Software development of a Vector controller for
Permanent-Magnet Synchronous Motors using Matlab/Simulink

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📌 Outline

❏ Introduction

❏ Project Overview

❏ Theory

❏ Procedure

❏ Result

◼ Simulation

◼ Implementation

🔍 Introduction

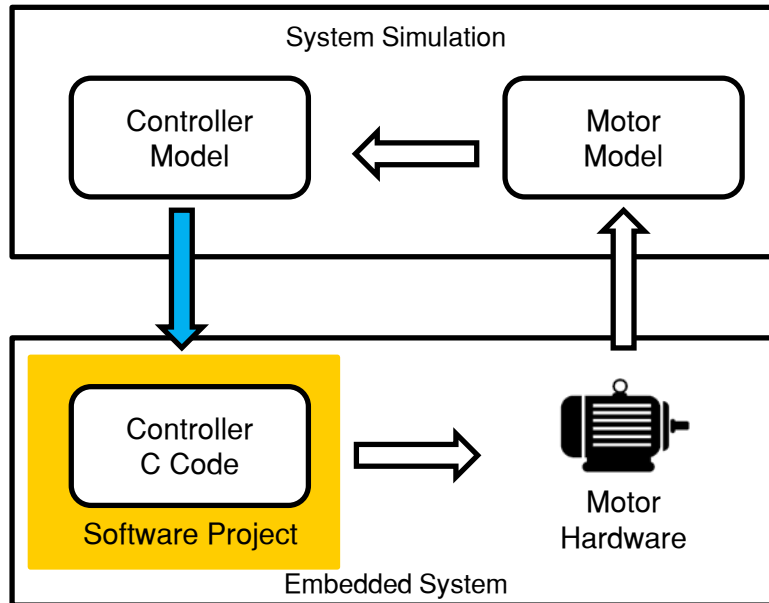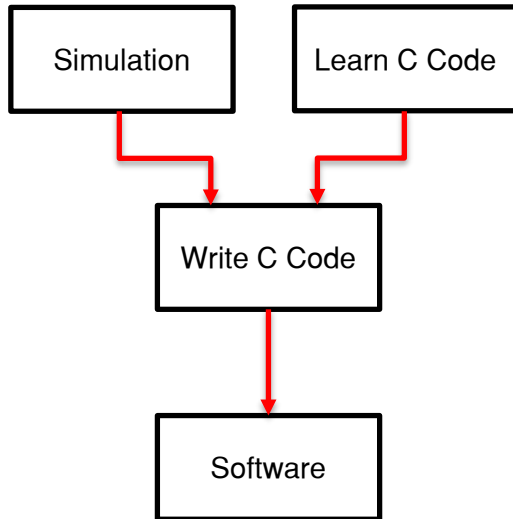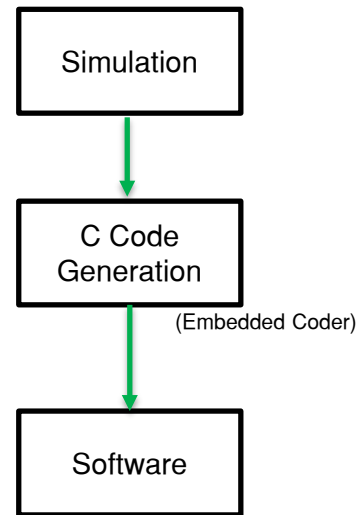Fig.1 Development & Design Motor control system

☹ Project Overview

OLD Approach

Simulation → Write C Code

Learn C Code → Write C Code

Write C Code → Software

New Approach

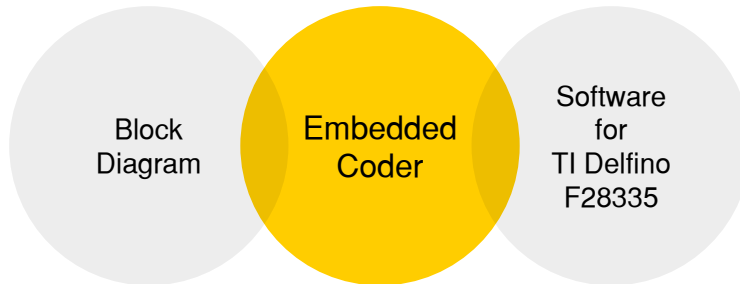Simulation → C Code Generation (Embedded Coder) → Software

