

3.1.2.1 ia . . . 5

3.1.2.2 ib . . . 5

3.1.2.3 ic . . . 6

3.1.2.4 vDC . . . 6

3.2 Duties Struct Reference . . . 6

3.2.1 Detailed Description . . . 6

3.2.2 Field Documentation . . . 6

3.2.2.1 Da . . . 6

3.2.2.2 Db . . . 6

3.2.2.3 Dc . . . 7

3.3 Encoder Struct Reference . . . 7

3.3.1 Detailed Description . . . 7

3.3.2 Field Documentation . . . 7

3.3.2.1 A . . . 7

3.3.2.2 B . . . 7

3.3.2.3 cosTheta_e . . . 8

3.3.2.4 directionMeas . . . 8

3.3.2.5 sinTheta_e . . . 8

3.3.2.6 theta_e . . . 8

3.3.2.7 we . . . 8

3.3.2.8 Z . . . 8

3.4 Feedback Struct Reference . . . 8

3.4.1 Detailed Description . . . 9

3.4.2 Field Documentation . . . 9

3.4.2.1 idMeas . . . 9

3.4.2.2 iqMeas . . . 9

3.4.2.3 speedMeas . . . 9

3.4.2.4 torqueCalc . . . 9

3.5 InverterStruct Struct Reference . . . 10

3.5.1 Detailed Description . . . 10

3.5.2 Field Documentation . . . 10

3.5.2.1 analog . . . 10

3.5.2.2 direction . . . 11

3.5.2.3 duties . . . 11
3.5.2.4 enable_pin . . . 11
3.5.2.5 enable_port . . . 11
3.5.2.6 encoder . . . 11
3.5.2.7 feedback . . . 11
3.5.2.8 hadc . . . 11
3.5.2.9 htim . . . 11
3.5.2.10 idLoop . . . 12
3.5.2.11 iqLoop . . . 12
3.5.2.12 led . . . 12
3.5.2.13 motor . . . 12
3.5.2.14 reference . . . 12
3.5.2.15 speedLoop . . . 12
3.5.2.16 state . . . 12
3.5.2.17 tempInverter . . . 12
3.5.2.18 tempMotor . . . 13
3.5.2.19 vd . . . 13
3.5.2.20 vq . . . 13
3.5.2.21 vsMax . . . 13
3.6 LED Struct Reference . . . 13
3.6.1 Detailed Description . . . 13
3.6.2 Field Documentation . . . 14
3.6.2.1 mode . . . 14
3.6.2.2 pin . . . 14
3.6.2.3 port . . . 14
3.7 MotorParameters Struct Reference . . . 14
3.7.1 Detailed Description . . . 14
3.7.2 Field Documentation . . . 15
3.7.2.1 b . . . 15
3.7.2.2 dTorqueMax . . . 15
3.7.2.3 iMax . . . 15
3.7.2.4 J . . . 15
3.7.2.5 lambda . . . 15
3.7.2.6 Ld . . . 15
3.7.2.7 Lq . . . 15
3.7.2.8 pp . . . 16
3.7.2.9 Rs . . . 16
3.7.2.10 speedMax_RPM . . . 16
3.7.2.11 torqueMax . . . 16
3.7.2.12 vDCMax . . . 16
3.8 Reference Struct Reference . . . 16
3.8.1 Detailed Description . . . 17

3.8.2 Field Documentation . . . 17
3.8.2.1 idRef . . . 17
3.8.2.2 iqRef . . . 17
3.8.2.3 torqueRef . . . 17

4 File Documentation **19**
4.1 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CONTROL.h File Reference . . . 19
4.1.1 Detailed Description . . . 20
4.1.2 Function Documentation . . . 20
4.1.2.1 calc_current_loop() . . . 20
4.1.2.2 calc_current_reference() . . . 21
4.1.2.3 calc_duties() . . . 21
4.1.2.4 saturate_voltage() . . . 22
4.2 CONTROL.h . . . 23
4.3 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/FSM.h File Reference . . . 23
4.3.1 Detailed Description . . . 24
4.3.2 Function Documentation . . . 24
4.3.2.1 eval_inv_FSM() . . . 24
4.4 FSM.h . . . 25
4.5 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h File Reference . . . 25
4.5.1 Detailed Description . . . 27
4.5.2 Macro Definition Documentation . . . 27
4.5.2.1 DT . . . 27
4.5.2.2 TS . . . 27
4.5.3 Enumeration Type Documentation . . . 27
4.5.3.1 InverterState . . . 27
4.5.4 Function Documentation . . . 28
4.5.4.1 disable_control_loops() . . . 28
4.5.4.2 enable_control_loops() . . . 28
4.5.4.3 init_control_loops() . . . 28
4.5.4.4 initialize_inverter() . . . 29
4.5.5 Variable Documentation . . . 30
4.5.5.1 inverter_left . . . 30
4.5.5.2 inverter_right . . . 30
4.6 INVERTER.h . . . 31
4.7 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/main.h File Reference . . . 31
4.7.1 Detailed Description . . . 34
4.7.2 Macro Definition Documentation . . . 34
4.7.2.1 A_L_GPIO_Port . . . 34
4.7.2.2 A_L_Pin . . . 34
4.7.2.3 A_R_GPIO_Port . . . 34
4.7.2.4 A_R_Pin . . . 35

4.7.2.5 B_L_GPIO_Port . . . 35
4.7.2.6 B_L_Pin . . . 35
4.7.2.7 B_R_GPIO_Port . . . 35
4.7.2.8 B_R_Pin . . . 35
4.7.2.9 DAC_GPIO_Port . . . 35
4.7.2.10 DAC_Pin . . . 35
4.7.2.11 DIR_GPIO_Port . . . 35
4.7.2.12 DIR_Pin . . . 35
4.7.2.13 ENABLE_L_GPIO_Port . . . 35
4.7.2.14 ENABLE_L_Pin . . . 36
4.7.2.15 ENABLE_R_GPIO_Port . . . 36
4.7.2.16 ENABLE_R_Pin . . . 36
4.7.2.17 ia_L_GPIO_Port . . . 36
4.7.2.18 ia_L_Pin . . . 36
4.7.2.19 ia_R_GPIO_Port . . . 36
4.7.2.20 ia_R_Pin . . . 36
4.7.2.21 ib_L_GPIO_Port . . . 36
4.7.2.22 ib_L_Pin . . . 36
4.7.2.23 ib_R_GPIO_Port . . . 36
4.7.2.24 ib_R_Pin . . . 37
4.7.2.25 ic_L_GPIO_Port . . . 37
4.7.2.26 ic_L_Pin . . . 37
4.7.2.27 ic_R_GPIO_Port . . . 37
4.7.2.28 ic_R_Pin . . . 37
4.7.2.29 LED_ERR_GPIO_Port . . . 37
4.7.2.30 LED_ERR_Pin . . . 37
4.7.2.31 LED_LEFT_GPIO_Port . . . 37
4.7.2.32 LED_LEFT_Pin . . . 37
4.7.2.33 LED_RIGHT_GPIO_Port . . . 37
4.7.2.34 LED_RIGHT_Pin . . . 38
4.7.2.35 PWM1_L_GPIO_Port . . . 38
4.7.2.36 PWM1_L_Pin . . . 38
4.7.2.37 PWM1_R_GPIO_Port . . . 38
4.7.2.38 PWM1_R_Pin . . . 38
4.7.2.39 PWM2_L_GPIO_Port . . . 38
4.7.2.40 PWM2_L_Pin . . . 38
4.7.2.41 PWM2_R_GPIO_Port . . . 38
4.7.2.42 PWM2_R_Pin . . . 38
4.7.2.43 PWM3_L_GPIO_Port . . . 38
4.7.2.44 PWM3_L_Pin . . . 39
4.7.2.45 PWM3_R_GPIO_Port . . . 39
4.7.2.46 PWM3_R_Pin . . . 39

4.7.2.47 PWM4_L_GPIO_Port . . . 39
4.7.2.48 PWM4_L_Pin . . . 39
4.7.2.49 PWM4_R_GPIO_Port . . . 39
4.7.2.50 PWM4_R_Pin . . . 39
4.7.2.51 PWM5_L_GPIO_Port . . . 39
4.7.2.52 PWM5_L_Pin . . . 39
4.7.2.53 PWM5_R_GPIO_Port . . . 39
4.7.2.54 PWM5_R_Pin . . . 40
4.7.2.55 PWM6_L_GPIO_Port . . . 40
4.7.2.56 PWM6_L_Pin . . . 40
4.7.2.57 PWM6_R_GPIO_Port . . . 40
4.7.2.58 PWM6_R_Pin . . . 40
4.7.2.59 SC_det_GPIO_Port . . . 40
4.7.2.60 SC_det_Pin . . . 40
4.7.2.61 Tinv_L_GPIO_Port . . . 40
4.7.2.62 Tinv_L_Pin . . . 40
4.7.2.63 Tinv_R_GPIO_Port . . . 40
4.7.2.64 Tinv_R_Pin . . . 41
4.7.2.65 Tmot_L_GPIO_Port . . . 41
4.7.2.66 Tmot_L_Pin . . . 41
4.7.2.67 Tmot_R_GPIO_Port . . . 41
4.7.2.68 Tmot_R_Pin . . . 41
4.7.2.69 TRIP_L_GPIO_Port . . . 41
4.7.2.70 TRIP_L_Pin . . . 41
4.7.2.71 TRIP_R_GPIO_Port . . . 41
4.7.2.72 TRIP_R_Pin . . . 41
4.7.2.73 VDC_L_GPIO_Port . . . 41
4.7.2.74 VDC_L_Pin . . . 42
4.7.2.75 VDC_R_GPIO_Port . . . 42
4.7.2.76 VDC_R_Pin . . . 42
4.7.2.77 WRN_L_GPIO_Port . . . 42
4.7.2.78 WRN_L_Pin . . . 42
4.7.2.79 WRN_R_GPIO_Port . . . 42
4.7.2.80 WRN_R_Pin . . . 42
4.7.2.81 Z_L_GPIO_Port . . . 42
4.7.2.82 Z_L_Pin . . . 42
4.7.2.83 Z_R_GPIO_Port . . . 42
4.7.2.84 Z_R_Pin . . . 42
4.7.3 Function Documentation . . . 42
4.7.3.1 Error_Handler() . . . 42
4.8 main.h . . . 43
4.9 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h File Reference . . . 45

4.9.1 Detailed Description . . . 46
4.9.2 Macro Definition Documentation . . . 46
4.9.2.1 CURRENT_OFFSET . . . 46
4.9.2.2 CURRENT_SLOPE . . . 46
4.9.2.3 VOLTAGE_OFFSET . . . 47
4.9.2.4 VOLTAGE_SLOPE . . . 47
4.9.3 Function Documentation . . . 47
4.9.3.1 get_currents_voltage() . . . 47
4.9.3.2 get_idiq() . . . 48
4.9.3.3 get_linear() . . . 49
4.9.3.4 get_temperature() . . . 50
4.9.4 Variable Documentation . . . 50
4.9.4.1 rawADC_left . . . 50
4.9.4.2 rawADC_right . . . 50
4.9.4.3 rawADC_temp . . . 51
4.9.4.4 tempInverterLUT . . . 51
4.9.4.5 tempMotorLUT . . . 51
4.10 MEASUREMENTS.h . . . 51
4.11 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h File Reference . . . 52
4.11.1 Detailed Description . . . 53
4.11.2 Function Documentation . . . 53
4.11.2.1 check_motor_parameters() . . . 53
4.11.3 Variable Documentation . . . 54
4.11.3.1 motor_left . . . 54
4.11.3.2 motor_right . . . 54
4.12 MOTOR.h . . . 54
4.13 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PCB_IO.h File Reference . . . 55
4.13.1 Detailed Description . . . 56
4.13.2 Macro Definition Documentation . . . 56
4.13.2.1 DIR_STATE . . . 56
4.13.2.2 DISABLE . . . 56
4.13.2.3 ENABLE . . . 57
4.13.2.4 SC_DET_STATE . . . 57
4.13.2.5 WRN_STATE . . . 57
4.13.3 Enumeration Type Documentation . . . 57
4.13.3.1 LEDMode . . . 57
4.13.4 Function Documentation . . . 57
4.13.4.1 handle_direction() . . . 57
4.13.4.2 handle_LED() . . . 58
4.13.5 Variable Documentation . . . 58
4.13.5.1 led_left . . . 58
4.13.5.2 led_right . . . 59

4.13.5.3 ledError . . . 59
4.14 PCB_IO.h . . . 59
4.15 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PWM.h File Reference . . . 59
4.15.1 Detailed Description . . . 61
4.15.2 Function Documentation . . . 61
4.15.2.1 disable_PWM() . . . 61
4.15.2.2 enable_PWM() . . . 61
4.15.2.3 update_PWM() . . . 61
4.16 PWM.h . . . 62
4.17 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/REFERENCE.h File Reference . . . 62
4.17.1 Detailed Description . . . 64
4.17.2 Function Documentation . . . 64
4.17.2.1 handle_torqueRef() . . . 64
4.17.2.2 limit_torque_to_prevent_overspeed() . . . 65
4.17.2.3 saturate_symmetric() . . . 66
4.17.2.4 set_torque_direction() . . . 67
4.18 REFERENCE.h . . . 67
4.19 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_1ms.h File Reference . . . 68
4.19.1 Detailed Description . . . 68
4.19.2 Function Documentation . . . 69
4.19.2.1 tasks_1ms() . . . 69
4.20 TASKS_1ms.h . . . 69
4.21 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_20us.h File Reference . . . 70
4.21.1 Detailed Description . . . 70
4.21.2 Function Documentation . . . 71
4.21.2.1 tasks_20us_left() . . . 71
4.21.2.2 tasks_20us_right() . . . 71
4.22 TASKS_20us.h . . . 72
4.23 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CAN_e-Tech.c File Reference . . . 72
4.23.1 Detailed Description . . . 73
4.23.2 Function Documentation . . . 73
4.23.2.1 handle_CAN() . . . 73
4.23.2.2 send_CAN_message() . . . 74
4.23.3 Variable Documentation . . . 74
4.23.3.1 keepAlive . . . 74
4.24 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CONTROL.c File Reference . . . 74
4.24.1 Detailed Description . . . 75
4.24.2 Function Documentation . . . 76
4.24.2.1 calc_current_loop() . . . 76
4.24.2.2 calc_current_reference() . . . 76
4.24.2.3 calc_duties() . . . 77
4.24.2.4 saturate_voltage() . . . 77

4.25 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/FSM.c File Reference . . . 78
4.25.1 Detailed Description . . . 79
4.25.2 Function Documentation . . . 79
4.25.2.1 eval_inv_FSM() . . . 79
4.26 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/INVERTER.c File Reference . . . 79
4.26.1 Detailed Description . . . 80
4.26.2 Function Documentation . . . 81
4.26.2.1 disable_control_loops() . . . 81
4.26.2.2 enable_control_loops() . . . 81
4.26.2.3 init_control_loops() . . . 81
4.26.2.4 initialize_inverter() . . . 82
4.26.3 Variable Documentation . . . 83
4.26.3.1 inverter_left . . . 83
4.26.3.2 inverter_right . . . 83
4.27 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/main.c File Reference . . . 83
4.27.1 Detailed Description . . . 84
4.27.2 Function Documentation . . . 84
4.27.2.1 Error_Handler() . . . 84
4.27.2.2 main() . . . 84
4.27.2.3 SystemClock_Config() . . . 85
4.28 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MEASUREMENTS.c File Reference . . . 86
4.28.1 Detailed Description . . . 96
4.28.2 Function Documentation . . . 96
4.28.2.1 get_currents_voltage() . . . 96
4.28.2.2 get_idiq() . . . 97
4.28.2.3 get_linear() . . . 98
4.28.2.4 get_temperature() . . . 98
4.28.3 Variable Documentation . . . 99
4.28.3.1 rawADC_left . . . 99
4.28.3.2 rawADC_right . . . 99
4.28.3.3 rawADC_temp . . . 99
4.28.3.4 tempInverterLUT . . . 100
4.28.3.5 tempMotorLUT . . . 105
4.29 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MOTOR.c File Reference . . . 110
4.29.1 Detailed Description . . . 111
4.29.2 Function Documentation . . . 111
4.29.2.1 check_motor_parameters() . . . 111
4.29.3 Variable Documentation . . . 112
4.29.3.1 motor_left . . . 112
4.29.3.2 motor_right . . . 112
4.30 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PCB_IO.c File Reference . . . 113
4.30.1 Detailed Description . . . 113

4.30.2 Function Documentation . . . 114
4.30.2.1 handle_direction() . . . 114
4.30.2.2 handle_LED() . . . 114
4.30.3 Variable Documentation . . . 115
4.30.3.1 led_left . . . 115
4.30.3.2 led_right . . . 115
4.30.3.3 ledError . . . 115
4.31 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PWM.c File Reference . . . 115
4.31.1 Detailed Description . . . 116
4.31.2 Function Documentation . . . 116
4.31.2.1 disable_PWM() . . . 116
4.31.2.2 enable_PWM() . . . 116
4.31.2.3 update_PWM() . . . 117
4.32 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/REFERENCE.c File Reference . . . 117
4.32.1 Detailed Description . . . 118
4.32.2 Function Documentation . . . 119
4.32.2.1 handle_torqueRef() . . . 119
4.32.2.2 limit_torque_to_prevent_overspeed() . . . 120
4.32.2.3 saturate_symmetric() . . . 120
4.32.2.4 set_torque_direction() . . . 121
4.33 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/stm32f7xx_it.c File Reference . . . 121
4.33.1 Detailed Description . . . 123
4.33.2 Function Documentation . . . 123
4.33.2.1 BusFault_Handler() . . . 123
4.33.2.2 CAN1_RX0_IRQHandler() . . . 123
4.33.2.3 DebugMon_Handler() . . . 124
4.33.2.4 DMA2_Stream0_IRQHandler() . . . 124
4.33.2.5 DMA2_Stream1_IRQHandler() . . . 124
4.33.2.6 DMA2_Stream2_IRQHandler() . . . 124
4.33.2.7 HardFault_Handler() . . . 124
4.33.2.8 MemManage_Handler() . . . 124
4.33.2.9 NMI_Handler() . . . 124
4.33.2.10 PendSV_Handler() . . . 125
4.33.2.11 SVC_Handler() . . . 125
4.33.2.12 SysTick_Handler() . . . 125
4.33.2.13 TIM1_UP_TIM10_IRQHandler() . . . 125
4.33.2.14 TIM6_DAC_IRQHandler() . . . 126
4.33.2.15 UsageFault_Handler() . . . 126
4.33.3 Variable Documentation . . . 126
4.33.3.1 hcan1 . . . 126
4.33.3.2 hdac . . . 126
4.33.3.3 hdma_adc1 . . . 126

