

# HARDWARE SELECTION & SIMULATION

An abstract graphic consisting of several thin, white, parallel lines that originate from the bottom right corner and extend diagonally towards the top right corner. The lines are set against a background with a blue gradient, transitioning from a lighter blue at the top to a darker blue at the bottom.



## 2 PACK IGBT

- ▶ 62 mm Housing
- ▶  $I_c$  max 200 A
- ▶  $V_{ce}$  saturation 1.45V
- ▶ Small Delay time (.13-.53u)
- ▶ Low energy loss (3.3-8.3 mJ)

## 6 PACK IGBT

- ▶  $I_c$  max 200 A
- ▶  $V_{ce}$  saturation 1.45V
- ▶ Small Delay time (.17-.38u)
- ▶ Low energy loss (1.8-6.9 mJ)
- ▶ Super Cheap
- ▶ Housing EconoPak



# FINAL CHOICE

- Housing
- Reliability
- Flexibility





# GATE DRIVERS

## Similarities

- ▶ Logic
- ▶ UVLO
- ▶ 600 V
- ▶ Bootstrap Operation
- ▶ DV/DT Immune

## 6 Pack Advantages

- ▶ Separate Control
- ▶ Shoot Through

## Disadvantages

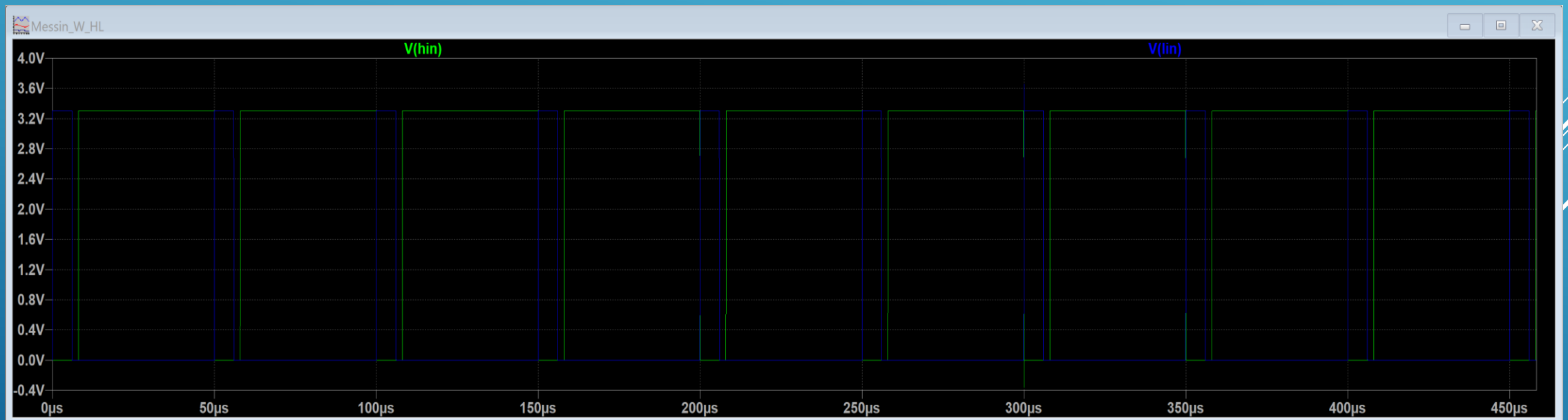
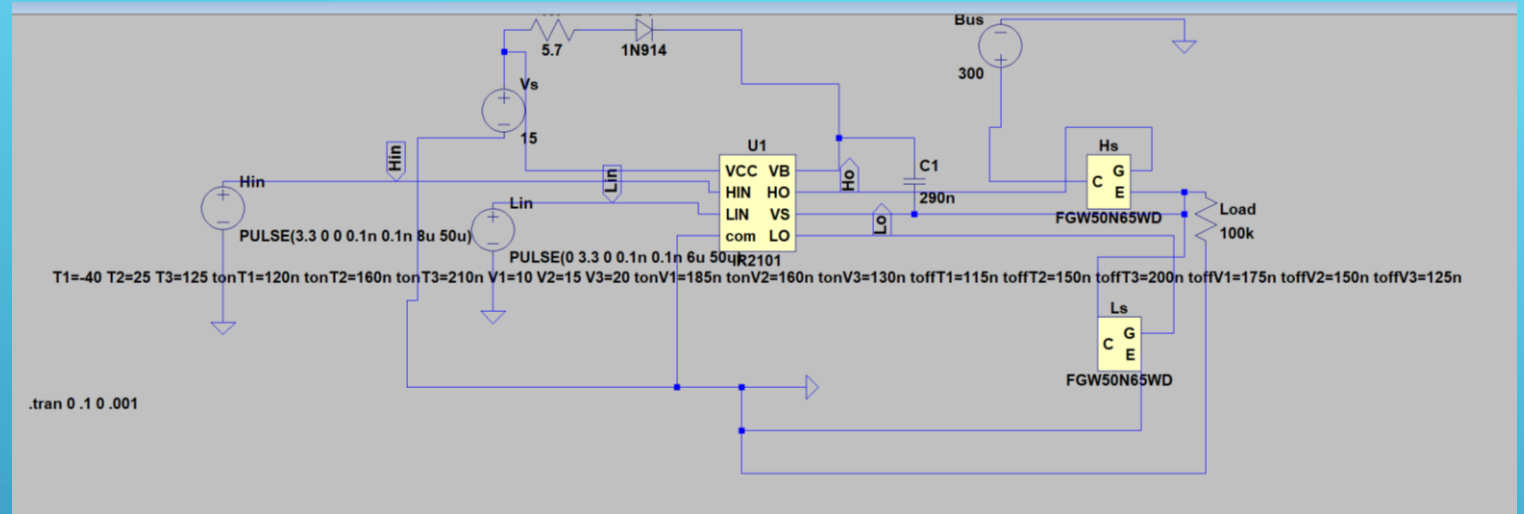
- ▶ SMT