Project Overview

Objective

➢ To develop software of a vector controller for Permanent-Magnet Synchronous Motors using Embedded Coder of Matlab/Simulink.
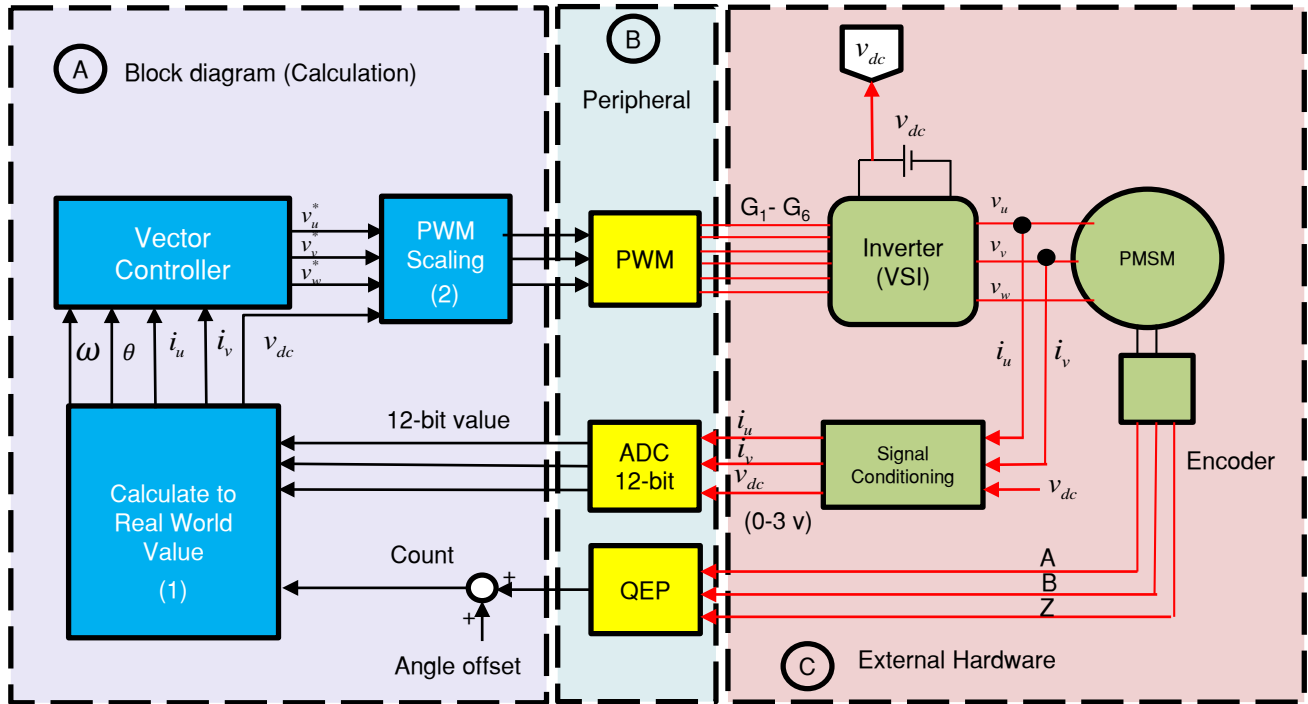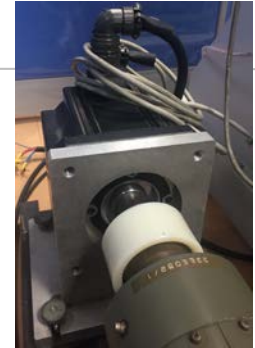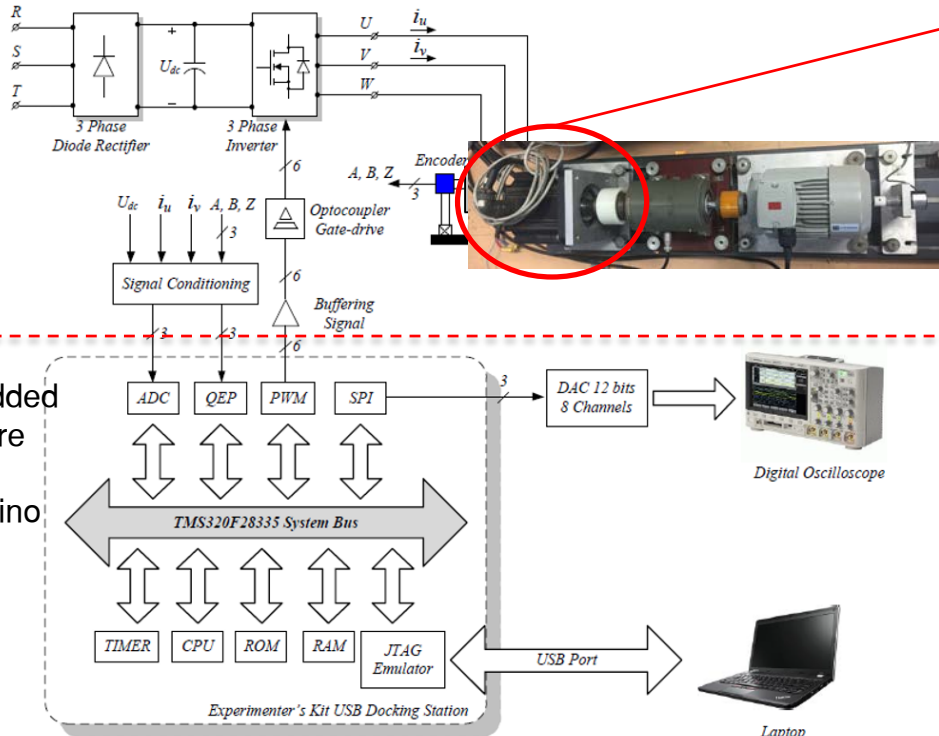
Block Diagram

Embedded Coder

Software for TI Delfino F28335

Overview structure in project

Fig.2 overview structure used in this project

♡ External Hardware

PMSM

External Hardware

Embedded software of TI Delfino 28335

Fig.3 External hardware structure

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📝 **Permanent-magnet Synchronous Motor (PMSM)**

Stator

Stator
winding

Rotor
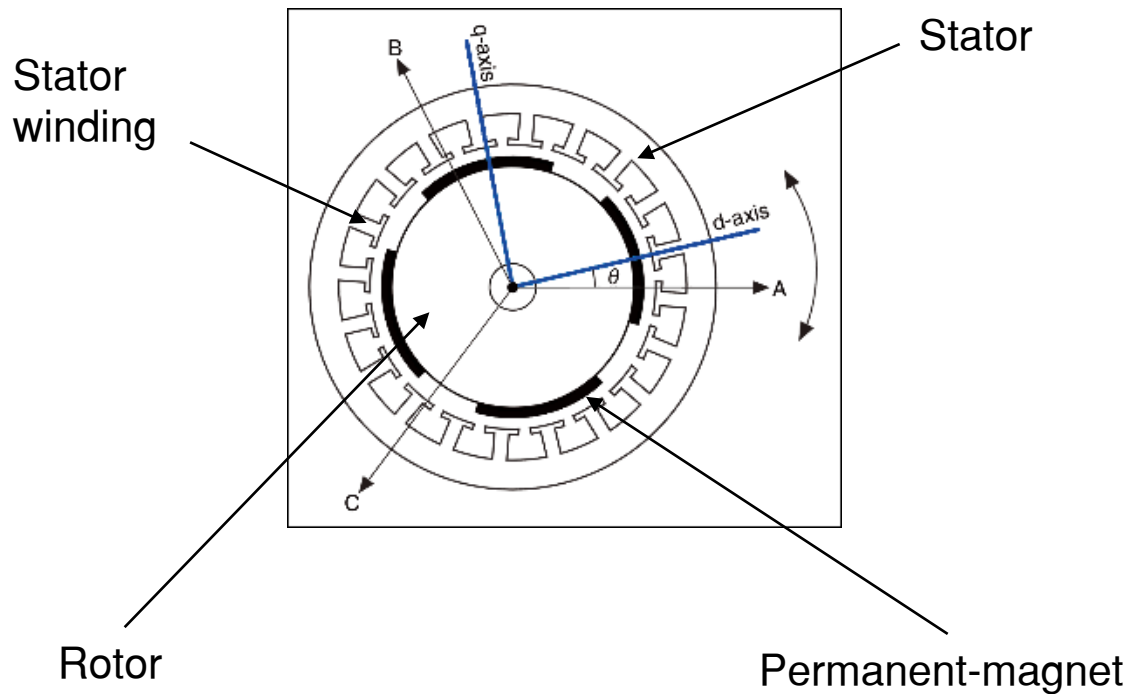
Permanent-magnet

Fig.4 Permanent-magnet synchronous motor

📖 PMSM Dynamic Model

Stator current

$$\vec{i}_s e^{-J\theta}$$
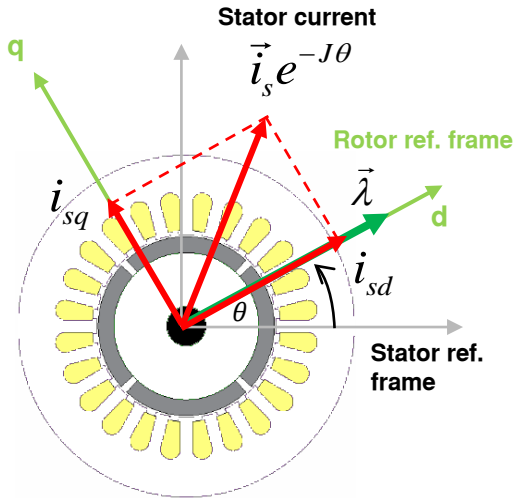

Fig.5 PMSM model on rotor reference frame [2]

Rotor reference frame

$$v_{sd} = Ri_{sd} + L_s \frac{di_{sd}}{dt} - \omega L_s i_{sq}$$

$$v_{sq} = Ri_{sq} + L_s \frac{di_{sq}}{dt} + \omega L_s i_{sd} + \omega\lambda$$

where

v_{sd} and v_{sq} are   stator voltage on rotor ref. frame d and q axis.

i_{sd} and i_{sq} are   stator current on rotor ref. frame d and q axis.