4.33.3.4 hdma_adc2 . . . 126
4.33.3.5 hdma_adc3 . . . 127
4.33.3.6 htim1 . . . 127
4.33.3.7 htim6 . . . 127
4.34 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_1ms.c File Reference . . . 127
4.34.1 Detailed Description . . . 128
4.34.2 Function Documentation . . . 128
4.34.2.1 tasks_1ms() . . . 128
4.35 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_20us.c File Reference . . . 129
4.35.1 Detailed Description . . . 130
4.35.2 Function Documentation . . . 130
4.35.2.1 tasks_20us_left() . . . 130
4.35.2.2 tasks_20us_right() . . . 131
4.35.3 Variable Documentation . . . 131
4.35.3.1 angle_left . . . 131
4.35.3.2 elapsed_ticks . . . 131
4.35.3.3 freqRamp_left . . . 131
4.35.3.4 start_ticks . . . 131
4.35.3.5 torqueRefIn_left . . . 131
4.35.3.6 vd_left . . . 131
4.35.3.7 vDC_left . . . 131
4.35.3.8 vq_left . . . 131

Index **133**

Chapter 1

Data Structure Index

1.1 Data Structures

Here are the data structures with brief descriptions:

Analog
: Structure for ADC measurements in units 5

Duties
: Structure to hold PWM configuration parameters 6

Encoder
: Structure for encoder reading 7

Feedback
: Structure for feedback values 8

InverterStruct
: Inverter structure 10

LED
: LED structure 13

MotorParameters
: Structure to hold motor parameters 14

Reference
: Structure for reference values 16

Chapter 2

File Index

2.1 File List

Here is a list of all files with brief descriptions:

C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CONTROL.h
Header file for the control loop . . . 19
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/FSM.h
Header for the inverter Finite State Machine . . . 23
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h
Header file for the inverter struct and extern variables . . . 25
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/main.h
: Header for main.c file. This file contains the common defines of the application . . . 31
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h
Header file for handling measurements . . . 45
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h
Header file for motor parameters . . . 52
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PCB_IO.h
Header file for handling GPIOs . . . 55
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PWM.h
Header file for controlling PWM output . . . 59
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/REFERENCE.h
Header file for torque reference handling . . . 62
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_1ms.h
Header file for functions related to tasks executed every 1ms . . . 68
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_20us.h
Header file for functions related to tasks executed every 20us in each PWM timer interruption . 70
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CAN_e-Tech.c
This file contains functions to handle CAN communication with the car . . . 72
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CONTROL.c
This file provides code for the control loop . . . 74
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/FSM.c
This file provides code for the inverter Finite State Machine . . . 78
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/INVERTER.c
This file provides code for the inverter struct . . . 79
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/main.c
: Main program body . . . 83
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MEASUREMENTS.c
This file provides functions for handling measurements . . . 86
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MOTOR.c
Source file for motor parameters . . . 110

C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PCB_IO.c
This file provides functions for handling GPIOs 113
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PWM.c
This file provides functions for controlling PWM output 115
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/REFERENCE.c
Source file for torque reference handling 117
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/stm32f7xx_it.c
Interrupt Service Routines 121
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_1ms.c
This file contains functions to execute tasks every 1ms 127
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_20us.c
This file contains functions executed every 20us in each PWM timer interruption 129

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

3.1.1 Detailed Description

Structure for ADC measurements in units.

3.1.2 Field Documentation

3.1.2.1 ia

`float ia`

Phase A current in A

3.1.2.2 ib

`float ib`

Phase B current in A

3.1.2.3 ic

```
float ic
```

Phase C current in A

3.1.2.4 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 Duties Struct Reference

Structure to hold PWM configuration parameters.

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

Data Fields

- float Da
- float Db
- float Dc

3.2.1 Detailed Description

Structure to hold PWM configuration parameters.

3.2.2 Field Documentation

3.2.2.1 Da

```
float Da
```

Duty cycle for channel 1

3.2.2.2 Db

```
float Db
```

Duty cycle for channel 2

3.2.2.3 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

3.3 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

3.3.1 Detailed Description

Structure for encoder reading.

3.3.2 Field Documentation

3.3.2.1 A

```
uint16_t A
```

Encoder channel A value

3.3.2.2 B

```
uint16_t B
```

Encoder channel B value

3.3.2.3 cosTheta_e

```
float cosTheta_e
```

Electrical rotor position cosine

3.3.2.4 directionMeas

```
uint8_t directionMeas
```

Measured direction

3.3.2.5 sinTheta_e

```
float sinTheta_e
```

Electrical rotor position sine

3.3.2.6 theta_e

```
float theta_e
```

Electrical rotor position

3.3.2.7 we

```
float we
```

Electrical angular velocity

3.3.2.8 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

3.4 Feedback Struct Reference

Structure for feedback values.

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

Data Fields

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

3.4.1 Detailed Description

Structure for feedback values.

3.4.2 Field Documentation

3.4.2.1 idMeas

```
float idMeas
```

Measured d-axis current in A

3.4.2.2 iqMeas

```
float iqMeas
```

Measured q-axis current in A

3.4.2.3 speedMeas

```
float speedMeas
```

Measured speed in RPM

3.4.2.4 torqueCalc

```
float torqueCalc
```

Calculated torque in N·m

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

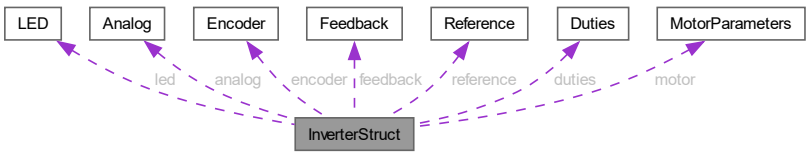
- C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h

3.5 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

3.5.1 Detailed Description

Inverter structure.

3.5.2 Field Documentation

3.5.2.1 analog

`Analog analog`

Structure for phase currents and DC voltage measurements

3.5.2.2 direction

```
int8_t direction
```

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

3.5.2.3 duties

```
Duties duties
```

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

3.5.2.4 enable_pin

```
uint16_t enable_pin
```

Pin number for enabling/disabling the inverter

3.5.2.5 enable_port

```
GPIO_TypeDef* enable_port
```

Pointer to GPIO port for enabling/disabling the inverter

3.5.2.6 encoder

```
Encoder encoder
```

Structure for encoder input

3.5.2.7 feedback

```
Feedback feedback
```

Structure for measured currents and calculated mechanical torque and speed

3.5.2.8 hadc

```
ADC_HandleTypeDef* hadc
```

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

3.5.2.9 htim

```
TIM_HandleTypeDef* htim
```

Handle of the timer peripheral for PWM output

3.5.2.10 idLoop

```
pi_struct idLoop
```

PI controller for d-axis current

3.5.2.11 iqLoop

```
pi_struct iqLoop
```

PI controller for q-axis current

3.5.2.12 led

```
LED* led
```

Pointer to LED control structure

3.5.2.13 motor

```
MotorParameters* motor
```

Motor parameters struct

3.5.2.14 reference

```
Reference reference
```

Structure for referece currents and torque

3.5.2.15 speedLoop

```
pi_struct speedLoop
```

PI controller for motor speed

3.5.2.16 state

```
InverterState state
```

Current state of inverter operation

3.5.2.17 tempInverter

```
float tempInverter
```

Semiconductor temperature in degC

3.5.2.18 tempMotor

```
float tempMotor
```

Motor temperature in degC

3.5.2.19 vd

```
float vd
```

d-axis voltage

3.5.2.20 vq

```
float vq
```

q-axis voltage

3.5.2.21 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

3.6 LED Struct Reference

LED structure.

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

Data Fields

- GPIO_TypeDef * port
- uint16_t pin
- LEDMode mode

3.6.1 Detailed Description

LED structure.

3.6.2 Field Documentation

3.6.2.1 mode

```
LEDMode mode
```

Current LED mode

3.6.2.2 pin

```
uint16_t pin
```

Pin number for controlling the LED

3.6.2.3 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

3.7 MotorParameters Struct Reference

Structure to hold motor parameters.

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

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

3.7.1 Detailed Description

Structure to hold motor parameters.

3.7.2 Field Documentation

3.7.2.1 b

```
float b
```

Viscous friction in N·m·s

3.7.2.2 dTorqueMax

```
float dTorqueMax
```

Maximum torque increment in N·m/s

3.7.2.3 iMax

```
float iMax
```

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

3.7.2.4 J

```
float J
```

Rotational inertia in N·m·s^2

3.7.2.5 lambda

```
float lambda
```

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

3.7.2.6 Ld

```
float Ld
```

D-axis inductance in Henries

3.7.2.7 Lq

```
float Lq
```

Q-axis inductance in Henries

3.7.2.8 pp

```
uint8_t pp
```

Pole pairs (total number of poles divided by 2)

3.7.2.9 Rs

```
float Rs
```

Stator resistance in Ohms

3.7.2.10 speedMax_RPM

```
float speedMax_RPM
```

Maximum speed in RPM

3.7.2.11 torqueMax

```
float torqueMax
```

Maximum torque in N·m

3.7.2.12 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

3.8 Reference Struct Reference

Structure for reference values.

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

Data Fields

- float idRef
- float iqRef
- float torqueRef

3.8.1 Detailed Description

Structure for reference values.

3.8.2 Field Documentation

3.8.2.1 idRef

```
float idRef
```

Reference d-axis current in A

3.8.2.2 iqRef

```
float iqRef
```

Reference q-axis current in A

3.8.2.3 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

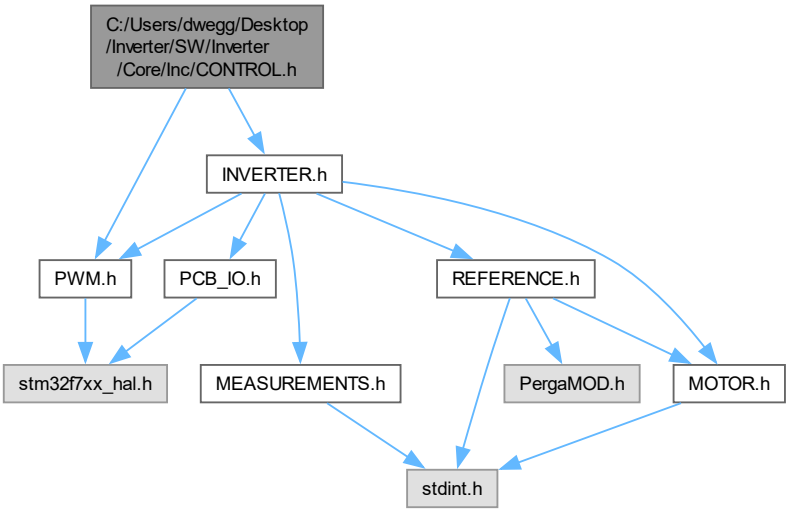
File Documentation

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

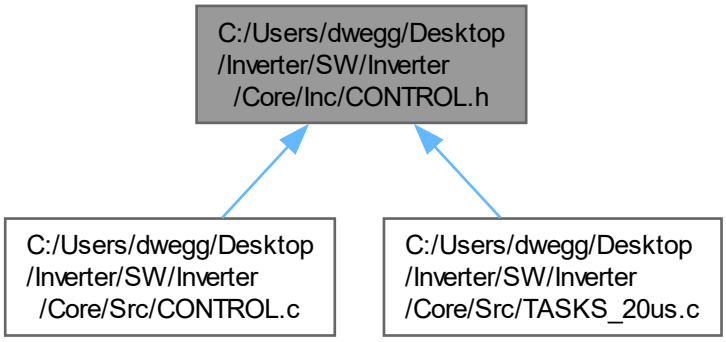
Header file for the control loop.

```
#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 (float we, float torqueRef, float vsRef, MotorParameters ∗motor, volatile float ∗idRef, volatile float ∗iqRef)

  Calculates the current references based on electrical speed, torque reference, voltage reference, motor parameters, and updates the d-axis and q-axis current references. Just MTPA for now.
- 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.

4.1.1 Detailed Description

Header file for the control loop.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.1.2 Function Documentation

4.1.2.1 calc_current_loop()

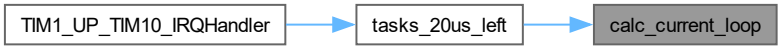
```
void calc_current_loop (
            volatile InverterStruct * inv )
```

Calculates the id-iq loops.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.1.2.2 calc_current_reference()

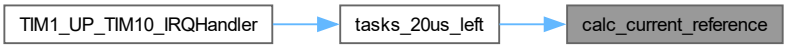
```
void calc_current_reference (
            float we,
            float torqueRef,
            float vsRef,
            MotorParameters * motor,
            volatile float * idRef,
            volatile float * iqRef )
```

Calculates the current references based on electrical speed, torque reference, voltage reference, motor parameters, and updates the d-axis and q-axis current references. Just MTPA for now.

Parameters

in	*we*	Electrical speed in radians per second.
in	*torqueRef*	Torque reference.
in	*vsRef*	Voltage reference.
in	*motor*	Pointer to the motor parameters structure.
out	*idRef*	Pointer to the d-axis current reference.
out	*iqRef*	Pointer to the q-axis current reference.

Here is the caller graph for this function:



4.1.2.3 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:

4.1.2.4 saturate_voltage()

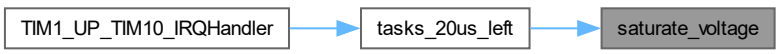
```
void saturate_voltage (
            volatile InverterStruct * inv )
```

Saturates PI output to not surpass DC voltage.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.2 CONTROL.h

Go to the documentation of this file.

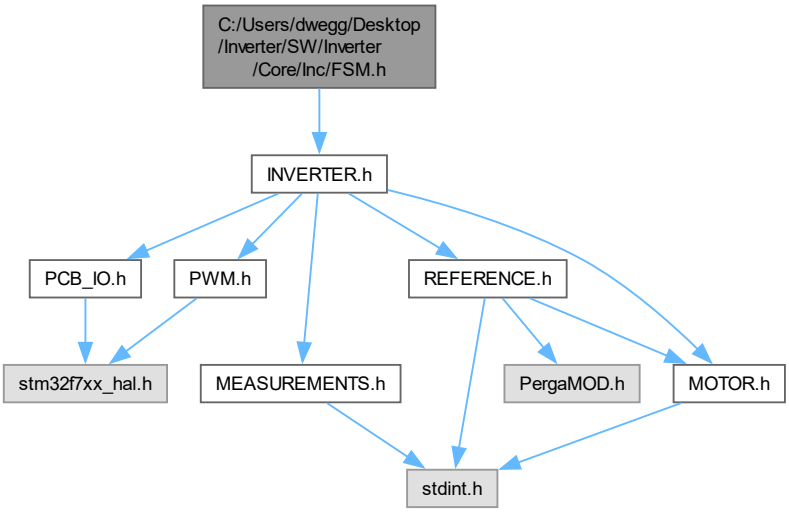
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef CONTROL_H
00021 #define CONTROL_H
00022
00023 #include "PWM.h" // duties struct
00024 #include "INVERTER.h" // TS & Inverter struct
00025
00037 void calc_current_reference(float we, float torqueRef, float vsRef, MotorParameters *motor, volatile
      float * idRef, volatile float * iqRef);
00038
00044 void calc_current_loop(volatile InverterStruct *inv);
00045
00051 void saturate_voltage(volatile InverterStruct *inv);
00052
00065 void calc_duties(float vd, float vq, float vDC, float sinTheta_e, float cosTheta_e, volatile Duties
      *duties);
00066
00067 #endif /* CONTROL_H */
```

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

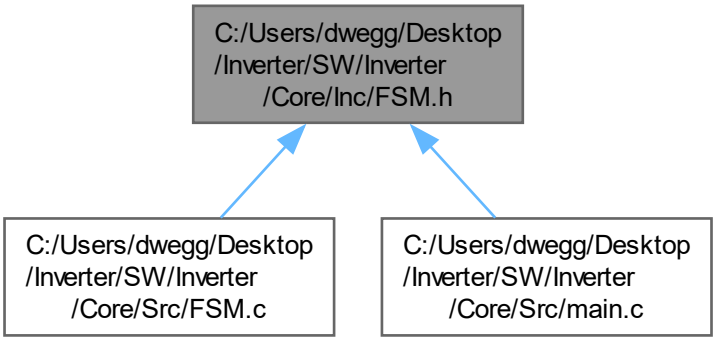
Header for the inverter Finite State Machine.

```
#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.

4.3.1 Detailed Description

Header for the inverter Finite State Machine.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.3.2 Function Documentation

4.3.2.1 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.

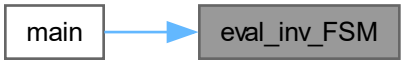
Run the Finite State Machine (FSM) for inverter operation control.

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:



4.4 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 */
```

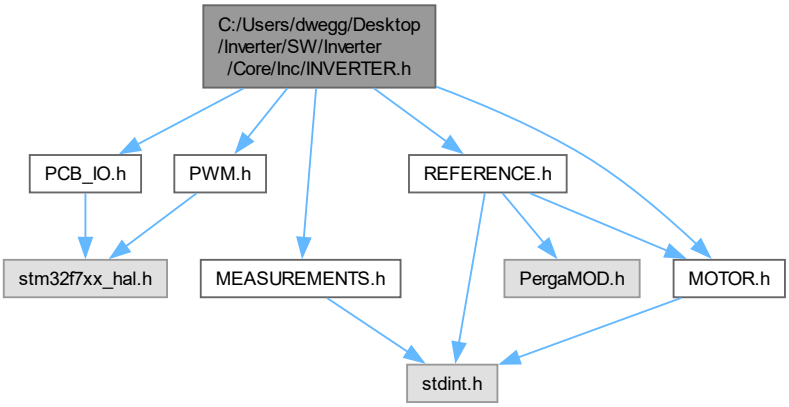
4.5 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h File Reference

Header file for the inverter struct and extern variables.