# FINAL CHOICE

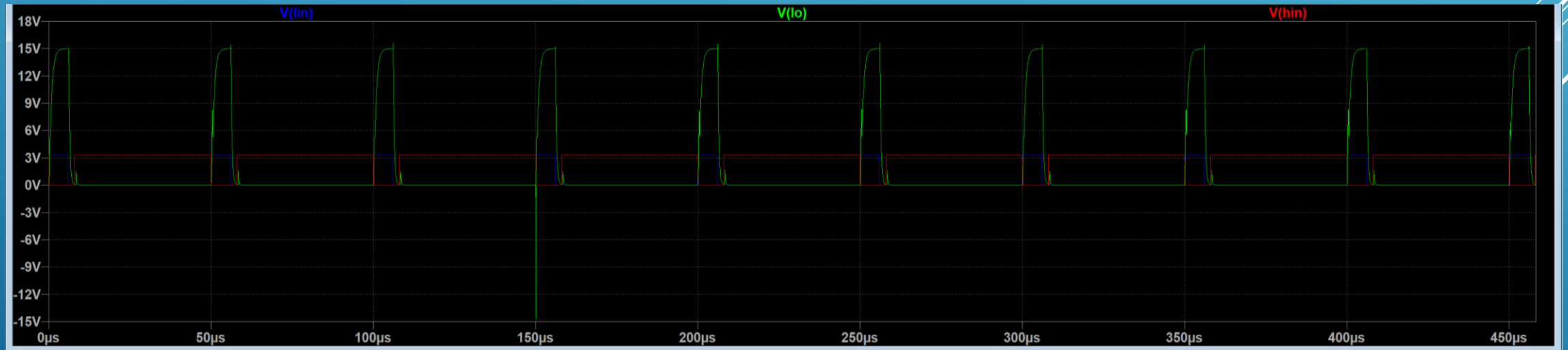
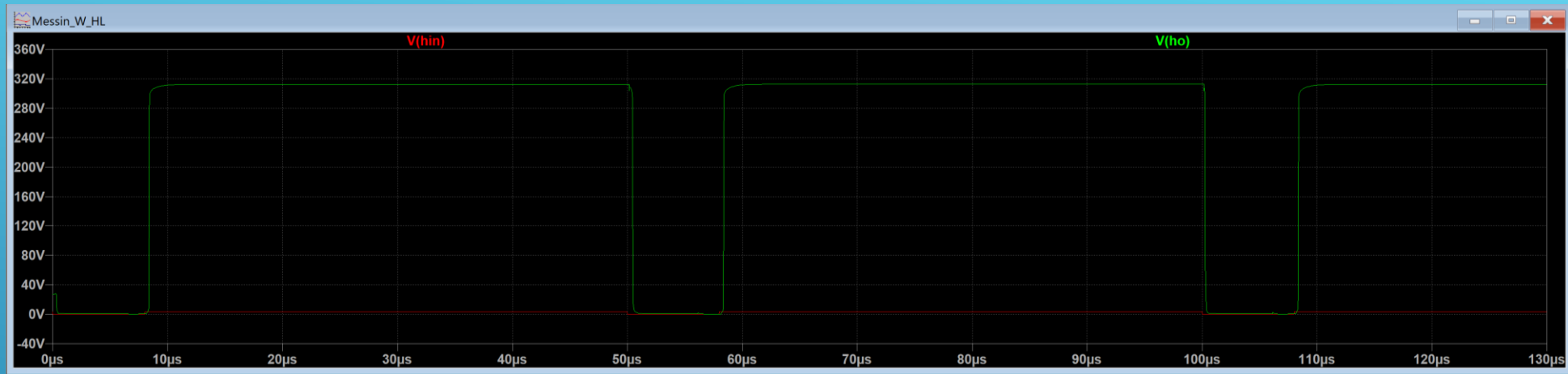
- Testing/Familiarization
- Final Design