R is   stator resistance.

L_s is   stator inductance.

λ is   permanent-magnet flux linkage.

θ and ω are   rotor angle and rotor speed (electical).
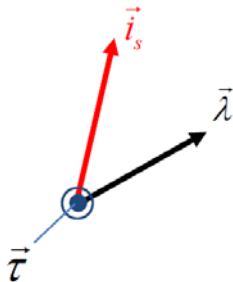
📖 Vector Controller

Motor torque equation

$$T_e = \frac{3}{2}\left(\frac{p}{2}\right)\lambda i_{sq}$$

where

T_e is torque motor.

p is number of poles.

Mechanical torque equation

$$T_e - T_L = J\frac{d\omega_m}{dt}$$

where

T_L is torque load
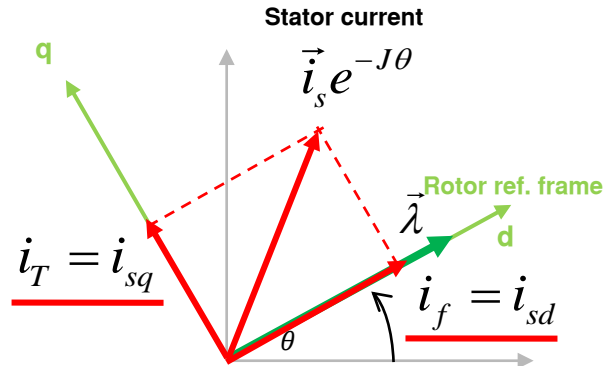
J is inertia

ω_m is rotor speed (mechanical)

Stator current

$\vec{i}_s e^{-J\theta}$

Rotor ref. frame

$\vec{\lambda}$ d

$i_T = i_{sq}$

$i_f = i_{sd}$

q

θ

$\vec{i}_s$

$\vec{\lambda}$

$\vec{\tau}$

Fig.6 Space vector representation [2]

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Controller block diagram
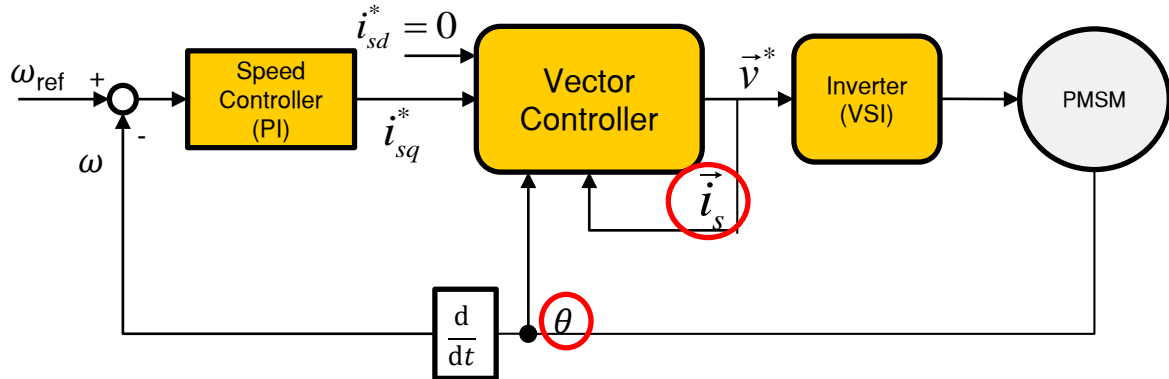
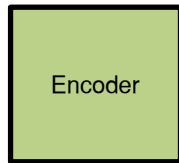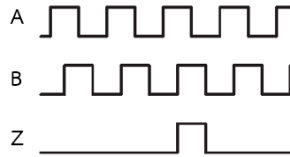Fig.7 Block diagram of speed control system with vector controller [3]
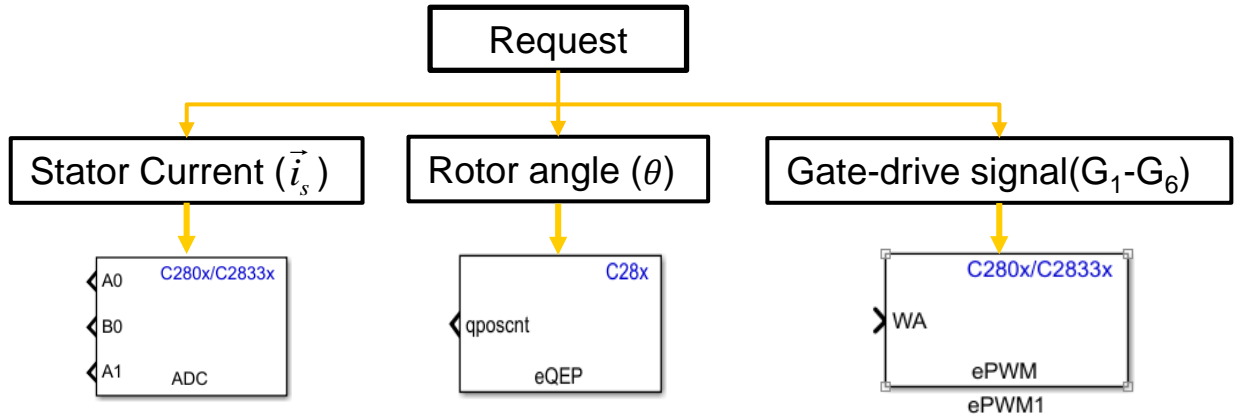
♡ ADC (Analog-to-Digital converter)

Measure instruments (CT,VT) → i_u, i_v, v_{dc} → Signal Conditioning (0-3 V) → ADCINA0, ADCINB0, ADCINA1 → Analog signal

Controller Block ← i_u, i_v, v_{dc} ← ADC Scaling ← A0, B0, A1 (C280x/C2833x ADC) → Digital signal

12-bit value
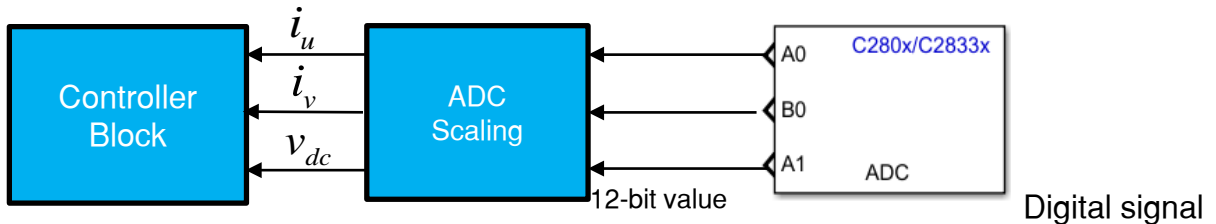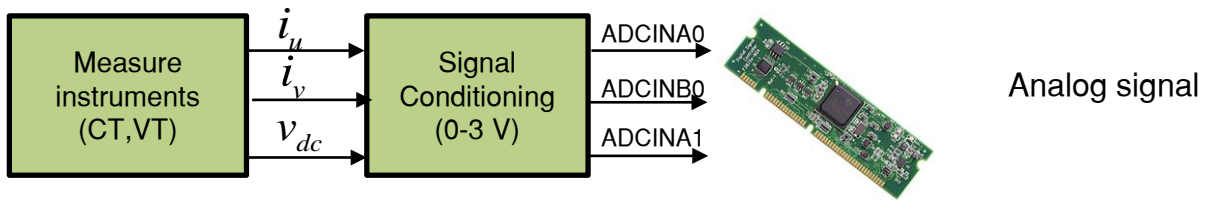
QEP (Quadrature Encoder Pulse)