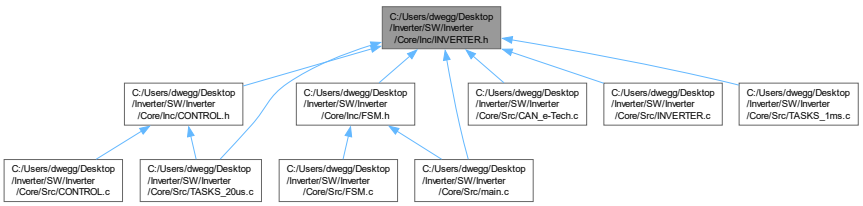
```
#include "PCB_IO.h"
#include "MEASUREMENTS.h"
#include "REFERENCE.h"
#include "MOTOR.h"
```

```
#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 0.00000015

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)

  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.

4.5.1 Detailed Description

Header file for the inverter struct and extern variables.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.5.2 Macro Definition Documentation

4.5.2.1 DT

```
#define DT 0.00000015
```

Dead time in seconds (150 ns), time in which both top and bottom transistors are open

4.5.2.2 TS

```
#define TS 0.000025
```

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

4.5.3 Enumeration Type Documentation

4.5.3.1 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

4.5.4 Function Documentation

4.5.4.1 disable_control_loops()

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

Disables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.5.4.2 enable_control_loops()

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

Enables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.5.4.3 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:

4.5.4.4 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 )
```

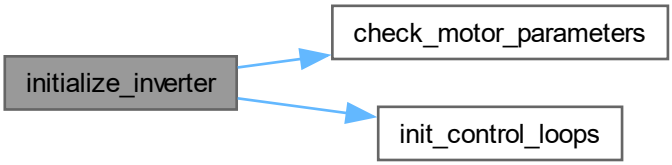
Initialize the inverter.

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:

4.5.5 Variable Documentation

4.5.5.1 inverter_left

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

Left inverter structure.

External declaration of the left inverter structure

External declaration of the left inverter structure.

4.5.5.2 inverter_right

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

Right inverter structure.

External declaration of the right inverter structure

External declaration of the right inverter structure.

4.6 INVERTER.h

Go to the documentation of this file.

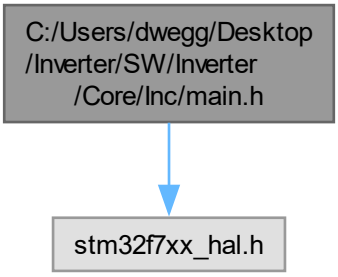
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef INVERTER_H
00021 #define INVERTER_H
00022
00023 #include "PCB_IO.h" // peripheral types
00024 #include "MEASUREMENTS.h" // a few structs
00025 #include "REFERENCE.h" // reference struct
00026 #include "MOTOR.h" // motor struct
00027 #include "PWM.h" // duties struct
00028
00029
00030
00031 #define TS 0.000025
00032 #define DT 0.00000015
00040 typedef enum {
00041     INV_STATE_IDLE,
00042     INV_STATE_STARTUP,
00043     INV_STATE_RUNNING,
00044     INV_STATE_FAULT
00045 } InverterState;
00046
00050 typedef struct {
00051     LED *led;
00052     GPIO_TypeDef *enable_port;
00053     uint16_t enable_pin;
00054     TIM_HandleTypeDef *htim;
00055     ADC_HandleTypeDef *hadc;
00056     InverterState state;
00057     Analog analog;
00058     Encoder encoder;
00059     Feedback feedback;
00060     Reference reference;
00061     Duties duties;
00062     int8_t direction;
00063     float tempInverter;
00064     float tempMotor;
00065     MotorParameters *motor;
00066     pi_struct idLoop;
00067     pi_struct iqLoop;
00068     float vsMax;
00069     float vd;
00070     float vq;
00071     pi_struct speedLoop;
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);
00092
00093
00099 void init_control_loops(volatile InverterStruct *inv, MotorParameters *motor);
00100
00106 void enable_control_loops(volatile InverterStruct *inv);
00107
00113 void disable_control_loops(volatile InverterStruct *inv);
00114
00115 #endif /* INVERTER_H */
```

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

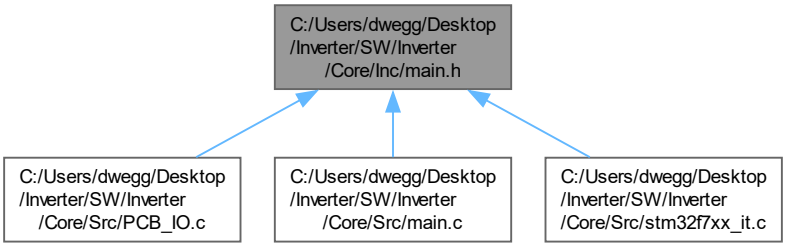
: Header for main.c file. This file contains the common defines of the application.

```
#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.

4.7.1 Detailed Description

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

Attention

Copyright (c) 2023 STMicroelectronics. All rights reserved.

This software is licensed under terms that can be found in the LICENSE file in the root directory of this software component. If no LICENSE file comes with this software, it is provided AS-IS.

4.7.2 Macro Definition Documentation

4.7.2.1 A_L_GPIO_Port

```
#define A_L_GPIO_Port GPIOD
```

4.7.2.2 A_L_Pin

```
#define A_L_Pin GPIO_PIN_12
```

4.7.2.3 A_R_GPIO_Port

```
#define A_R_GPIO_Port GPIOA
```

4.7.2.4 A_R_Pin

```
#define A_R_Pin GPIO_PIN_15
```

4.7.2.5 B_L_GPIO_Port

```
#define B_L_GPIO_Port GPIOD
```

4.7.2.6 B_L_Pin

```
#define B_L_Pin GPIO_PIN_14
```

4.7.2.7 B_R_GPIO_Port

```
#define B_R_GPIO_Port GPIOB
```

4.7.2.8 B_R_Pin

```
#define B_R_Pin GPIO_PIN_10
```

4.7.2.9 DAC_GPIO_Port

```
#define DAC_GPIO_Port GPIOA
```

4.7.2.10 DAC_Pin

```
#define DAC_Pin GPIO_PIN_4
```

4.7.2.11 DIR_GPIO_Port

```
#define DIR_GPIO_Port GPIOD
```

4.7.2.12 DIR_Pin

```
#define DIR_Pin GPIO_PIN_3
```

4.7.2.13 ENABLE_L_GPIO_Port

```
#define ENABLE_L_GPIO_Port GPIOE
```

4.7.2.14 ENABLE_L_Pin

```
#define ENABLE_L_Pin GPIO_PIN_7
```

4.7.2.15 ENABLE_R_GPIO_Port

```
#define ENABLE_R_GPIO_Port GPIOB
```

4.7.2.16 ENABLE_R_Pin

```
#define ENABLE_R_Pin GPIO_PIN_2
```

4.7.2.17 ia_L_GPIO_Port

```
#define ia_L_GPIO_Port GPIOA
```

4.7.2.18 ia_L_Pin

```
#define ia_L_Pin GPIO_PIN_0
```

4.7.2.19 ia_R_GPIO_Port

```
#define ia_R_GPIO_Port GPIOA
```

4.7.2.20 ia_R_Pin

```
#define ia_R_Pin GPIO_PIN_6
```

4.7.2.21 ib_L_GPIO_Port

```
#define ib_L_GPIO_Port GPIOA
```

4.7.2.22 ib_L_Pin

```
#define ib_L_Pin GPIO_PIN_1
```

4.7.2.23 ib_R_GPIO_Port

```
#define ib_R_GPIO_Port GPIOA
```

4.7.2.24 ib_R_Pin

```
#define ib_R_Pin GPIO_PIN_7
```

4.7.2.25 ic_L_GPIO_Port

```
#define ic_L_GPIO_Port GPIOA
```

4.7.2.26 ic_L_Pin

```
#define ic_L_Pin GPIO_PIN_2
```

4.7.2.27 ic_R_GPIO_Port

```
#define ic_R_GPIO_Port GPIOB
```

4.7.2.28 ic_R_Pin

```
#define ic_R_Pin GPIO_PIN_0
```

4.7.2.29 LED_ERR_GPIO_Port

```
#define LED_ERR_GPIO_Port GPIOD
```

4.7.2.30 LED_ERR_Pin

```
#define LED_ERR_Pin GPIO_PIN_6
```

4.7.2.31 LED_LEFT_GPIO_Port

```
#define LED_LEFT_GPIO_Port GPIOD
```

4.7.2.32 LED_LEFT_Pin

```
#define LED_LEFT_Pin GPIO_PIN_4
```

4.7.2.33 LED_RIGHT_GPIO_Port

```
#define LED_RIGHT_GPIO_Port GPIOD
```

4.7.2.34 LED_RIGHT_Pin

```
#define LED_RIGHT_Pin GPIO_PIN_5
```

4.7.2.35 PWM1_L_GPIO_Port

```
#define PWM1_L_GPIO_Port GPIOE
```

4.7.2.36 PWM1_L_Pin

```
#define PWM1_L_Pin GPIO_PIN_8
```

4.7.2.37 PWM1_R_GPIO_Port

```
#define PWM1_R_GPIO_Port GPIOA
```

4.7.2.38 PWM1_R_Pin

```
#define PWM1_R_Pin GPIO_PIN_5
```

4.7.2.39 PWM2_L_GPIO_Port

```
#define PWM2_L_GPIO_Port GPIOE
```

4.7.2.40 PWM2_L_Pin

```
#define PWM2_L_Pin GPIO_PIN_9
```

4.7.2.41 PWM2_R_GPIO_Port

```
#define PWM2_R_GPIO_Port GPIOC
```

4.7.2.42 PWM2_R_Pin

```
#define PWM2_R_Pin GPIO_PIN_6
```

4.7.2.43 PWM3_L_GPIO_Port

```
#define PWM3_L_GPIO_Port GPIOE
```

4.7.2.44 PWM3_L_Pin

```
#define PWM3_L_Pin GPIO_PIN_10
```

4.7.2.45 PWM3_R_GPIO_Port

```
#define PWM3_R_GPIO_Port GPIOB
```

4.7.2.46 PWM3_R_Pin

```
#define PWM3_R_Pin GPIO_PIN_14
```

4.7.2.47 PWM4_L_GPIO_Port

```
#define PWM4_L_GPIO_Port GPIOE
```

4.7.2.48 PWM4_L_Pin

```
#define PWM4_L_Pin GPIO_PIN_11
```

4.7.2.49 PWM4_R_GPIO_Port

```
#define PWM4_R_GPIO_Port GPIOC
```

4.7.2.50 PWM4_R_Pin

```
#define PWM4_R_Pin GPIO_PIN_7
```

4.7.2.51 PWM5_L_GPIO_Port

```
#define PWM5_L_GPIO_Port GPIOE
```

4.7.2.52 PWM5_L_Pin

```
#define PWM5_L_Pin GPIO_PIN_12
```

4.7.2.53 PWM5_R_GPIO_Port

```
#define PWM5_R_GPIO_Port GPIOB
```

4.7.2.54 PWM5_R_Pin

```
#define PWM5_R_Pin GPIO_PIN_15
```

4.7.2.55 PWM6_L_GPIO_Port

```
#define PWM6_L_GPIO_Port GPIOE
```

4.7.2.56 PWM6_L_Pin

```
#define PWM6_L_Pin GPIO_PIN_13
```

4.7.2.57 PWM6_R_GPIO_Port

```
#define PWM6_R_GPIO_Port GPIOC
```

4.7.2.58 PWM6_R_Pin

```
#define PWM6_R_Pin GPIO_PIN_8
```

4.7.2.59 SC_det_GPIO_Port

```
#define SC_det_GPIO_Port GPIOC
```

4.7.2.60 SC_det_Pin

```
#define SC_det_Pin GPIO_PIN_4
```

4.7.2.61 Tinv_L_GPIO_Port

```
#define Tinv_L_GPIO_Port GPIOC
```

4.7.2.62 Tinv_L_Pin

```
#define Tinv_L_Pin GPIO_PIN_0
```

4.7.2.63 Tinv_R_GPIO_Port

```
#define Tinv_R_GPIO_Port GPIOC
```

4.7.2.64 Tinv_R_Pin

```
#define Tinv_R_Pin GPIO_PIN_1
```

4.7.2.65 Tmot_L_GPIO_Port

```
#define Tmot_L_GPIO_Port GPIOC
```

4.7.2.66 Tmot_L_Pin

```
#define Tmot_L_Pin GPIO_PIN_2
```

4.7.2.67 Tmot_R_GPIO_Port

```
#define Tmot_R_GPIO_Port GPIOC
```

4.7.2.68 Tmot_R_Pin

```
#define Tmot_R_Pin GPIO_PIN_3
```

4.7.2.69 TRIP_L_GPIO_Port

```
#define TRIP_L_GPIO_Port GPIOA
```

4.7.2.70 TRIP_L_Pin

```
#define TRIP_L_Pin GPIO_PIN_8
```

4.7.2.71 TRIP_R_GPIO_Port

```
#define TRIP_R_GPIO_Port GPIOC
```

4.7.2.72 TRIP_R_Pin

```
#define TRIP_R_Pin GPIO_PIN_9
```

4.7.2.73 VDC_L_GPIO_Port

```
#define VDC_L_GPIO_Port GPIOA
```

4.7.2.74 VDC_L_Pin

```
#define VDC_L_Pin GPIO_PIN_3
```

4.7.2.75 VDC_R_GPIO_Port

```
#define VDC_R_GPIO_Port GPIOB
```

4.7.2.76 VDC_R_Pin

```
#define VDC_R_Pin GPIO_PIN_1
```

4.7.2.77 WRN_L_GPIO_Port

```
#define WRN_L_GPIO_Port GPIOE
```

4.7.2.78 WRN_L_Pin

```
#define WRN_L_Pin GPIO_PIN_14
```

4.7.2.79 WRN_R_GPIO_Port

```
#define WRN_R_GPIO_Port GPIOE
```

4.7.2.80 WRN_R_Pin

```
#define WRN_R_Pin GPIO_PIN_15
```

4.7.2.81 Z_L_GPIO_Port

```
#define Z_L_GPIO_Port GPIOD
```

4.7.2.82 Z_L_Pin

```
#define Z_L_Pin GPIO_PIN_15
```

4.7.2.83 Z_R_GPIO_Port

```
#define Z_R_GPIO_Port GPIOB
```

4.7.2.84 Z_R_Pin

```
#define Z_R_Pin GPIO_PIN_11
```

4.7.3 Function Documentation

4.7.3.1 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:

4.8 main.h

Go to the documentation of this file.

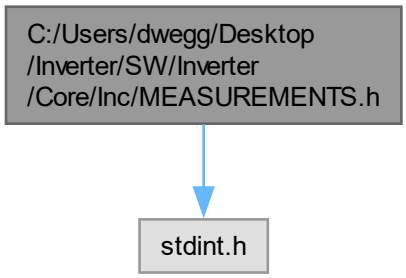
```
00001 /* USER CODE BEGIN Header */
00019 /* USER CODE END Header */
00020
00021 /* Define to prevent recursive inclusion -------------------------------------*/
00022 #ifndef __MAIN_H
00023 #define __MAIN_H
00024
00025 #ifdef __cplusplus
00026 extern "C" {
00027 #endif
00028
00029 /* Includes ------------------------------------------------------------------*/
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 */
```

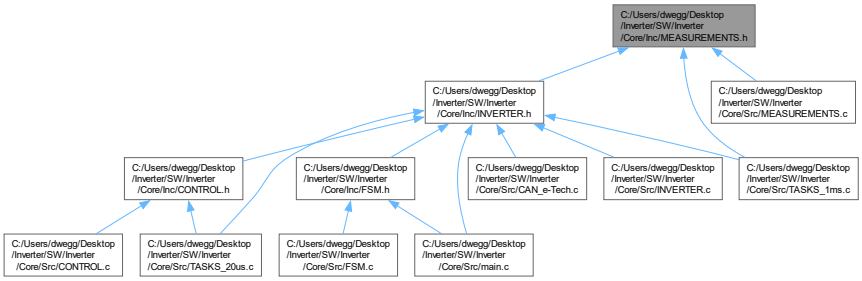
4.9 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/↩ MEASUREMENTS.h File Reference

Header file for handling measurements.

`#include <stdint.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 54.4217687f
- #define CURRENT_OFFSET 1.70068027211f
- #define VOLTAGE_SLOPE 263.435f
- #define VOLTAGE_OFFSET 0.02083f

Functions

- uint8_t get_currents_voltage (volatile uint32_t ADC_raw[ ], volatile Analog ∗analog, volatile Feedback ∗feedback, 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.

Variables

- const float tempInverterLUT [ ]
- const float tempMotorLUT [ ]
- volatile uint32_t rawADC_left [4]

  Raw ADC data for the left inverter.
- volatile uint32_t rawADC_right [4]

  Raw ADC data for the right inverter.
- volatile uint32_t rawADC_temp [4]

  Raw ADC data for the temperatures.