External Hardware

Encoder

A
B
Z

C28x
qposcnt
eQEP

Count

Calculate Rotor
Position & Speed

θ

ω

Controller
Block

Software (Block diagram)

A
B
CLK
DIR
POSCNT
count

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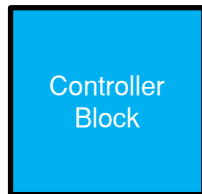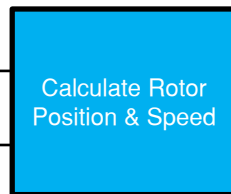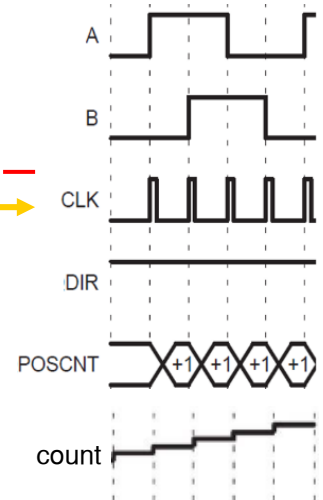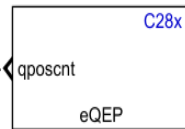
♡ PWM (Pulse width modulation)
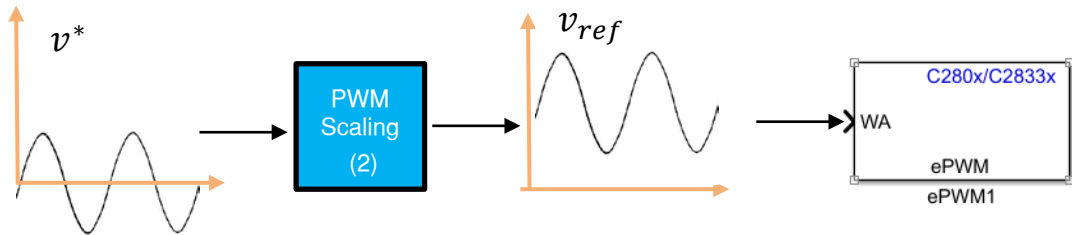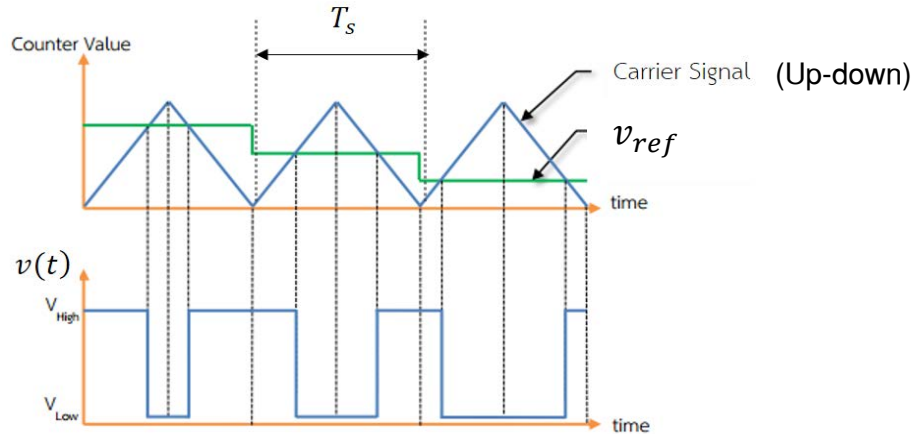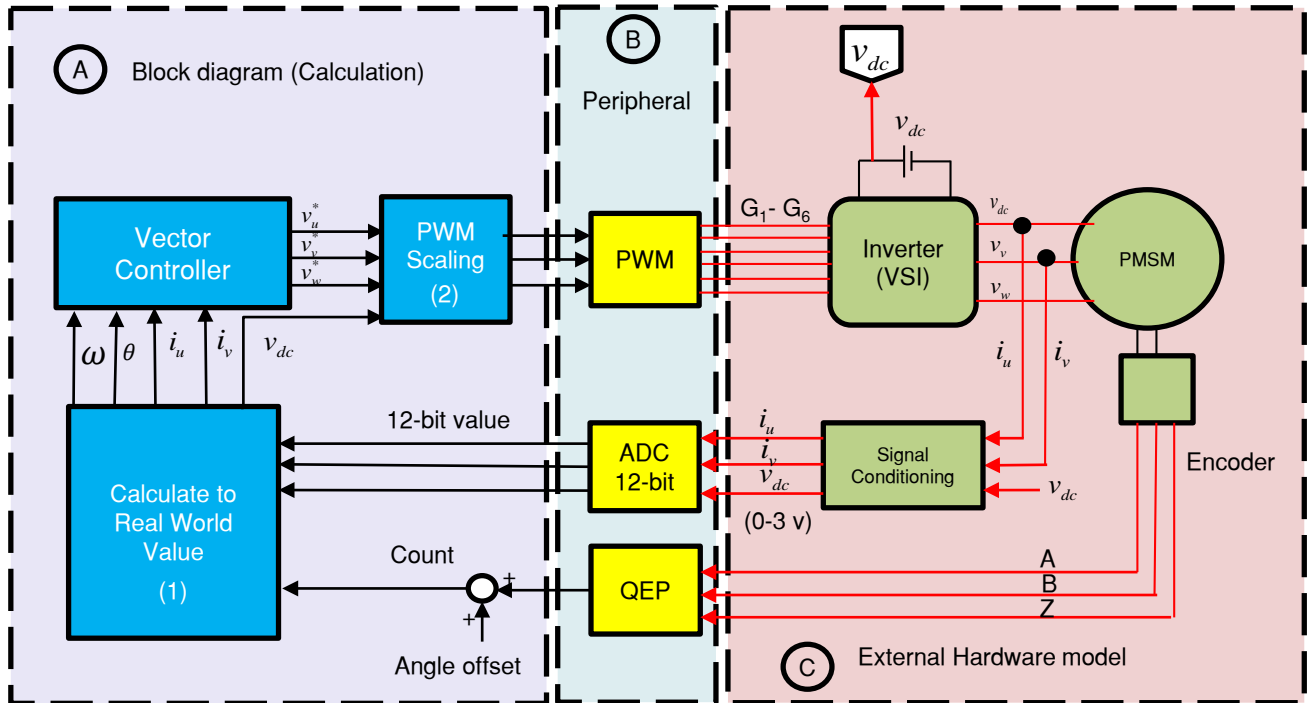
♡ Simulation system block diagram (Procedure 1)

Fig.8 Simulation system of vector controller

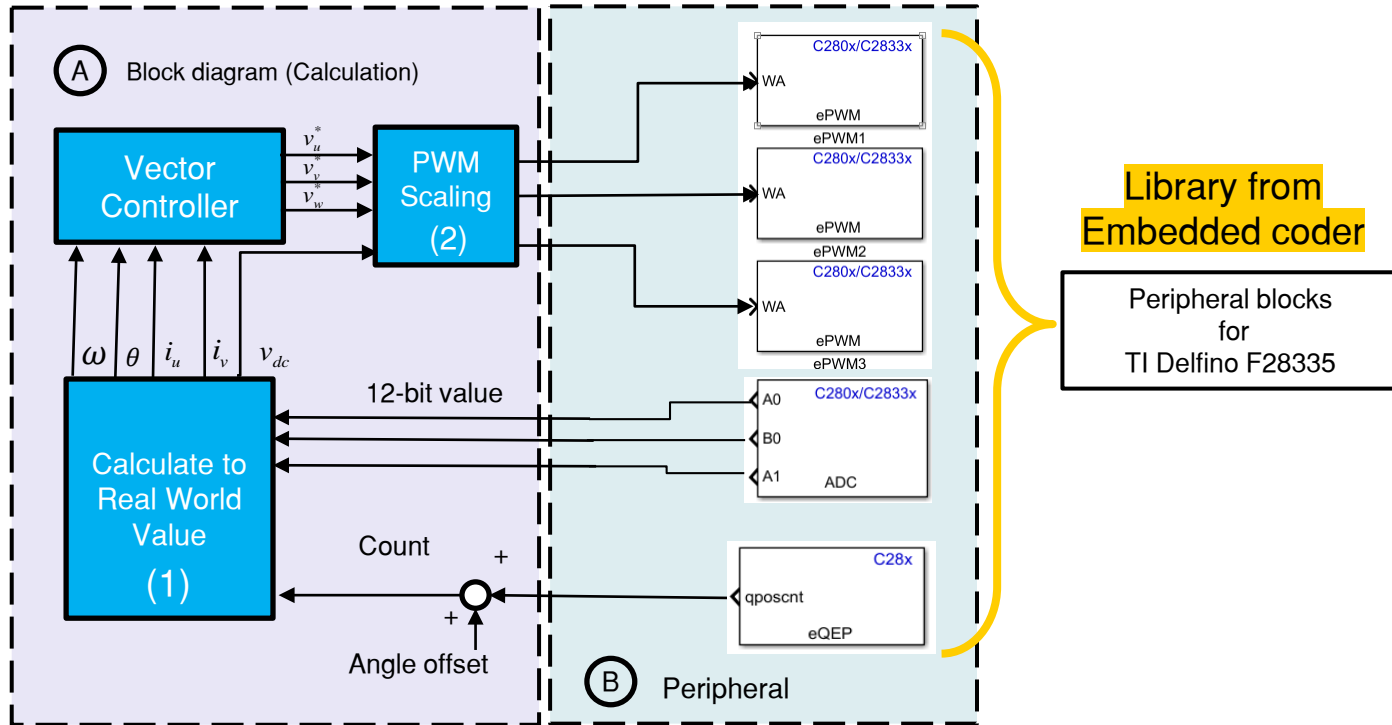# ♡ Block diagram for C code generation (Procedure 2)

Fig.9 Block diagram for C Code generation
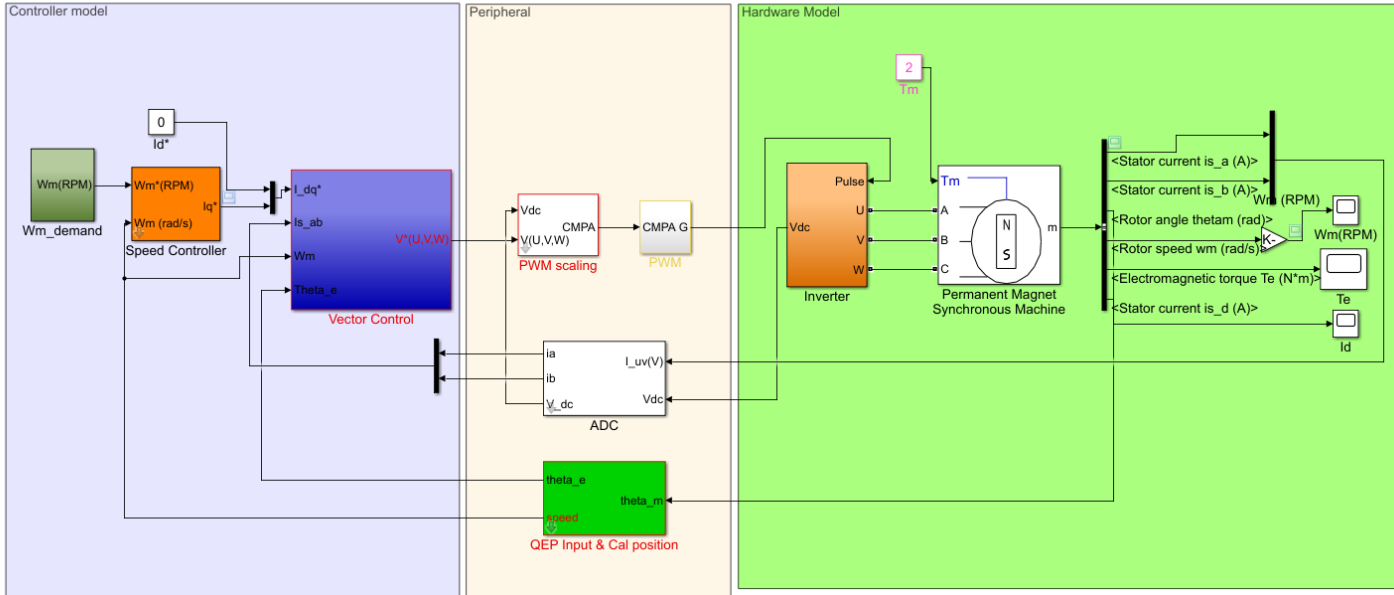
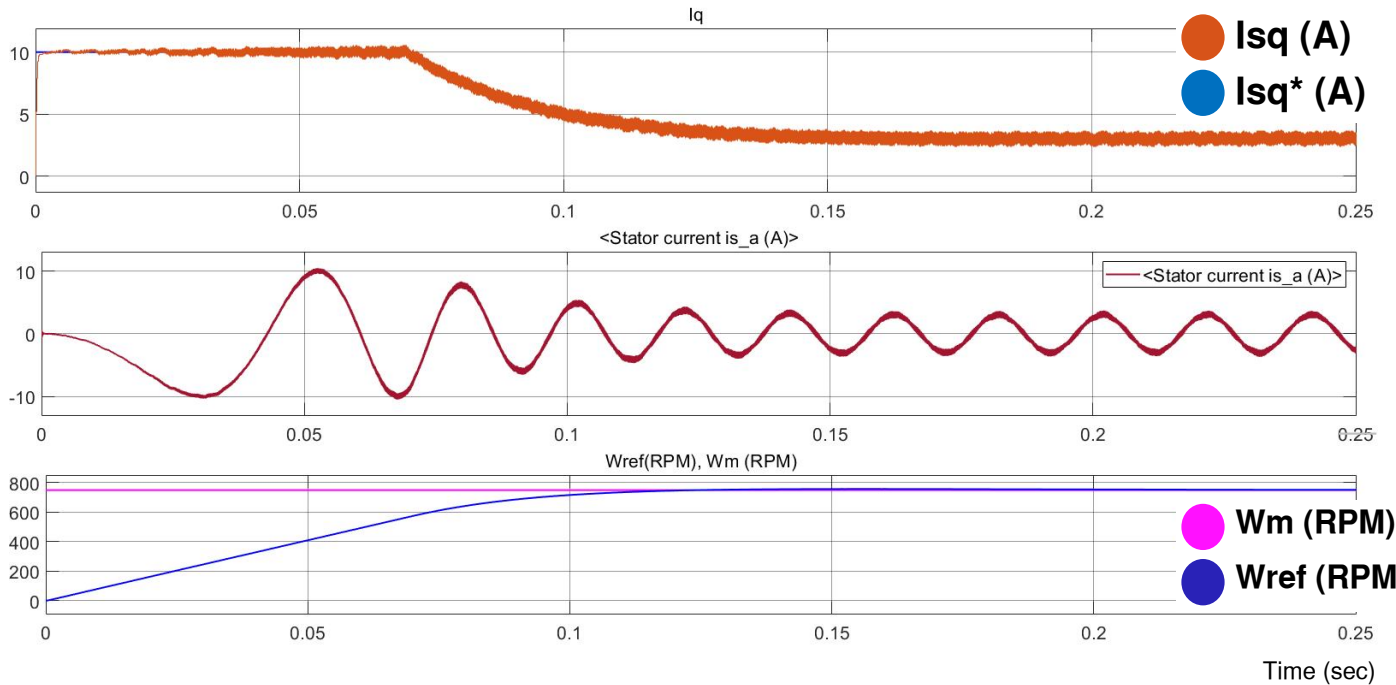Fig.10 Simulink block diagram of speed control system with vector controller