4.9.1 Detailed Description

Header file for handling measurements.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.9.2 Macro Definition Documentation

4.9.2.1 CURRENT_OFFSET

```
#define CURRENT_OFFSET 1.70068027211f
```

[V] (10/(4.7+10))∗ 2.5 V

4.9.2.2 CURRENT_SLOPE

```
#define CURRENT_SLOPE 54.4217687f
```

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

4.9.2.3 VOLTAGE_OFFSET

```
#define VOLTAGE_OFFSET 0.02083f
```

[V] (100/(4700+100) ∗ 5 V

4.9.2.4 VOLTAGE_SLOPE

```
#define VOLTAGE_SLOPE 263.435f
```

[V/V] 1/(1/3 ∗ 0.011388) V

4.9.3 Function Documentation

4.9.3.1 get_currents_voltage()

```
uint8_t get_currents_voltage (
            volatile uint32_t ADC_raw[],
            volatile Analog * analog,
            volatile Feedback * feedback,
            float sinTheta_e,
            float cosTheta_e )
```

Get electrical ADC measurements.

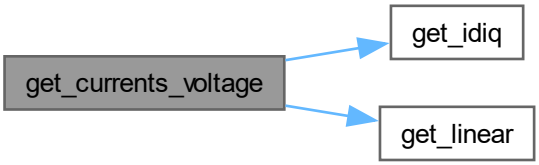
Parameters

in	*ADC_raw*	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)

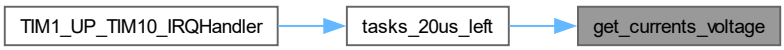
Return values

OK	0 if an error occurred, 1 if successful.

Here is the call graph for this function:



Here is the caller graph for this function:



4.9.3.2 get_idiq()

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

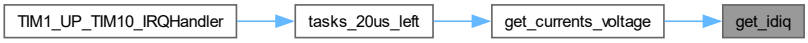
Computes d-q currents from current measurements and electrical angle.

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)
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:



4.9.3.3 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.

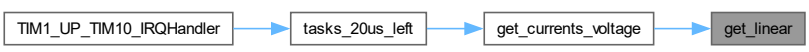
Parameters

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:



4.9.3.4 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.

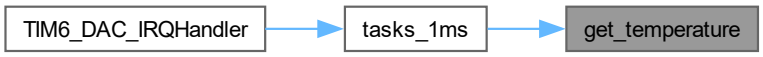
Parameters

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:



4.9.4 Variable Documentation

4.9.4.1 rawADC_left

```
volatile uint32_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.

4.9.4.2 rawADC_right

```
volatile uint32_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.

4.9.4.3 rawADC_temp

```
volatile uint32_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.

4.9.4.4 tempInverterLUT

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

4.9.4.5 tempMotorLUT

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

4.10 MEASUREMENTS.h

Go to the documentation of this file.

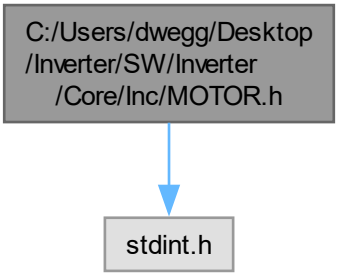
```
00001 /* USER CODE BEGIN Header */
00017 /* USER CODE END Header */
00018
00019
00020 #ifndef MEASUREMENTS_H
00021 #define MEASUREMENTS_H
00022
00023 /* Define current and voltage gains/offsets */
00024 #define CURRENT_SLOPE  54.4217687f
00025 #define CURRENT_OFFSET 1.70068027211f
00026 #define VOLTAGE_SLOPE  263.435f
00027 #define VOLTAGE_OFFSET 0.02083f
00029 #include <stdint.h>
00030
00031 extern const float tempInverterLUT[];
00032 extern const float tempMotorLUT[];
00033
00034 extern volatile uint32_t rawADC_left[4];
00035 extern volatile uint32_t rawADC_right[4];
00036 extern volatile uint32_t rawADC_temp[4];
00042 typedef struct {
00043     uint16_t A;
00044     uint16_t B;
00045     uint16_t Z;
00046     float we;
00047     float theta_e;
00048     float sinTheta_e;
00049     float cosTheta_e;
00050     uint8_t directionMeas;
00051 } Encoder;
00052
00056 typedef struct {
00057     float ia;
00058     float ib;
00059     float ic;
00060     float vDC;
00061 } Analog;
00062
00066 typedef struct {
00067     float idMeas;
00068     float iqMeas;
00069     float torqueCalc;
00070     float speedMeas;
00071 } Feedback;
00072
```

```
00082 uint8_t get_currents_voltage(volatile uint32_t ADC_raw[], volatile Analog* analog, volatile Feedback*
      feedback, float sinTheta_e, float cosTheta_e);
00083
00091 float get_linear(uint32_t bits, float slope, float offset);
00092
00107 void get_idiq(float ia, float ib, float ic, float sinTheta_e, float cosTheta_e, float *idMeas, float
      *iqMeas);
00108
00109
00120 float get_temperature(uint32_t bits, const float tempLUT[]);
00121 #endif /* MEASUREMENTS_H */
```

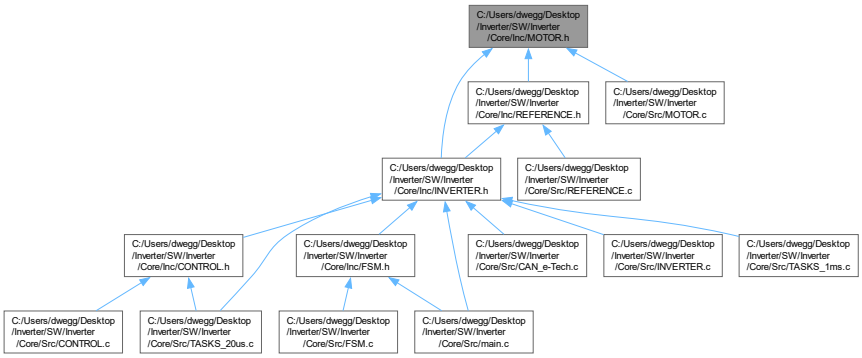
4.11 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h File Reference

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 MotorParameters

  Structure to hold motor parameters.

Functions

- 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.

4.11.1 Detailed Description

Header file for motor parameters.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.11.2 Function Documentation

4.11.2.1 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:

4.11.3 Variable Documentation

4.11.3.1 motor_left

```
MotorParameters motor_left  [extern]
```

Left motor parameters.

4.11.3.2 motor_right

```
MotorParameters motor_right  [extern]
```

Right motor parameters.

4.12 MOTOR.h

Go to the documentation of this file.

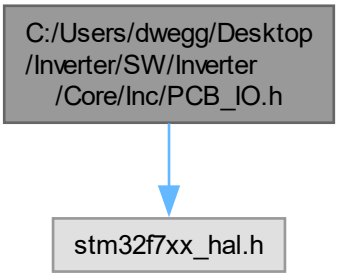
```
00001 /* USER CODE BEGIN Header */
00017 /* USER CODE END Header */
00018
00019 #ifndef MOTOR_H
00020 #define MOTOR_H
00021
00022 #include <stdint.h>
00023
00027 typedef struct {
00028     float Ld;
00029     float Lq;
00030     float Rs;
00031     float lambda;
00032     uint8_t pp;
00033     float J;
00034     float b;
00035     float torqueMax;
00036     float dTorqueMax;
00037     float speedMax_RPM;
00038     float iMax;
00039     float vDCMax;
00041 } MotorParameters;
00042
00043 extern MotorParameters motor_left;
00044 extern MotorParameters motor_right;
00045
00051 int check_motor_parameters(MotorParameters *motor, float Ts);
00052 #endif /* MOTOR_H */
```

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

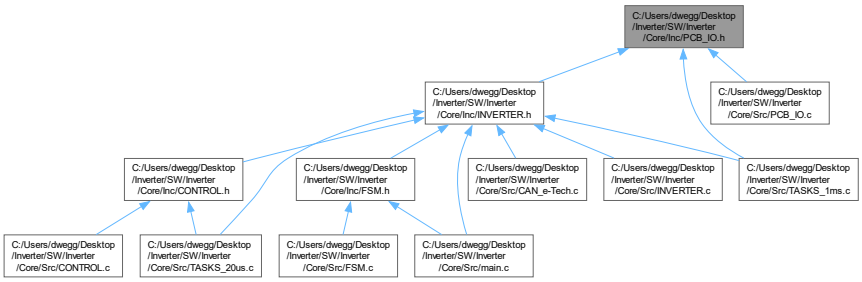
Header file for handling GPIOs.

```
#include "stm32f7xx_hal.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.

Variables

- LED led_left
- LED led_right
- LED ledError

4.13.1 Detailed Description

Header file for handling GPIOs.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.13.2 Macro Definition Documentation

4.13.2.1 DIR_STATE

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

4.13.2.2 DISABLE

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

4.13.2.3 ENABLE

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

4.13.2.4 SC_DET_STATE

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

4.13.2.5 WRN_STATE

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

4.13.3 Enumeration Type Documentation

4.13.3.1 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

4.13.4 Function Documentation

4.13.4.1 handle_direction()

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

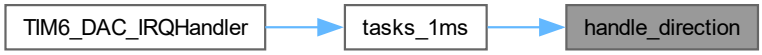
Handles the direction of the motors.

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:



4.13.4.2 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:

4.13.5 Variable Documentation

4.13.5.1 led_left

```
LED led_left  [extern]
```

4.13.5.2 led_right

```
LED led_right  [extern]
```

4.13.5.3 ledError

```
LED ledError  [extern]
```

4.14 PCB_IO.h

Go to the documentation of this file.

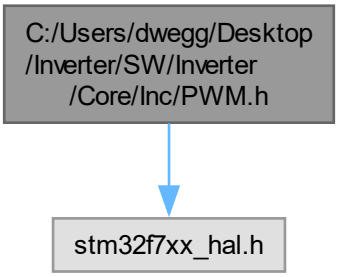
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020
00021 #ifndef PCB_IO_H
00022 #define PCB_IO_H
00023
00024 #include "stm32f7xx_hal.h"
00025
00026 // Read SC_det and DIR GPIOs
00027 #define SC_DET_STATE()              (HAL_GPIO_ReadPin(SC_det_GPIO_Port, SC_det_Pin))
00028 #define DIR_STATE()                 (HAL_GPIO_ReadPin(DIR_GPIO_Port, DIR_Pin))
00029
00030 // Read WRN GPIOs
00031 #define WRN_STATE(port, pin)        (HAL_GPIO_ReadPin(port, pin))
00032
00033 // Control ENABLE GPIOs
00034 #define ENABLE(port, pin)           do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_SET); } while(0)
00035 #define DISABLE(port, pin)          do { HAL_GPIO_WritePin(port, pin, GPIO_PIN_RESET); } while(0)
00036
00037 // Define LED modes
00038 typedef enum {
00039     LED_MODE_BLINK_FAST,
00040     LED_MODE_BLINK_SLOW,
00041     LED_MODE_ON,
00042     LED_MODE_OFF
00043 } LEDMode;
00044
00048 typedef struct {
00049     GPIO_TypeDef *port;
00050     uint16_t pin;
00051     LEDMode mode;
00052 } LED;
00053
00054 // Declare LED variables as extern
00055 extern LED led_left;
00056 extern LED led_right;
00057 extern LED ledError;
00058
00059 // Function prototypes
00068 void handle_LED(LED *led, uint32_t ms_counter);
00069
00081 void handle_direction(volatile int8_t *dir_left, volatile int8_t *dir_right);
00082
00083 #endif /* PCB_IO_H */
```

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

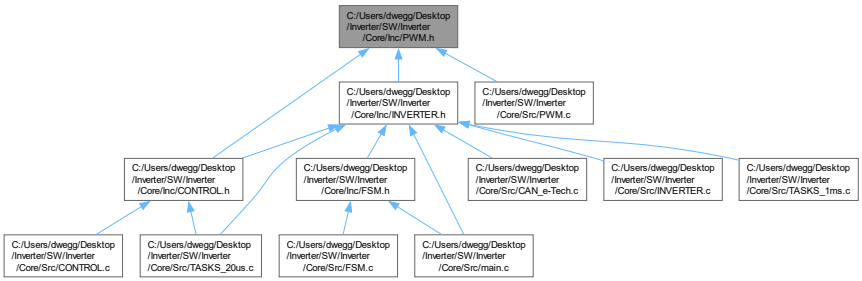
Header file for controlling PWM output.

```
#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.

4.15.1 Detailed Description

Header file for controlling PWM output.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.15.2 Function Documentation

4.15.2.1 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.

4.15.2.2 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.

4.15.2.3 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:

4.16 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 */
```

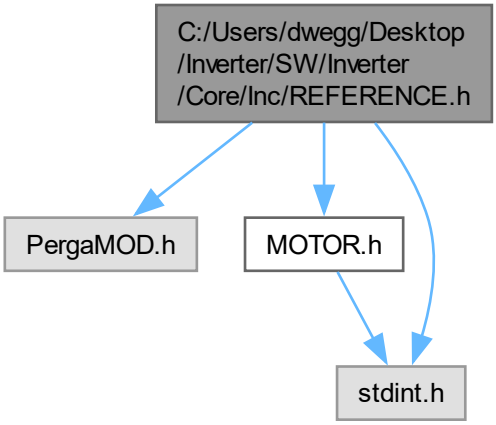
4.17 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/↩ REFERENCE.h File Reference

Header file for torque reference handling.

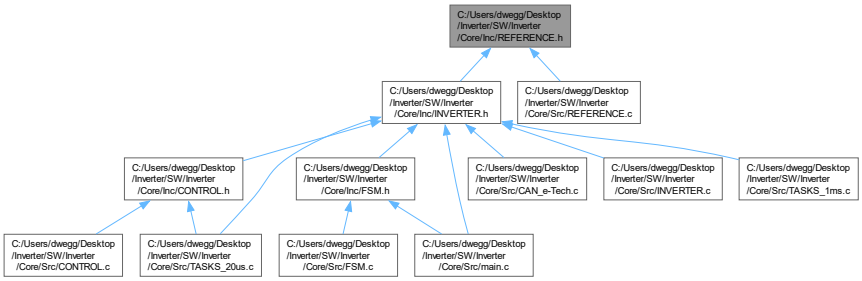
```
#include "PergaMOD.h"
#include "MOTOR.h"
```

```
#include <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.

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.

4.17.1 Detailed Description

Header file for torque reference handling.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.17.2 Function Documentation

4.17.2.1 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.

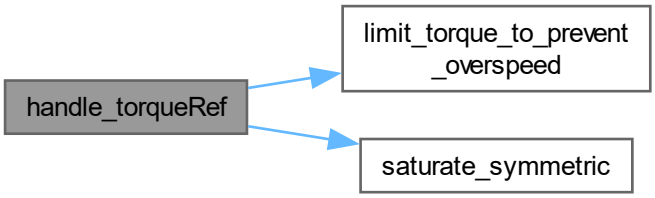
Parameters

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.

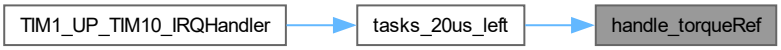
Returns

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:



4.17.2.2 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:

4.17.2.3 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.

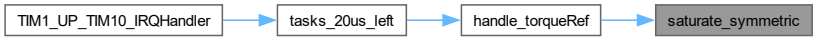
Parameters

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:



4.17.2.4 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.

4.18 REFERENCE.h

Go to the documentation of this file.

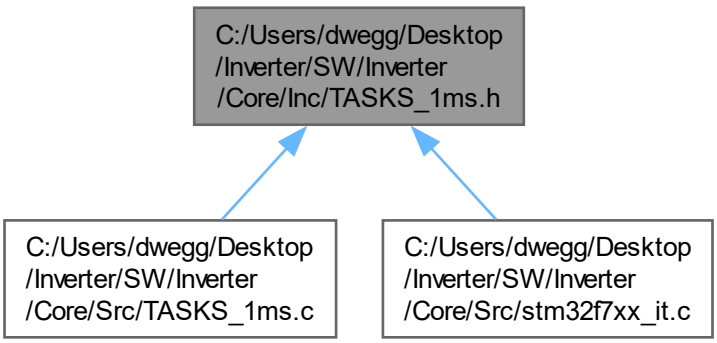
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020 #ifndef REFERENCE_H
00021 #define REFERENCE_H
00022
00023 #include "PergaMOD.h" // ramp, pi struct
00024 #include "MOTOR.h" // motor struct
00025 #include <stdint.h>
00026
00030 typedef struct {
00031     float idRef;
00032     float iqRef;
00033     float torqueRef;
00034 } Reference;
00035
00036
00050 float handle_torqueRef(float torqueRefIn, int8_t direction, float torqueMax, float speedMaxRPM, float
      speedMeas, volatile pi_struct *loopSpeed);
00051
```

```
00052
00064 float set_torque_direction(float torqueRef, int8_t direction);
00065
00077 float saturate_symmetric(float ref, float max);
00078
00087 float limit_torque_to_prevent_overspeed(float speedMax, float speedMeas, float torqueRefIn, volatile
      pi_struct *loopSpeed);
00088
00089 #endif /* REFERENCE_H */
```

4.19 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_1ms.h File Reference

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

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



Functions

- void tasks_1ms (void)

  Function to be executed every 1ms.

4.19.1 Detailed Description

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

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.19.2 Function Documentation

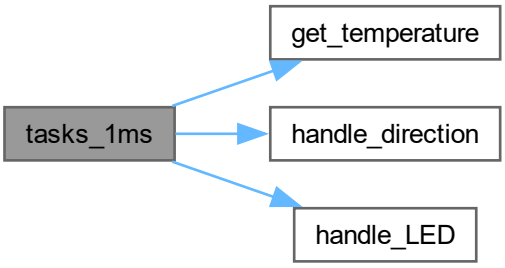
4.19.2.1 tasks_1ms()

```
void tasks_1ms (
            void  )
```

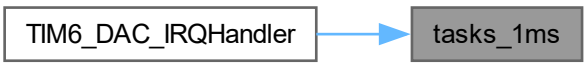
Function to be executed every 1ms.

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:



4.20 TASKS_1ms.h

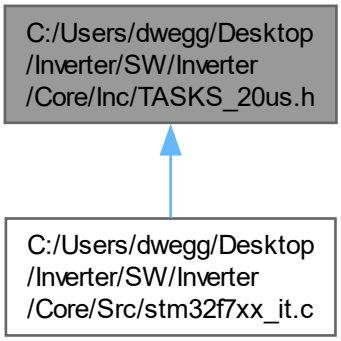
Go to the documentation of this file.