Fig.11 Time response when change speed from 0 to 750 RPM

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Result : Simulation of speed control system with vector controller (3)
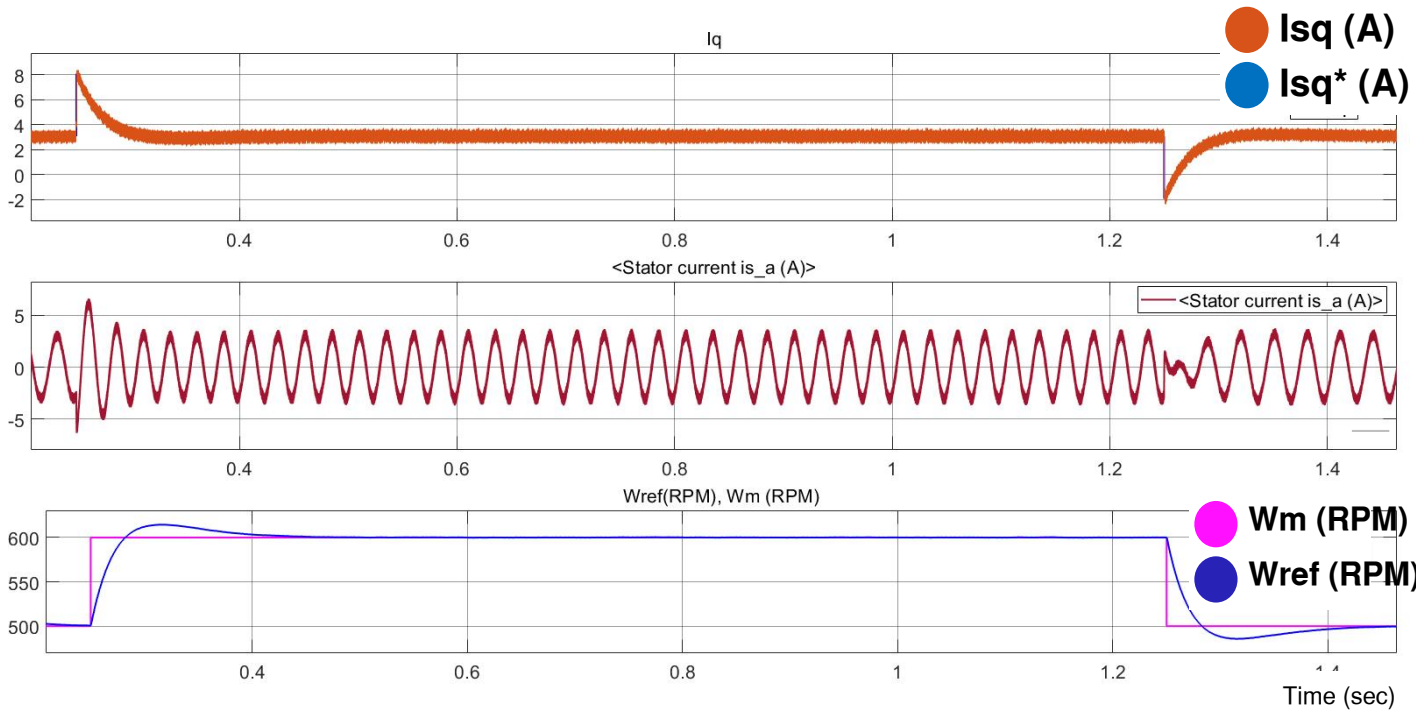
Fig.12 Time response when change speed between 500 and 600 RPM