```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00020
00021 #ifndef TASKS_1MS_H
00022 #define TASKS_1MS_H
00023
00029 void tasks_1ms(void);
00030
00031 #endif /* TASKS_1MS_H */
```

4.21 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_↩ 20us.h File Reference

Header file for functions related to tasks executed every 20us in each PWM timer interruption.

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



Functions

- void tasks_20us_left ()

  Function to be executed every TS.
- void tasks_20us_right ()

  Function to be executed every TS.

4.21.1 Detailed Description

Header file for functions related to tasks executed every 20us in each PWM timer interruption.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩ 0/legalcode

4.21.2 Function Documentation

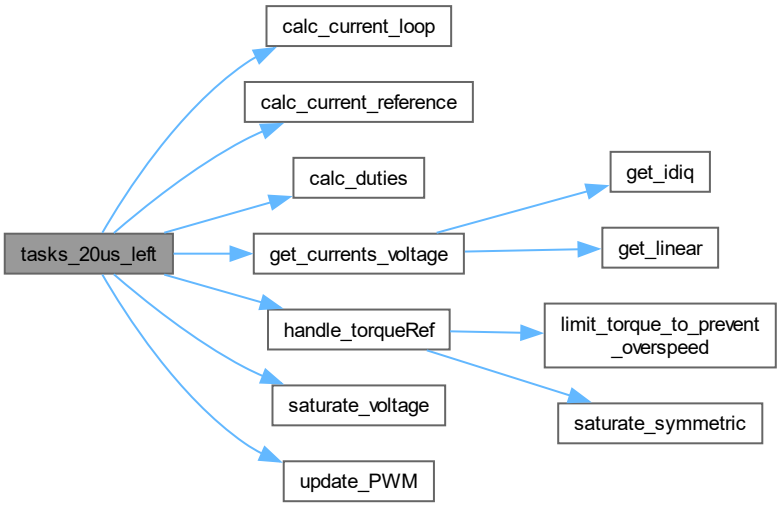
4.21.2.1 tasks_20us_left()

```
void tasks_20us_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:

4.21.2.2 tasks_20us_right()

```
void tasks_20us_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.

4.22 TASKS_20us.h

Go to the documentation of this file.

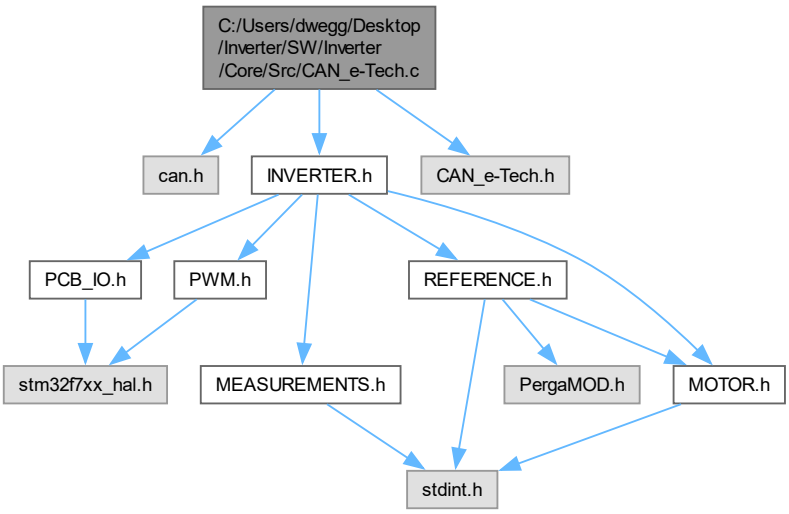
```
00001 /* USER CODE BEGIN Header */
00018 /* USER CODE END Header */
00019
00025 void tasks_20us_left();
00026
00032 void tasks_20us_right();
```

4.23 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

4.23.1 Detailed Description

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

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.23.2 Function Documentation

4.23.2.1 handle_CAN()

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

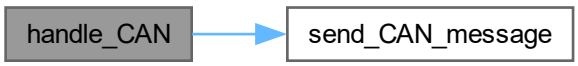
Handle CAN messages.

This function implements the logic to handle received CAN messages.

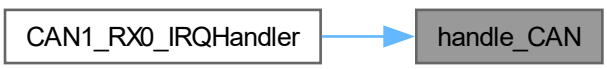
Parameters

hcan	Pointer to the CAN handle structure.

Here is the call graph for this function:



Here is the caller graph for this function:



4.23.2.2 send_CAN_message()

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

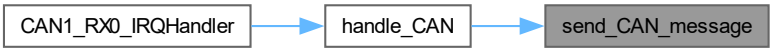
Send a CAN message using CAN1db.h information.

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:



4.23.3 Variable Documentation

4.23.3.1 keepAlive

```
uint8_t keepAlive
```

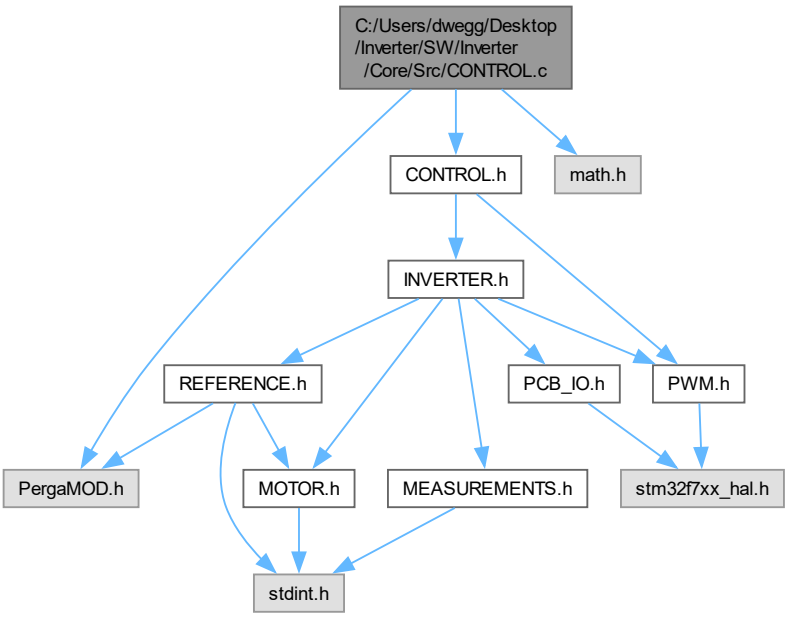
4.24 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CONTROL.c File Reference

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 (float we, float torqueRef, float vsRef, MotorParameters *motor, volatile float *idRef, volatile float *iqRef)

  Calculates the current references based on electrical speed, torque reference, voltage reference, motor parameters, and updates the d-axis and q-axis current references. Just MTPA for now.
- 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.

4.24.1 Detailed Description

This file provides code for the control loop.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.24.2 Function Documentation

4.24.2.1 calc_current_loop()

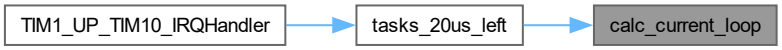
```
void calc_current_loop (
            volatile InverterStruct * inv )
```

Calculates the id-iq loops.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:



4.24.2.2 calc_current_reference()

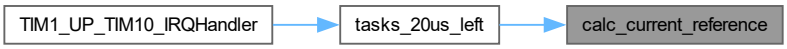
```
void calc_current_reference (
            float we,
            float torqueRef,
            float vsRef,
            MotorParameters * motor,
            volatile float * idRef,
            volatile float * iqRef )
```

Calculates the current references based on electrical speed, torque reference, voltage reference, motor parameters, and updates the d-axis and q-axis current references. Just MTPA for now.

Parameters

in	*we*	Electrical speed in radians per second.
in	*torqueRef*	Torque reference.
in	*vsRef*	Voltage reference.
in	*motor*	Pointer to the motor parameters structure.
out	*idRef*	Pointer to the d-axis current reference.
out	*iqRef*	Pointer to the q-axis current reference.

Here is the caller graph for this function:



4.24.2.3 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:

4.24.2.4 saturate_voltage()

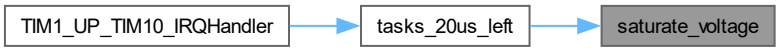
```
void saturate_voltage (
            volatile InverterStruct * inv )
```

Saturates PI output to not surpass DC voltage.

Parameters

inv	Pointer to the inverter structure.

Here is the caller graph for this function:

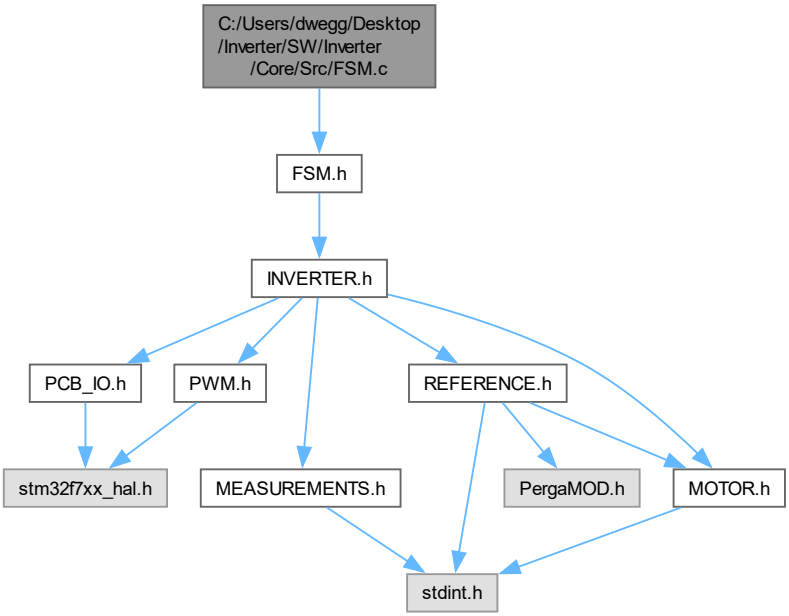


4.25 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/FSM.c File Reference

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.

4.25.1 Detailed Description

This file provides code for the inverter Finite State Machine.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.25.2 Function Documentation

4.25.2.1 eval_inv_FSM()

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

Execute the finite state machine for inverter.

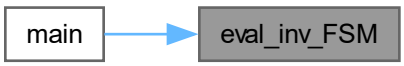
Run the Finite State Machine (FSM) for inverter operation control.

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:

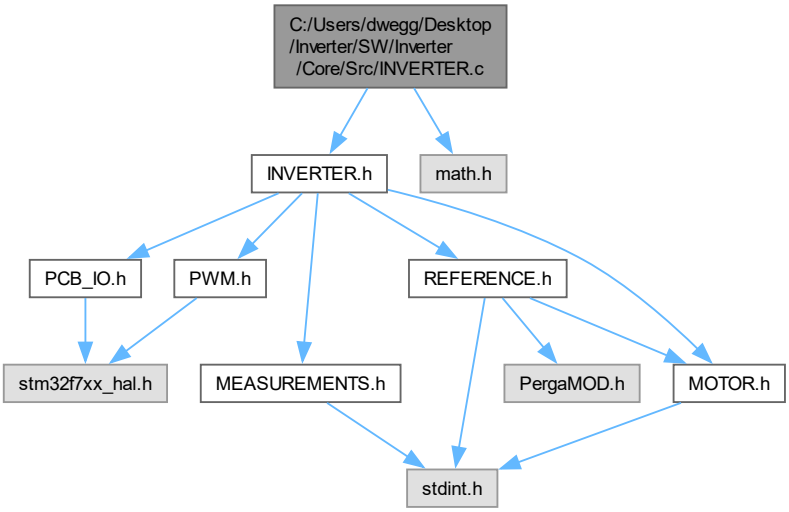


4.26 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/INVERTER.c File Reference

This file provides code for the inverter struct.

```
#include "INVERTER.h"
#include <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)

  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.

4.26.1 Detailed Description

This file provides code for the inverter struct.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.26.2 Function Documentation

4.26.2.1 disable_control_loops()

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

Disables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.26.2.2 enable_control_loops()

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

Enables the PI controllers.

Parameters

inv	Pointer to the inverter structure.

4.26.2.3 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:

4.26.2.4 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 )
```

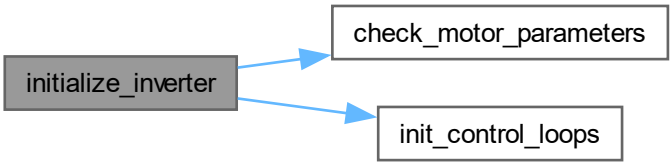
Initialize the inverter.

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:

4.26.3 Variable Documentation

4.26.3.1 inverter_left

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

Left inverter structure.

External declaration of the left inverter structure.

4.26.3.2 inverter_right

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

Right inverter structure.

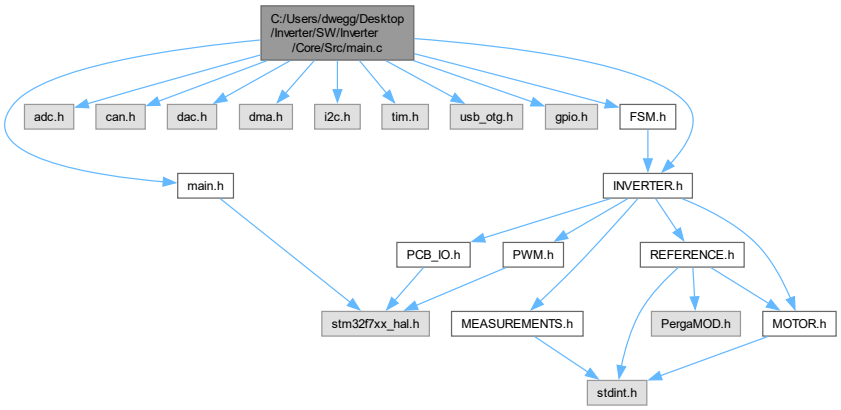
External declaration of the right inverter structure.

4.27 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.

4.27.1 Detailed Description

: Main program body

Attention

Copyright (c) 2023 STMicroelectronics. All rights reserved.

This software is licensed under terms that can be found in the LICENSE file in the root directory of this software component. If no LICENSE file comes with this software, it is provided AS-IS.

4.27.2 Function Documentation

4.27.2.1 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:

4.27.2.2 main()

```
int main (
```

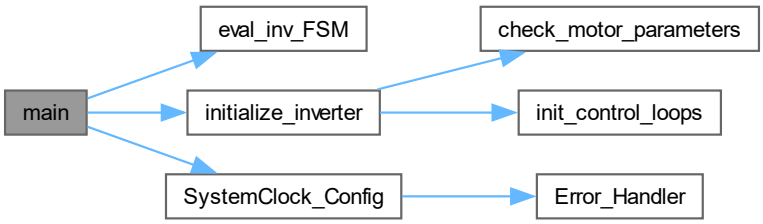
```
            void  )
```

The application entry point.

Return values

int	

Here is the call graph for this function:



4.27.2.3 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:

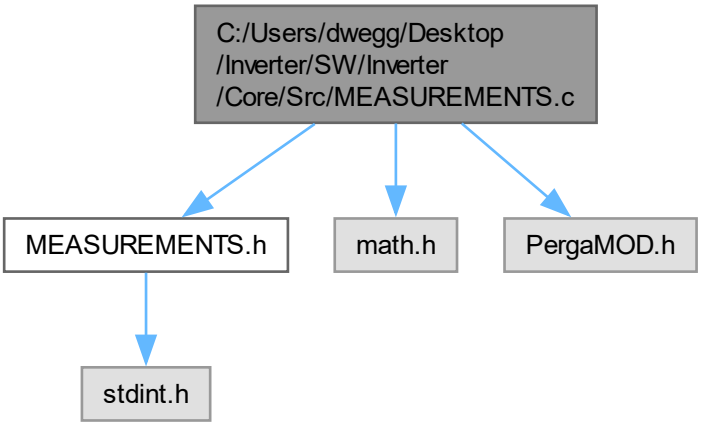
Here is the caller graph for this function:

4.28 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

- uint8_t get_currents_voltage (volatile uint32_t ADC_raw[ ], volatile Analog ∗analog, volatile Feedback ∗feedback, 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.

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, 4.44, 4.45, 4.46, 4.47, 4.48, 4.48, 4.49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.62, 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, 5.60, 5.61, 5.62, 5.63, 5.64, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74, 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, 6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32, 6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.47, 6.48, 6.49, 6.50, 6.51, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61, 6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 6.75, 6.75, 6.76, 6.77, 6.78, 6.79, 6.80, 6.81, 6.82, 6.83, 6.84, 6.85, 6.86, 6.87, 6.88, 6.89, 6.90, 6.91, 6.92, 6.93, 6.94, 6.95, 6.96, 6.97, 6.98, 6.99, 7.00, 7.01, 7.02, 7.03, 7.04, 7.05, 7.06, 7.07, 7.08, 7.09, 7.10, 7.11, 7.12, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17, 7.18, 7.19, 7.20, 7.21, 7.22, 7.23, 7.24, 7.25, 7.26, 7.27, 7.28, 7.29, 7.30, 7.31, 7.32, 7.33, 7.34, 7.35, 7.36, 7.37, 7.38, 7.39, 7.40, 7.41, 7.42, 7.43, 7.44, 7.45, 7.46, 7.47, 7.48, 7.49, 7.50, 7.51, 7.52, 7.53, 7.54, 7.55, 7.56, 7.57, 7.58, 7.59, 7.60, 7.61, 7.62, 7.63, 7.64, 7.65, 7.66, 7.67, 7.68, 7.69, 7.70, 7.71, 7.72, 7.73, 7.74, 7.75, 7.76, 7.77, 7.78, 7.79, 7.80, 7.81, 7.82, 7.83, 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, 8.00, 8.01, 8.02, 8.03, 8.04, 8.05, 8.06, 8.07, 8.08, 8.09, 8.10, 8.11, 8.12, 8.13, 8.14, 8.15, 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, 8.32, 8.33, 8.34, 8.35, 8.36, 8.37, 8.38, 8.39, 8.40, 8.41, 8.42, 8.43, 8.44, 8.45, 8.46, 8.47, 8.48, 8.49, 8.50, 8.51, 8.52, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.64, 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, 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, 17.75, 17.77, 17.79, 17.80, 17.82, 17.83, 17.85, 17.86, 17.88, 17.90, 17.91, 17.93, 17.94, 17.96, 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.↩
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, 19.24, 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, 20.37, 20.39, 20.41, 20.42, 20.44, 20.46, 20.48, 20.49, 20.51, 20.53, 20.55, 20.57, 20.58, 20.60, 20.62, 20.64, 20.66, 20.67, 20.69, 20.71, 20.↩
73, 20.75, 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, 43.12, 43.17, 43.21, 43.26, 43.30, 43.35, 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, 44.56, 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, 49.40, 49.46, 49.52, 49.57, 49.63, 49.69, 49.75, 49.80, 49.86, 49.92, 49.98, 50.04, 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, 51.61, 51.67, 51.73, 51.79, 51.86, 51.92, 51.98, 52.04, 52.11, 52.17, 52.23, 52.30, 52.36, 52.43, 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}

- 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, 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, 4.44, 4.45, 4.46, 4.47, 4.48, 4.48, 4.49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.62, 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, 5.60, 5.61, 5.62, 5.63, 5.64, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74, 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, 6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32, 6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.47, 6.48, 6.49, 6.50, 6.51, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61, 6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 6.75, 6.75, 6.76, 6.77, 6.78, 6.79, 6.80, 6.81, 6.82, 6.83, 6.84, 6.85, 6.86, 6.87, 6.88, 6.89, 6.90, 6.91, 6.92, 6.93, 6.94, 6.95, 6.96, 6.97, 6.98, 6.99, 7.00, 7.01, 7.02, 7.03, 7.04, 7.05, 7.06, 7.07, 7.08, 7.09, 7.10, 7.11, 7.12, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17, 7.18, 7.19, 7.20, 7.21, 7.22, 7.23, 7.24, 7.25, 7.26, 7.27, 7.28, 7.29, 7.30, 7.31, 7.32, 7.33, 7.34, 7.35, 7.36, 7.37, 7.38, 7.39, 7.40, 7.41, 7.42, 7.43, 7.44, 7.45, 7.46, 7.47, 7.48, 7.49, 7.50, 7.51, 7.52, 7.53, 7.54, 7.55, 7.56, 7.57, 7.58, 7.59, 7.60, 7.61, 7.62, 7.63, 7.64, 7.65, 7.66, 7.67, 7.68, 7.69, 7.70, 7.71, 7.72, 7.73, 7.74, 7.75, 7.76, 7.77, 7.78, 7.79, 7.80, 7.81, 7.82, 7.83, 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, 8.00, 8.01, 8.02, 8.03, 8.04, 8.05, 8.06, 8.07, 8.08, 8.09, 8.10, 8.11, 8.12, 8.13, 8.14, 8.15, 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, 8.32, 8.33, 8.34, 8.35, 8.36, 8.37, 8.38, 8.39, 8.40, 8.41, 8.42, 8.43, 8.44, 8.45, 8.46, 8.47, 8.48, 8.49, 8.50, 8.51, 8.52, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.64, 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, 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, 17.75, 17.77, 17.79, 17.80, 17.82, 17.83, 17.85, 17.86, 17.88, 17.90, 17.91, 17.93, 17.94, 17.96, 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, 18.59, 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, 19.24, 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, 20.37, 20.39, 20.41, 20.42, 20.44, 20.46, 20.48, 20.49, 20.51, 20.53, 20.55, 20.57, 20.58, 20.60, 20.62, 20.64, 20.66, 20.67, 20.69, 20.71, 20.73, 20.↩
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.↩
12, 43.17, 43.21, 43.26, 43.30, 43.35, 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.↩
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.↩
40, 49.46, 49.52, 49.57, 49.63, 49.69, 49.75, 49.80, 49.86, 49.92, 49.98, 50.04, 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, 51.61, 51.67, 51.73, 51.79, 51.86, 51.92, 51.98, 52.04, 52.11, 52.17, 52.23, 52.30, 52.36, 52.43, 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}

- volatile uint32_t rawADC_left [4] = {0}

    Raw ADC data for the left inverter.

- volatile uint32_t rawADC_right [4] = {0}

    Raw ADC data for the right inverter.

- volatile uint32_t rawADC_temp [4] = {0}

    Raw ADC data for the temperatures.

4.28.1 Detailed Description

This file provides functions for handling measurements.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

4.28.2 Function Documentation

4.28.2.1 get_currents_voltage()

```
uint8_t get_currents_voltage (
            volatile uint32_t ADC_raw[],
            volatile Analog * analog,
            volatile Feedback * feedback,
            float sinTheta_e,
            float cosTheta_e )
```

Get electrical ADC measurements.

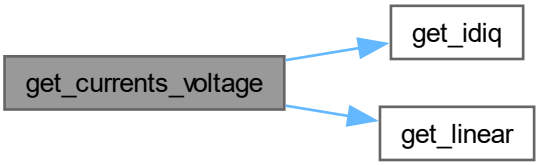
Parameters

in	*ADC_raw*	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)

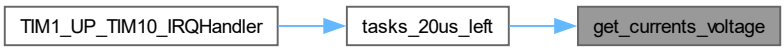
Return values

OK	0 if an error occurred, 1 if successful.

Here is the call graph for this function:



Here is the caller graph for this function:



4.28.2.2 get_idiq()

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

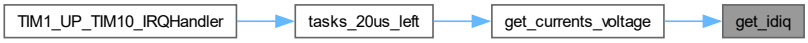
Computes d-q currents from current measurements and electrical angle.

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)
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:



4.28.2.3 get_linear()

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

Convert ADC reading to physical measurement with linear response.

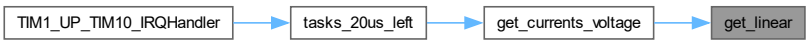
Parameters

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:



4.28.2.4 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.

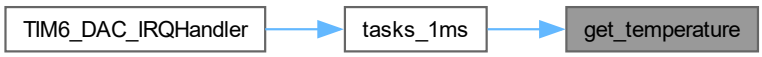
Parameters

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:



4.28.3 Variable Documentation

4.28.3.1 rawADC_left

```
volatile uint32_t rawADC_left[4] = {0}
```

Raw ADC data for the left inverter.

External declaration of raw ADC data for the left inverter.

4.28.3.2 rawADC_right

```
volatile uint32_t rawADC_right[4] = {0}
```

Raw ADC data for the right inverter.

External declaration of raw ADC data for the right inverter.

4.28.3.3 rawADC_temp

```
volatile uint32_t rawADC_temp[4] = {0}
```

Raw ADC data for the temperatures.

External declaration of raw ADC data for the temperature readings.

4.28.3.4 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,
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, 4.44, 4.45, 4.46, 4.47, 4.48, 4.48, 4.↩
49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.62,
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.↩
60, 5.61, 5.62, 5.63, 5.64, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74,
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,
6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.16, 6.↩
17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32,
6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.↩
47, 6.48, 6.49, 6.50, 6.51, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61,
6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 6.75, 6.75, 6.↩
76, 6.77, 6.78, 6.79, 6.80, 6.81, 6.82, 6.83, 6.84, 6.85, 6.86, 6.87, 6.88, 6.89, 6.90, 6.91,
6.92, 6.93, 6.94, 6.95, 6.96, 6.97, 6.98, 6.99, 7.00, 7.01, 7.02, 7.03, 7.04, 7.05, 7.06, 7.↩
07, 7.08, 7.09, 7.10, 7.11, 7.12, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17, 7.18, 7.19, 7.20, 7.21,
7.22, 7.23, 7.24, 7.25, 7.26, 7.27, 7.28, 7.29, 7.30, 7.31, 7.32, 7.33, 7.34, 7.35, 7.36, 7.↩
37, 7.38, 7.39, 7.40, 7.41, 7.42, 7.43, 7.44, 7.45, 7.46, 7.47, 7.48, 7.49, 7.50, 7.51, 7.52,
7.53, 7.54, 7.55, 7.56, 7.57, 7.58, 7.59, 7.60, 7.61, 7.62, 7.63, 7.64, 7.65, 7.66, 7.67, 7.↩
68, 7.69, 7.70, 7.71, 7.72, 7.73, 7.74, 7.75, 7.76, 7.77, 7.78, 7.79, 7.80, 7.81, 7.82, 7.83,
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.↩
00, 8.01, 8.02, 8.03, 8.04, 8.05, 8.06, 8.07, 8.08, 8.09, 8.10, 8.11, 8.12, 8.13, 8.14, 8.15,
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.↩
32, 8.33, 8.34, 8.35, 8.36, 8.37, 8.38, 8.39, 8.40, 8.41, 8.42, 8.43, 8.44, 8.45, 8.46, 8.47,
8.48, 8.49, 8.50, 8.51, 8.52, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.↩
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,
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.↩
75, 17.77, 17.79, 17.80, 17.82, 17.83, 17.85, 17.86, 17.88, 17.90, 17.91, 17.93, 17.94, 17.↩
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.↩
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.↩
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.↩
37, 20.39, 20.41, 20.42, 20.44, 20.46, 20.48, 20.49, 20.51, 20.53, 20.55, 20.57, 20.58, 20.↩
60, 20.62, 20.64, 20.66, 20.67, 20.69, 20.71, 20.73, 20.75, 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, 43.12, 43.17, 43.21, 43.26, 43.30, 43.↩
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.↩
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, 49.40, 49.46, 49.52, 49.57, 49.63, 49.69, 49.75, 49.80, 49.86, 49.92, 49.98, 50.↩
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.↩
61, 51.67, 51.73, 51.79, 51.86, 51.92, 51.98, 52.04, 52.11, 52.17, 52.23, 52.30, 52.36, 52.↩
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,
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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98,
421.98}
```

4.28.3.5 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,
```

```
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, 4.44, 4.45, 4.46, 4.47, 4.48, 4.48, 4.↩
49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.62,
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.↩
60, 5.61, 5.62, 5.63, 5.64, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74,
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,
6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.16, 6.↩
17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32,
6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.↩
47, 6.48, 6.49, 6.50, 6.51, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61,
6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 6.75, 6.75, 6.↩
76, 6.77, 6.78, 6.79, 6.80, 6.81, 6.82, 6.83, 6.84, 6.85, 6.86, 6.87, 6.88, 6.89, 6.90, 6.91,
6.92, 6.93, 6.94, 6.95, 6.96, 6.97, 6.98, 6.99, 7.00, 7.01, 7.02, 7.03, 7.04, 7.05, 7.06, 7.↩
07, 7.08, 7.09, 7.10, 7.11, 7.12, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17, 7.18, 7.19, 7.20, 7.21,
7.22, 7.23, 7.24, 7.25, 7.26, 7.27, 7.28, 7.29, 7.30, 7.31, 7.32, 7.33, 7.34, 7.35, 7.36, 7.↩
37, 7.38, 7.39, 7.40, 7.41, 7.42, 7.43, 7.44, 7.45, 7.46, 7.47, 7.48, 7.49, 7.50, 7.51, 7.52,
7.53, 7.54, 7.55, 7.56, 7.57, 7.58, 7.59, 7.60, 7.61, 7.62, 7.63, 7.64, 7.65, 7.66, 7.67, 7.↩
68, 7.69, 7.70, 7.71, 7.72, 7.73, 7.74, 7.75, 7.76, 7.77, 7.78, 7.79, 7.80, 7.81, 7.82, 7.83,
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.↩
00, 8.01, 8.02, 8.03, 8.04, 8.05, 8.06, 8.07, 8.08, 8.09, 8.10, 8.11, 8.12, 8.13, 8.14, 8.15,
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.↩
32, 8.33, 8.34, 8.35, 8.36, 8.37, 8.38, 8.39, 8.40, 8.41, 8.42, 8.43, 8.44, 8.45, 8.46, 8.47,
```

8.48, 8.49, 8.50, 8.51, 8.52, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.↩
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,
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.↩
75, 17.77, 17.79, 17.80, 17.82, 17.83, 17.85, 17.86, 17.88, 17.90, 17.91, 17.93, 17.94, 17.↩
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.↩

```
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.↩
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.↩
37, 20.39, 20.41, 20.42, 20.44, 20.46, 20.48, 20.49, 20.51, 20.53, 20.55, 20.57, 20.58, 20.↩
60, 20.62, 20.64, 20.66, 20.67, 20.69, 20.71, 20.73, 20.75, 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, 43.12, 43.17, 43.21, 43.26, 43.30, 43.↩
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.↩
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, 49.40, 49.46, 49.52, 49.57, 49.63, 49.69, 49.75, 49.80, 49.86, 49.92, 49.98, 50.↩
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.↩
61, 51.67, 51.73, 51.79, 51.86, 51.92, 51.98, 52.04, 52.11, 52.17, 52.23, 52.30, 52.36, 52.↩
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.↩
```

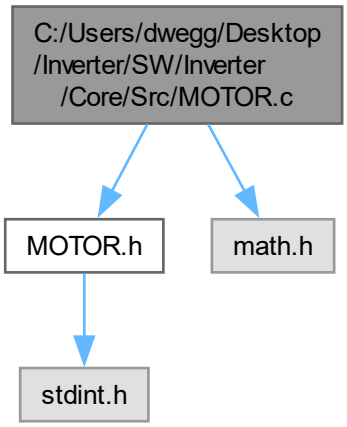
```
92, 115.42, 115.93, 116.44, 116.97, 117.50, 118.04, 118.59, 119.14, 119.71, 120.29, 120.87,
121.47, 122.07, 122.69, 123.32, 123.95, 124.61, 125.27, 125.94, 126.63, 127.33, 128.05, 128.↩
78, 129.52, 130.29, 131.06, 131.86, 132.67, 133.50, 134.35, 135.22, 136.12, 137.03, 137.97,
138.93, 139.92, 140.93, 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,
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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 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, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98, 421.98,
421.98}
```

4.29 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

- 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.

4.29.1 Detailed Description

Source file for motor parameters.

Attention

Copyright (c) 2024 David Redondo (@dweggg on GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.29.2 Function Documentation

4.29.2.1 check_motor_parameters()

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

Perform a parameter check and correct possible errors.

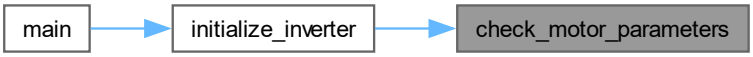
Parameters

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:



4.29.3 Variable Documentation

4.29.3.1 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.

4.29.3.2 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
}
```

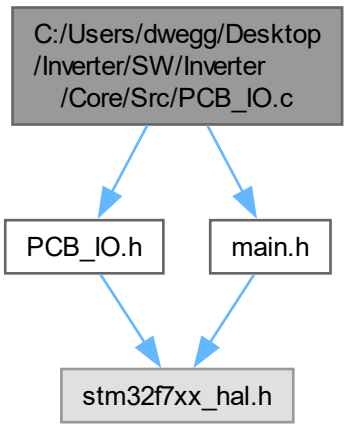
Right motor parameters.

4.30 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.

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 }

4.30.1 Detailed Description

This file provides functions for handling GPIOs.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.30.2 Function Documentation

4.30.2.1 handle_direction()

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

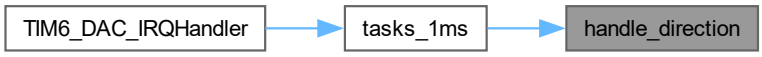
Handles the direction of the motors.

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:



4.30.2.2 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:

4.30.3 Variable Documentation

4.30.3.1 led_left

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

4.30.3.2 led_right

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

4.30.3.3 ledError

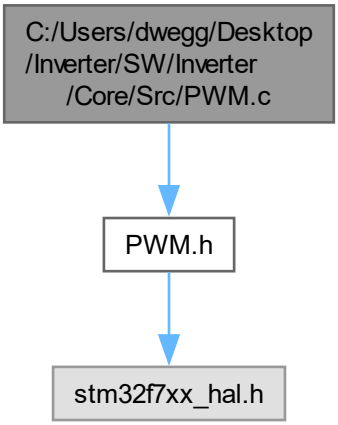
```
LED ledError = { .port = LED_ERR_GPIO_Port, .pin = LED_ERR_Pin, .mode = LED_MODE_OFF }
```

4.31 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.

4.31.1 Detailed Description

This file provides functions for controlling PWM output.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.31.2 Function Documentation

4.31.2.1 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.

4.31.2.2 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.

4.31.2.3 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.

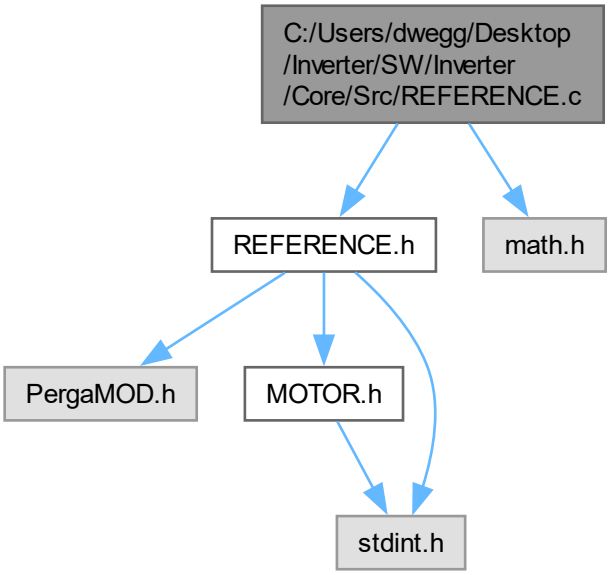
Here is the caller graph for this function:

4.32 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.