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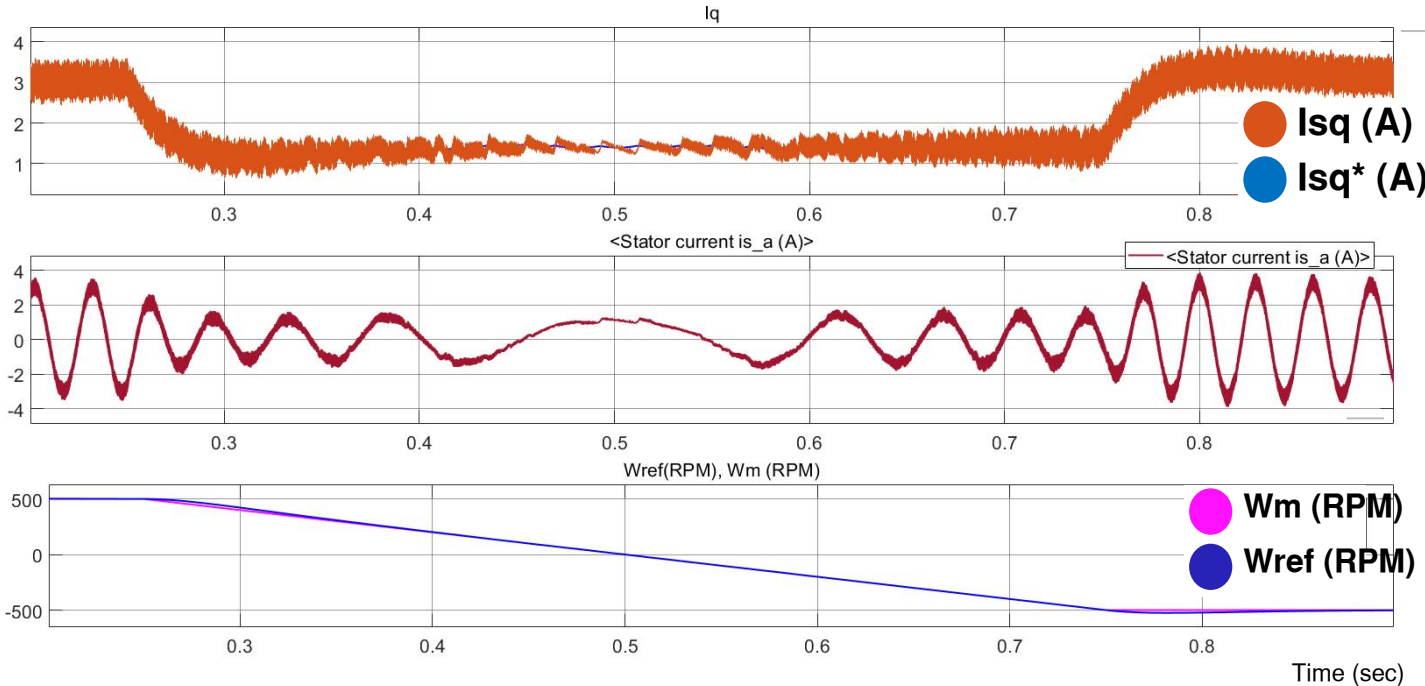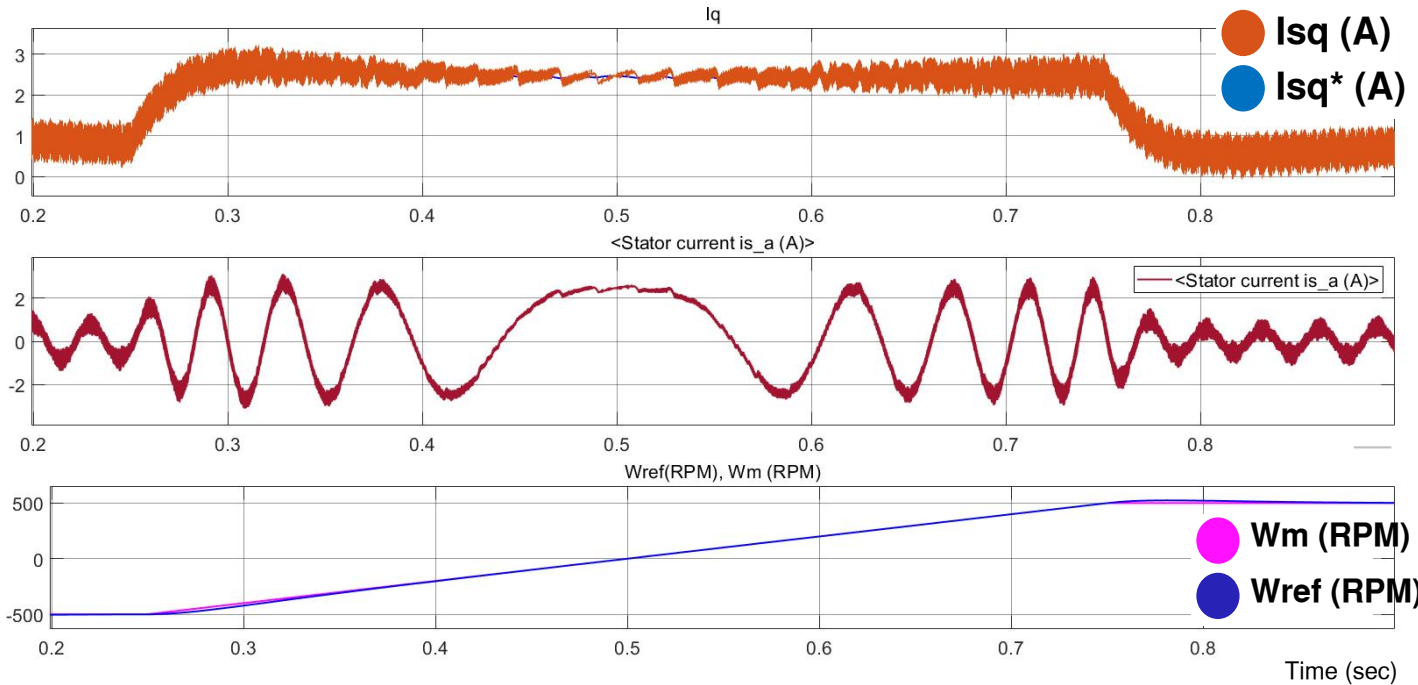**Result :** Simulation of speed control system with vector controller (4)

Fig.13 Time response when change speed from 500 to -500 RPM

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Fig.14 Time response when change speed from -500 to 500 RPM
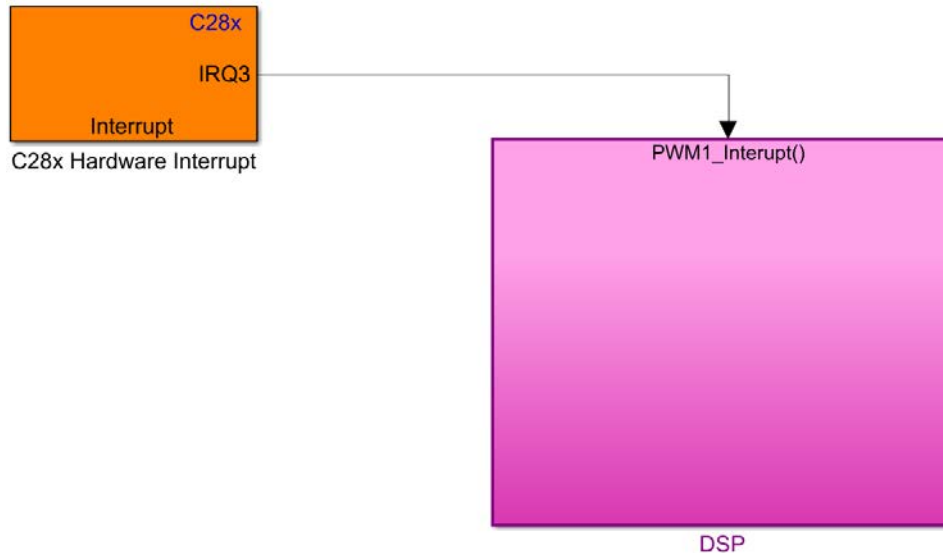
Fig.15 Simulink block diagram of speed control system with vector controller

Fig.16 Simulink block diagram of speed control system with vector controller
(Subsystem DSP)