4.32.1 Detailed Description

Source file for torque reference handling.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.↩0/legalcode

4.32.2 Function Documentation

4.32.2.1 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.

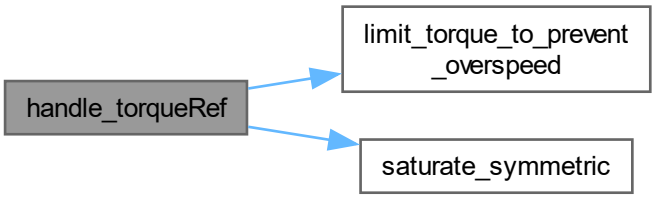
Parameters

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.

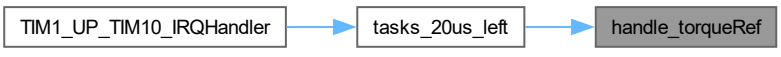
Returns

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:



4.32.2.2 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:

4.32.2.3 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:

4.32.2.4 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

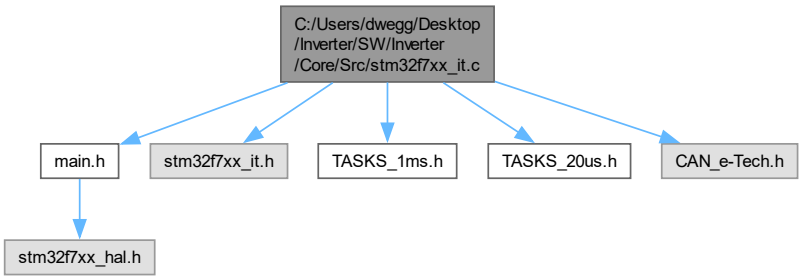
torqueRefOut The adjusted torque reference value.

4.33 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_20us.h"
#include "CAN_e-Tech.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.

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

4.33.1 Detailed Description

Interrupt Service Routines.

Attention

Copyright (c) 2023 STMicroelectronics. All rights reserved.

This software is licensed under terms that can be found in the LICENSE file in the root directory of this software component. If no LICENSE file comes with this software, it is provided AS-IS.

4.33.2 Function Documentation

4.33.2.1 BusFault_Handler()

```
void BusFault_Handler (
             void  )
```

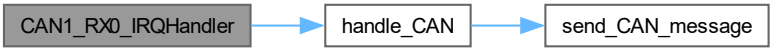
This function handles Pre-fetch fault, memory access fault.

4.33.2.2 CAN1_RX0_IRQHandler()

```
void CAN1_RX0_IRQHandler (
             void  )
```

This function handles CAN1 RX0 interrupts.

Here is the call graph for this function:



4.33.2.3 DebugMon_Handler()

```
void DebugMon_Handler (
             void  )
```

This function handles Debug monitor.

4.33.2.4 DMA2_Stream0_IRQHandler()

```
void DMA2_Stream0_IRQHandler (
             void  )
```

This function handles DMA2 stream0 global interrupt.

4.33.2.5 DMA2_Stream1_IRQHandler()

```
void DMA2_Stream1_IRQHandler (
             void  )
```

This function handles DMA2 stream1 global interrupt.

4.33.2.6 DMA2_Stream2_IRQHandler()

```
void DMA2_Stream2_IRQHandler (
             void  )
```

This function handles DMA2 stream2 global interrupt.

4.33.2.7 HardFault_Handler()

```
void HardFault_Handler (
             void  )
```

This function handles Hard fault interrupt.

4.33.2.8 MemManage_Handler()

```
void MemManage_Handler (
             void  )
```

This function handles Memory management fault.

4.33.2.9 NMI_Handler()

```
void NMI_Handler (
             void  )
```

This function handles Non maskable interrupt.

4.33.2.10 PendSV_Handler()

```
void PendSV_Handler (
            void  )
```

This function handles Pendable request for system service.

4.33.2.11 SVC_Handler()

```
void SVC_Handler (
            void  )
```

This function handles System service call via SWI instruction.

4.33.2.12 SysTick_Handler()

```
void SysTick_Handler (
            void  )
```

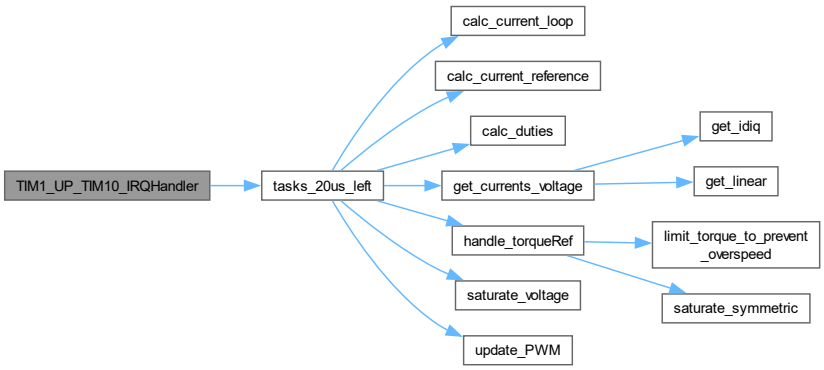
This function handles System tick timer.

4.33.2.13 TIM1_UP_TIM10_IRQHandler()

```
void TIM1_UP_TIM10_IRQHandler (
            void  )
```

This function handles TIM1 update interrupt and TIM10 global interrupt.

Here is the call graph for this function:

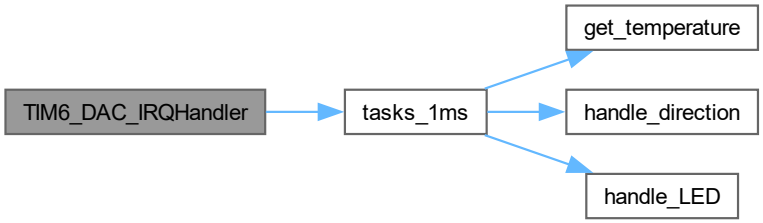


4.33.2.14 TIM6_DAC_IRQHandler()

```
void TIM6_DAC_IRQHandler (
            void  )
```

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

Here is the call graph for this function:



4.33.2.15 UsageFault_Handler()

```
void UsageFault_Handler (
            void  )
```

This function handles Undefined instruction or illegal state.

4.33.3 Variable Documentation

4.33.3.1 hcan1

```
CAN_HandleTypeDef hcan1  [extern]
```

4.33.3.2 hdac

```
DAC_HandleTypeDef hdac  [extern]
```

4.33.3.3 hdma_adc1

```
DMA_HandleTypeDef hdma_adc1  [extern]
```

4.33.3.4 hdma_adc2

```
DMA_HandleTypeDef hdma_adc2  [extern]
```

4.33.3.5 hdma_adc3

```
DMA_HandleTypeDef hdma_adc3  [extern]
```

4.33.3.6 htim1

```
TIM_HandleTypeDef htim1  [extern]
```

4.33.3.7 htim6

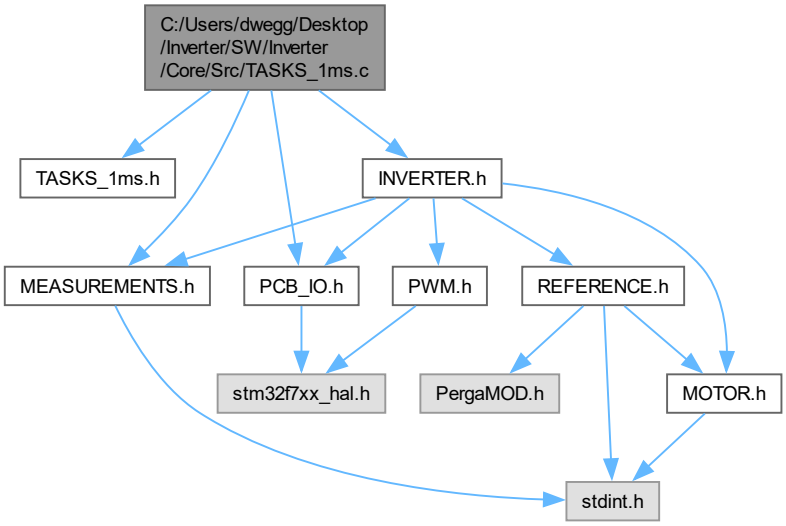
```
TIM_HandleTypeDef htim6  [extern]
```

4.34 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 "INVERTER.h"
#include "MEASUREMENTS.h"
```

Include dependency graph for TASKS_1ms.c:



Functions

- void tasks_1ms (void)

  Function to be executed every 1ms.

4.34.1 Detailed Description

This file contains functions to execute tasks every 1ms.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

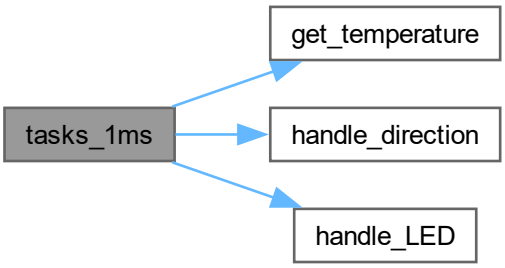
4.34.2 Function Documentation

4.34.2.1 tasks_1ms()

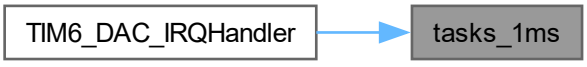
```
void tasks_1ms (
            void  )
```

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:

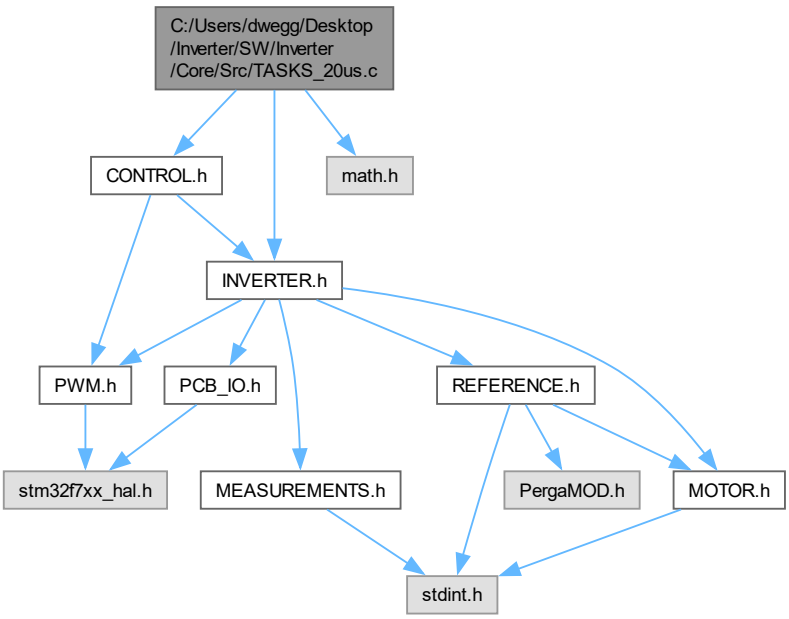


4.35 C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_↩ 20us.c File Reference

This file contains functions executed every 20us in each PWM timer interruption.

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

Include dependency graph for TASKS_20us.c:



Functions

- void tasks_20us_left (void)

  Function to be executed every TS.
- void tasks_20us_right (void)

  Function to be executed every TS.

Variables

- float vd_left = 0.0F
- float vq_left = 7.5F
- float vDC_left = 15.0F
- float torqueRefIn_left = 0.0F
- uint32_t start_ticks = 0
- uint32_t elapsed_ticks = 0
- angle_struct angle_left
- rampa_struct freqRamp_left

4.35.1 Detailed Description

This file contains functions executed every 20us in each PWM timer interruption.

Attention

Copyright (c) 2024 David Redondo (@dweggg in GitHub). All rights reserved.

This software is licensed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license. For more information, see: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode

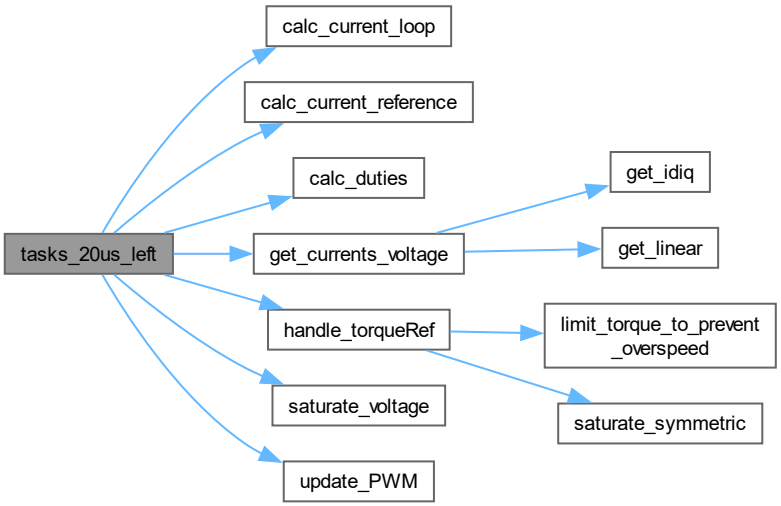
4.35.2 Function Documentation

4.35.2.1 tasks_20us_left()

```
void tasks_20us_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:

4.35.2.2 tasks_20us_right()

```
void tasks_20us_right (
            void  )
```

Function to be executed every TS.

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

4.35.3 Variable Documentation

4.35.3.1 angle_left

```
angle_struct angle_left
```

Initial value:

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

4.35.3.2 elapsed_ticks

```
uint32_t elapsed_ticks = 0
```

4.35.3.3 freqRamp_left

```
rampa_struct freqRamp_left
```

Initial value:

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

4.35.3.4 start_ticks

```
uint32_t start_ticks = 0
```

4.35.3.5 torqueRefIn_left

```
float torqueRefIn_left = 0.0F
```

4.35.3.6 vd_left

```
float vd_left = 0.0F
```

4.35.3.7 vDC_left

```
float vDC_left = 15.0F
```

4.35.3.8 vq_left

```
float vq_left = 7.5F
```

Index

A
Encoder, 7
A_L_GPIO_Port
main.h, 34
A_L_Pin
main.h, 34
A_R_GPIO_Port
main.h, 34
A_R_Pin
main.h, 34
Analog, 5
ia, 5
ib, 5
ic, 5
vDC, 6
analog
InverterStruct, 10
angle_left
TASKS_20us.c, 131

B
Encoder, 7
b
MotorParameters, 15
B_L_GPIO_Port
main.h, 35
B_L_Pin
main.h, 35
B_R_GPIO_Port
main.h, 35
B_R_Pin
main.h, 35
BusFault_Handler
stm32f7xx_it.c, 123

C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/CONTROL.h,
19, 23
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/FSM.h,
23, 25
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/INVERTER.h,
25, 31
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/main.h,
31, 43
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MEASUREMENTS.h,
45, 51
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/MOTOR.h,
52, 54
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PCB_IO.h,
55, 59
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/PWM.h,
59, 62
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/REFERENCE.h,
62, 67
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_1ms.h,
68, 69
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Inc/TASKS_20us.h,
70, 72
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CAN_e-
Tech.c, 72
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/CONTROL.c,
74
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/FSM.c,
78
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/INVERTER.c,
79
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/main.c,
83
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MEASUREMENT
86
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/MOTOR.c,
110
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PCB_IO.c,
113
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/PWM.c,
115
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/REFERENCE.c,
117
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/stm32f7xx_it.c,
121
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_1ms.c,
127
C:/Users/dwegg/Desktop/Inverter/SW/Inverter/Core/Src/TASKS_20us.c,
129
calc_current_loop
CONTROL.c, 76
CONTROL.h, 20
calc_current_reference
CONTROL.c, 76
CONTROL.h, 21
calc_duties
CONTROL.c, 77
CONTROL.h, 21
CAN1_RX0_IRQHandler
stm32f7xx_it.c, 123
CAN_e-Tech.c
handle_CAN, 73
keepAlive, 74
send_CAN_message, 73

check_motor_parameters
MOTOR.c, 111
MOTOR.h, 53
CONTROL.c
calc_current_loop, 76
calc_current_reference, 76
calc_duties, 77
saturate_voltage, 77
CONTROL.h
calc_current_loop, 20
calc_current_reference, 21
calc_duties, 21
saturate_voltage, 22
cosTheta_e
Encoder, 7
CURRENT_OFFSET
MEASUREMENTS.h, 46
CURRENT_SLOPE
MEASUREMENTS.h, 46

Da
Duties, 6
DAC_GPIO_Port
main.h, 35
DAC_Pin
main.h, 35
Db
Duties, 6
Dc
Duties, 6
DebugMon_Handler
stm32f7xx_it.c, 123
DIR_GPIO_Port
main.h, 35
DIR_Pin
main.h, 35
DIR_STATE
PCB_IO.h, 56
direction
InverterStruct, 10
directionMeas
Encoder, 8
DISABLE
PCB_IO.h, 56
disable_control_loops
INVERTER.c, 81
INVERTER.h, 28
disable_PWM
PWM.c, 116
PWM.h, 61
DMA2_Stream0_IRQHandler
stm32f7xx_it.c, 124
DMA2_Stream1_IRQHandler
stm32f7xx_it.c, 124
DMA2_Stream2_IRQHandler
stm32f7xx_it.c, 124
DT
INVERTER.h, 27
dTorqueMax
MotorParameters, 15
Duties, 6
Da, 6
Db, 6
Dc, 6
duties
InverterStruct, 11

elapsed_ticks
TASKS_20us.c, 131
ENABLE
PCB_IO.h, 56
enable_control_loops
INVERTER.c, 81
INVERTER.h, 28
ENABLE_L_GPIO_Port
main.h, 35
ENABLE_L_Pin
main.h, 35
enable_pin
InverterStruct, 11
enable_port
InverterStruct, 11
enable_PWM
PWM.c, 116
PWM.h, 61
ENABLE_R_GPIO_Port
main.h, 36
ENABLE_R_Pin
main.h, 36
Encoder, 7
A, 7
B, 7
cosTheta_e, 7
directionMeas, 8
sinTheta_e, 8
theta_e, 8
we, 8
Z, 8
encoder
InverterStruct, 11
Error_Handler
main.c, 84
main.h, 42
eval_inv_FSM
FSM.c, 79
FSM.h, 24

Feedback, 8
idMeas, 9
iqMeas, 9
speedMeas, 9
torqueCalc, 9
feedback
InverterStruct, 11
freqRamp_left
TASKS_20us.c, 131
FSM.c
eval_inv_FSM, 79

FSM.h
eval_inv_FSM, 24

get_currents_voltage
MEASUREMENTS.c, 96
MEASUREMENTS.h, 47
get_idiq
MEASUREMENTS.c, 97
MEASUREMENTS.h, 48
get_linear
MEASUREMENTS.c, 98
MEASUREMENTS.h, 49
get_temperature
MEASUREMENTS.c, 98
MEASUREMENTS.h, 49

hadc
InverterStruct, 11
handle_CAN
CAN_e-Tech.c, 73
handle_direction
PCB_IO.c, 114
PCB_IO.h, 57
handle_LED
PCB_IO.c, 114
PCB_IO.h, 58
handle_torqueRef
REFERENCE.c, 119
REFERENCE.h, 64
HardFault_Handler
stm32f7xx_it.c, 124
hcan1
stm32f7xx_it.c, 126
hdac
stm32f7xx_it.c, 126
hdma_adc1
stm32f7xx_it.c, 126
hdma_adc2
stm32f7xx_it.c, 126
hdma_adc3
stm32f7xx_it.c, 126
htim
InverterStruct, 11
htim1
stm32f7xx_it.c, 127
htim6
stm32f7xx_it.c, 127

ia
Analog, 5
ia_L_GPIO_Port
main.h, 36
ia_L_Pin
main.h, 36
ia_R_GPIO_Port
main.h, 36
ia_R_Pin
main.h, 36
ib
Analog, 5
ib_L_GPIO_Port
main.h, 36
ib_L_Pin
main.h, 36
ib_R_GPIO_Port
main.h, 36
ib_R_Pin
main.h, 36
ic
Analog, 5
ic_L_GPIO_Port
main.h, 37
ic_L_Pin
main.h, 37
ic_R_GPIO_Port
main.h, 37
ic_R_Pin
main.h, 37
idLoop
InverterStruct, 11
idMeas
Feedback, 9
idRef
Reference, 17
iMax
MotorParameters, 15
init_control_loops
INVERTER.c, 81
INVERTER.h, 28
initialize_inverter
INVERTER.c, 81
INVERTER.h, 29
INV_STATE_FAULT
INVERTER.h, 28
INV_STATE_IDLE
INVERTER.h, 28
INV_STATE_RUNNING
INVERTER.h, 28
INV_STATE_STARTUP
INVERTER.h, 28
INVERTER.c
disable_control_loops, 81
enable_control_loops, 81
init_control_loops, 81
initialize_inverter, 81
inverter_left, 83
inverter_right, 83
INVERTER.h
disable_control_loops, 28
DT, 27
enable_control_loops, 28
init_control_loops, 28
initialize_inverter, 29
INV_STATE_FAULT, 28
INV_STATE_IDLE, 28
INV_STATE_RUNNING, 28
INV_STATE_STARTUP, 28

inverter_left, 30
inverter_right, 30
InverterState, 27
TS, 27
inverter_left
INVERTER.c, 83
INVERTER.h, 30
inverter_right
INVERTER.c, 83
INVERTER.h, 30
InverterState
INVERTER.h, 27
InverterStruct, 10
analog, 10
direction, 10
duties, 11
enable_pin, 11
enable_port, 11
encoder, 11
feedback, 11
hadc, 11
htim, 11
idLoop, 11
iqLoop, 12
led, 12
motor, 12
reference, 12
speedLoop, 12
state, 12
tempInverter, 12
tempMotor, 12
vd, 13
vq, 13
vsMax, 13
iqLoop
InverterStruct, 12
iqMeas
Feedback, 9
iqRef
Reference, 17

J
MotorParameters, 15

keepAlive
CAN_e-Tech.c, 74

lambda
MotorParameters, 15
Ld
MotorParameters, 15
LED, 13
mode, 14
pin, 14
port, 14
led
InverterStruct, 12
LED_ERR_GPIO_Port
main.h, 37
LED_ERR_Pin
main.h, 37
led_left
PCB_IO.c, 115
PCB_IO.h, 58
LED_LEFT_GPIO_Port
main.h, 37
LED_LEFT_Pin
main.h, 37
LED_MODE_BLINK_FAST
PCB_IO.h, 57
LED_MODE_BLINK_SLOW
PCB_IO.h, 57
LED_MODE_OFF
PCB_IO.h, 57
LED_MODE_ON
PCB_IO.h, 57
led_right
PCB_IO.c, 115
PCB_IO.h, 58
LED_RIGHT_GPIO_Port
main.h, 37
LED_RIGHT_Pin
main.h, 37
ledError
PCB_IO.c, 115
PCB_IO.h, 59
LEDMode
PCB_IO.h, 57
limit_torque_to_prevent_overspeed
REFERENCE.c, 119
REFERENCE.h, 65
Lq
MotorParameters, 15

main
main.c, 84
main.c
Error_Handler, 84
main, 84
SystemClock_Config, 85
main.h
A_L_GPIO_Port, 34
A_L_Pin, 34
A_R_GPIO_Port, 34
A_R_Pin, 34
B_L_GPIO_Port, 35
B_L_Pin, 35
B_R_GPIO_Port, 35
B_R_Pin, 35
DAC_GPIO_Port, 35
DAC_Pin, 35
DIR_GPIO_Port, 35
DIR_Pin, 35
ENABLE_L_GPIO_Port, 35
ENABLE_L_Pin, 35
ENABLE_R_GPIO_Port, 36
ENABLE_R_Pin, 36
Error_Handler, 42

ia_L_GPIO_Port, 36
ia_L_Pin, 36
ia_R_GPIO_Port, 36
ia_R_Pin, 36
ib_L_GPIO_Port, 36
ib_L_Pin, 36
ib_R_GPIO_Port, 36
ib_R_Pin, 36
ic_L_GPIO_Port, 37
ic_L_Pin, 37
ic_R_GPIO_Port, 37
ic_R_Pin, 37
LED_ERR_GPIO_Port, 37
LED_ERR_Pin, 37
LED_LEFT_GPIO_Port, 37
LED_LEFT_Pin, 37
LED_RIGHT_GPIO_Port, 37
LED_RIGHT_Pin, 37
PWM1_L_GPIO_Port, 38
PWM1_L_Pin, 38
PWM1_R_GPIO_Port, 38
PWM1_R_Pin, 38
PWM2_L_GPIO_Port, 38
PWM2_L_Pin, 38
PWM2_R_GPIO_Port, 38
PWM2_R_Pin, 38
PWM3_L_GPIO_Port, 38
PWM3_L_Pin, 38
PWM3_R_GPIO_Port, 39
PWM3_R_Pin, 39
PWM4_L_GPIO_Port, 39
PWM4_L_Pin, 39
PWM4_R_GPIO_Port, 39
PWM4_R_Pin, 39
PWM5_L_GPIO_Port, 39
PWM5_L_Pin, 39
PWM5_R_GPIO_Port, 39
PWM5_R_Pin, 39
PWM6_L_GPIO_Port, 40
PWM6_L_Pin, 40
PWM6_R_GPIO_Port, 40
PWM6_R_Pin, 40
SC_det_GPIO_Port, 40
SC_det_Pin, 40
Tinv_L_GPIO_Port, 40
Tinv_L_Pin, 40
Tinv_R_GPIO_Port, 40
Tinv_R_Pin, 40
Tmot_L_GPIO_Port, 41
Tmot_L_Pin, 41
Tmot_R_GPIO_Port, 41
Tmot_R_Pin, 41
TRIP_L_GPIO_Port, 41
TRIP_L_Pin, 41
TRIP_R_GPIO_Port, 41
TRIP_R_Pin, 41
VDC_L_GPIO_Port, 41
VDC_L_Pin, 41
VDC_R_GPIO_Port, 42
VDC_R_Pin, 42
WRN_L_GPIO_Port, 42
WRN_L_Pin, 42
WRN_R_GPIO_Port, 42
WRN_R_Pin, 42
Z_L_GPIO_Port, 42
Z_L_Pin, 42
Z_R_GPIO_Port, 42
Z_R_Pin, 42
MEASUREMENTS.c
get_currents_voltage, 96
get_idiq, 97
get_linear, 98
get_temperature, 98
rawADC_left, 99
rawADC_right, 99
rawADC_temp, 99
tempInverterLUT, 99
tempMotorLUT, 105
MEASUREMENTS.h
CURRENT_OFFSET, 46
CURRENT_SLOPE, 46
get_currents_voltage, 47
get_idiq, 48
get_linear, 49
get_temperature, 49
rawADC_left, 50
rawADC_right, 50
rawADC_temp, 50
tempInverterLUT, 51
tempMotorLUT, 51
VOLTAGE_OFFSET, 46
VOLTAGE_SLOPE, 47
MemManage_Handler
stm32f7xx_it.c, 124
mode
LED, 14
motor
InverterStruct, 12
MOTOR.c
check_motor_parameters, 111
motor_left, 112
motor_right, 112
MOTOR.h
check_motor_parameters, 53
motor_left, 54
motor_right, 54
motor_left
MOTOR.c, 112
MOTOR.h, 54
motor_right
MOTOR.c, 112
MOTOR.h, 54
MotorParameters, 14
b, 15
dTorqueMax, 15
iMax, 15

J, 15
lambda, 15
Ld, 15
Lq, 15
pp, 15
Rs, 16
speedMax_RPM, 16
torqueMax, 16
vDCMax, 16

NMI_Handler
stm32f7xx_it.c, 124

PCB_IO.c
handle_direction, 114
handle_LED, 114
led_left, 115
led_right, 115
ledError, 115
PCB_IO.h
DIR_STATE, 56
DISABLE, 56
ENABLE, 56
handle_direction, 57
handle_LED, 58
led_left, 58
LED_MODE_BLINK_FAST, 57
LED_MODE_BLINK_SLOW, 57
LED_MODE_OFF, 57
LED_MODE_ON, 57
led_right, 58
ledError, 59
LEDMode, 57
SC_DET_STATE, 57
WRN_STATE, 57
PendSV_Handler
stm32f7xx_it.c, 124
pin
LED, 14
port
LED, 14
pp
MotorParameters, 15
PWM.c
disable_PWM, 116
enable_PWM, 116
update_PWM, 117
PWM.h
disable_PWM, 61
enable_PWM, 61
update_PWM, 61
PWM1_L_GPIO_Port
main.h, 38
PWM1_L_Pin
main.h, 38
PWM1_R_GPIO_Port
main.h, 38
PWM1_R_Pin
main.h, 38
PWM2_L_GPIO_Port
main.h, 38
PWM2_L_Pin
main.h, 38
PWM2_R_GPIO_Port
main.h, 38
PWM2_R_Pin
main.h, 38
PWM3_L_GPIO_Port
main.h, 38
PWM3_L_Pin
main.h, 38
PWM3_R_GPIO_Port
main.h, 39
PWM3_R_Pin
main.h, 39
PWM4_L_GPIO_Port
main.h, 39
PWM4_L_Pin
main.h, 39
PWM4_R_GPIO_Port
main.h, 39
PWM4_R_Pin
main.h, 39
PWM5_L_GPIO_Port
main.h, 39
PWM5_L_Pin
main.h, 39
PWM5_R_GPIO_Port
main.h, 39
PWM5_R_Pin
main.h, 39
PWM6_L_GPIO_Port
main.h, 40
PWM6_L_Pin
main.h, 40
PWM6_R_GPIO_Port
main.h, 40
PWM6_R_Pin
main.h, 40

rawADC_left
MEASUREMENTS.c, 99
MEASUREMENTS.h, 50
rawADC_right
MEASUREMENTS.c, 99
MEASUREMENTS.h, 50
rawADC_temp
MEASUREMENTS.c, 99
MEASUREMENTS.h, 50
Reference, 16
idRef, 17
iqRef, 17
torqueRef, 17
reference
InverterStruct, 12
REFERENCE.c
handle_torqueRef, 119
limit_torque_to_prevent_overspeed, 119

saturate_symmetric, 120
set_torque_direction, 121
REFERENCE.h
handle_torqueRef, 64
limit_torque_to_prevent_overspeed, 65
saturate_symmetric, 66
set_torque_direction, 66
Rs
MotorParameters, 16

saturate_symmetric
REFERENCE.c, 120
REFERENCE.h, 66
saturate_voltage
CONTROL.c, 77
CONTROL.h, 22
SC_det_GPIO_Port
main.h, 40
SC_det_Pin
main.h, 40
SC_DET_STATE
PCB_IO.h, 57
send_CAN_message
CAN_e-Tech.c, 73
set_torque_direction
REFERENCE.c, 121
REFERENCE.h, 66
sinTheta_e
Encoder, 8
speedLoop
InverterStruct, 12
speedMax_RPM
MotorParameters, 16
speedMeas
Feedback, 9
start_ticks
TASKS_20us.c, 131
state
InverterStruct, 12
stm32f7xx_it.c
BusFault_Handler, 123
CAN1_RX0_IRQHandler, 123
DebugMon_Handler, 123
DMA2_Stream0_IRQHandler, 124
DMA2_Stream1_IRQHandler, 124
DMA2_Stream2_IRQHandler, 124
HardFault_Handler, 124
hcan1, 126
hdac, 126
hdma_adc1, 126
hdma_adc2, 126
hdma_adc3, 126
htim1, 127
htim6, 127
MemManage_Handler, 124
NMI_Handler, 124
PendSV_Handler, 124
SVC_Handler, 125
SysTick_Handler, 125
TIM1_UP_TIM10_IRQHandler, 125
TIM6_DAC_IRQHandler, 125
UsageFault_Handler, 126
SVC_Handler
stm32f7xx_it.c, 125
SystemClock_Config
main.c, 85
SysTick_Handler
stm32f7xx_it.c, 125

tasks_1ms
TASKS_1ms.c, 128
TASKS_1ms.h, 69
TASKS_1ms.c
tasks_1ms, 128
TASKS_1ms.h
tasks_1ms, 69
TASKS_20us.c
angle_left, 131
elapsed_ticks, 131
freqRamp_left, 131
start_ticks, 131
tasks_20us_left, 130
tasks_20us_right, 130
torqueRefIn_left, 131
vd_left, 131
vDC_left, 131
vq_left, 131
TASKS_20us.h
tasks_20us_left, 71
tasks_20us_right, 71
tasks_20us_left
TASKS_20us.c, 130
TASKS_20us.h, 71
tasks_20us_right
TASKS_20us.c, 130
TASKS_20us.h, 71
tempInverter
InverterStruct, 12
tempInverterLUT
MEASUREMENTS.c, 99
MEASUREMENTS.h, 51
tempMotor
InverterStruct, 12
tempMotorLUT
MEASUREMENTS.c, 105
MEASUREMENTS.h, 51
theta_e
Encoder, 8
TIM1_UP_TIM10_IRQHandler
stm32f7xx_it.c, 125
TIM6_DAC_IRQHandler
stm32f7xx_it.c, 125
Tinv_L_GPIO_Port
main.h, 40
Tinv_L_Pin
main.h, 40
Tinv_R_GPIO_Port
main.h, 40

Tinv_R_Pin
main.h, 40
Tmot_L_GPIO_Port
main.h, 41
Tmot_L_Pin
main.h, 41
Tmot_R_GPIO_Port
main.h, 41
Tmot_R_Pin
main.h, 41
torqueCalc
Feedback, 9
torqueMax
MotorParameters, 16
torqueRef
Reference, 17
torqueRefIn_left
TASKS_20us.c, 131
TRIP_L_GPIO_Port
main.h, 41
TRIP_L_Pin
main.h, 41
TRIP_R_GPIO_Port
main.h, 41
TRIP_R_Pin
main.h, 41
TS
INVERTER.h, 27

update_PWM
PWM.c, 117
PWM.h, 61
UsageFault_Handler
stm32f7xx_it.c, 126

vd
InverterStruct, 13
vd_left
TASKS_20us.c, 131
vDC
Analog, 6
VDC_L_GPIO_Port
main.h, 41
VDC_L_Pin
main.h, 41
vDC_left
TASKS_20us.c, 131
VDC_R_GPIO_Port
main.h, 42
VDC_R_Pin
main.h, 42
vDCMax
MotorParameters, 16
VOLTAGE_OFFSET
MEASUREMENTS.h, 46
VOLTAGE_SLOPE
MEASUREMENTS.h, 47
vq
InverterStruct, 13
vq_left
TASKS_20us.c, 131
vsMax
InverterStruct, 13

we
Encoder, 8
WRN_L_GPIO_Port
main.h, 42
WRN_L_Pin
main.h, 42
WRN_R_GPIO_Port
main.h, 42
WRN_R_Pin
main.h, 42
WRN_STATE
PCB_IO.h, 57

Z
Encoder, 8
Z_L_GPIO_Port
main.h, 42
Z_L_Pin
main.h, 42
Z_R_GPIO_Port
main.h, 42
Z_R_Pin
main.h, 42