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Fig.17 Time response when change speed from 0 to 750 RPM
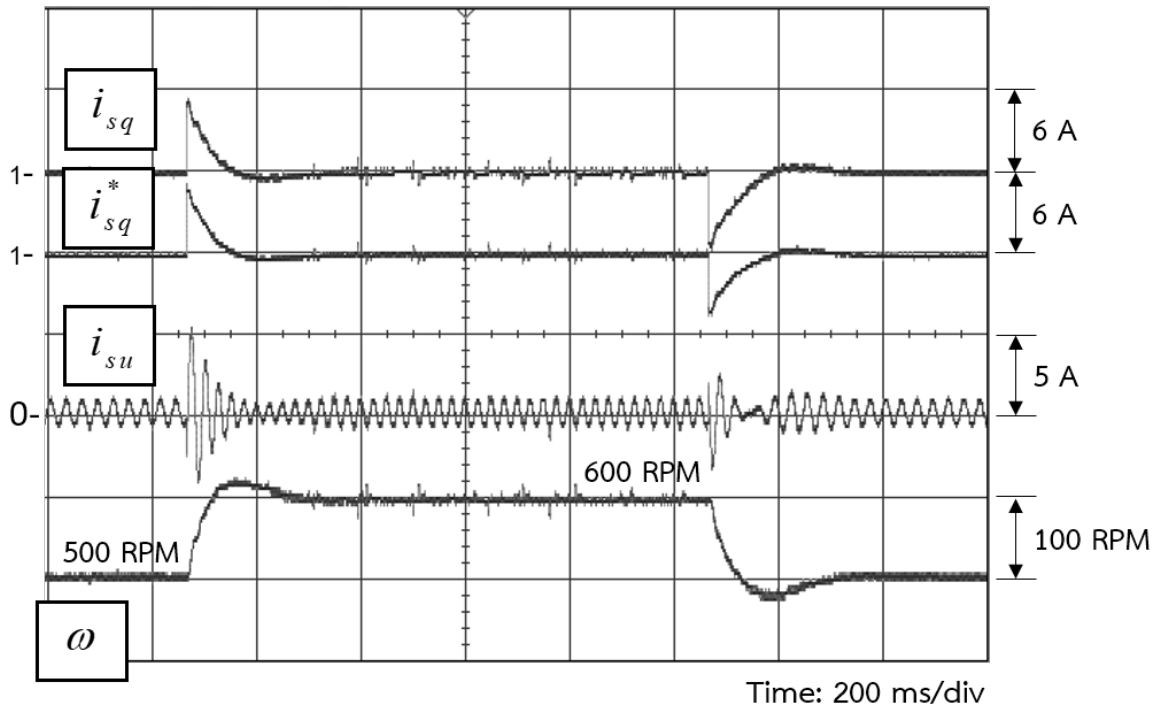
Fig.18 Time response when change speed from 500 to 600 to 500 RPM

Time: 100 ms/div

Fig.19 Time response when change speed from 500 to -500 RPM
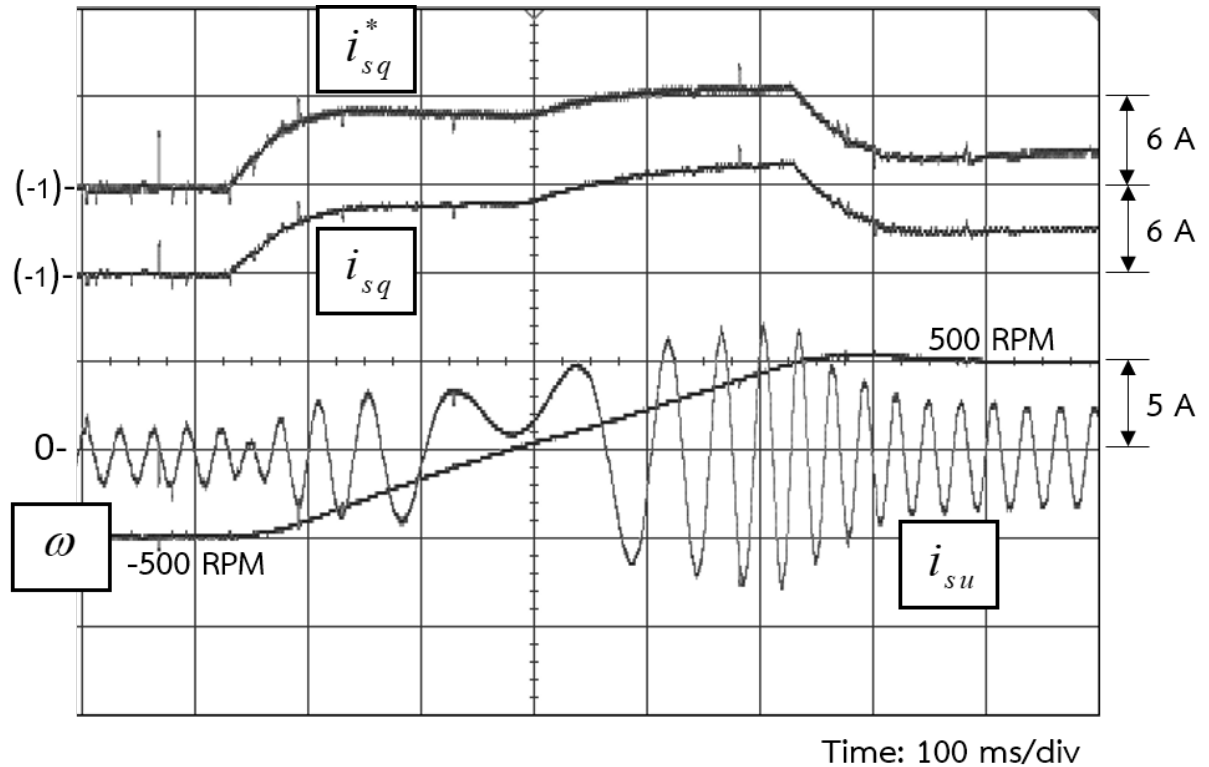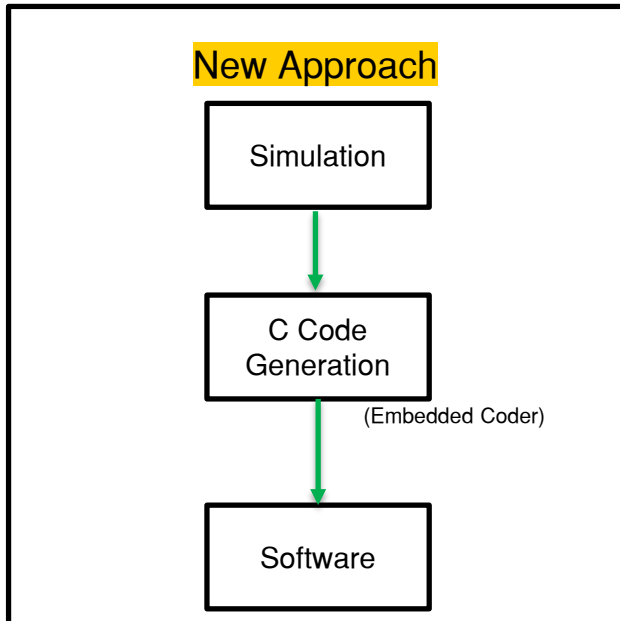
Fig.20 Time response when change speed from 500 to -500 RPM

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Summary :

New Approach

Simulation

↓

C Code
Generation

(Embedded Coder)

↓

Software

Thank You!