# SPICE SIMULATION

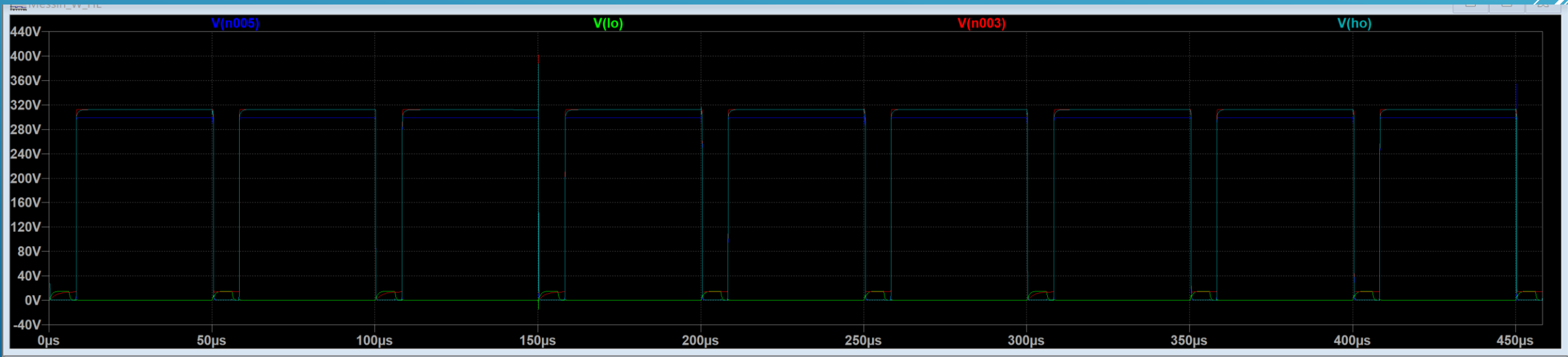
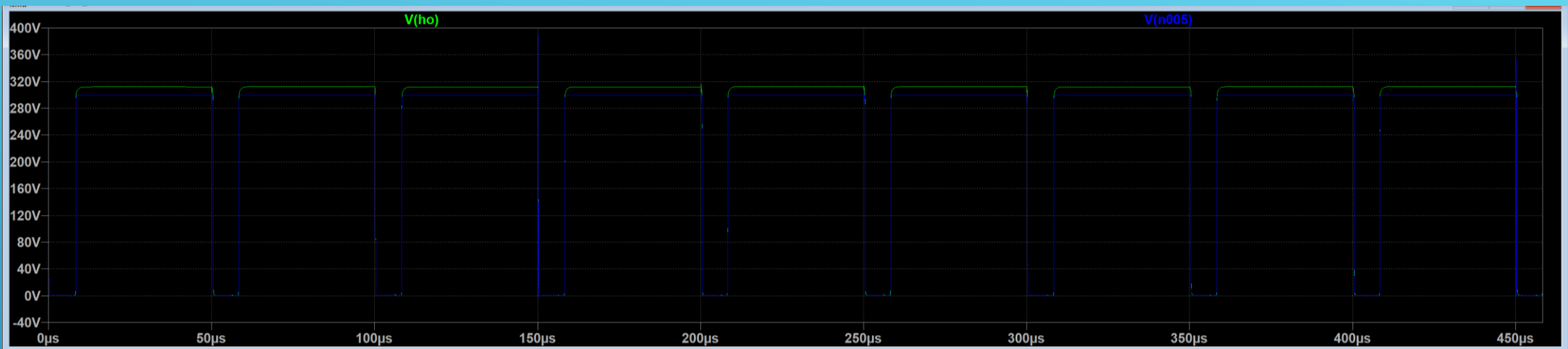


# SIMULATIONS





# SIMULATIONS

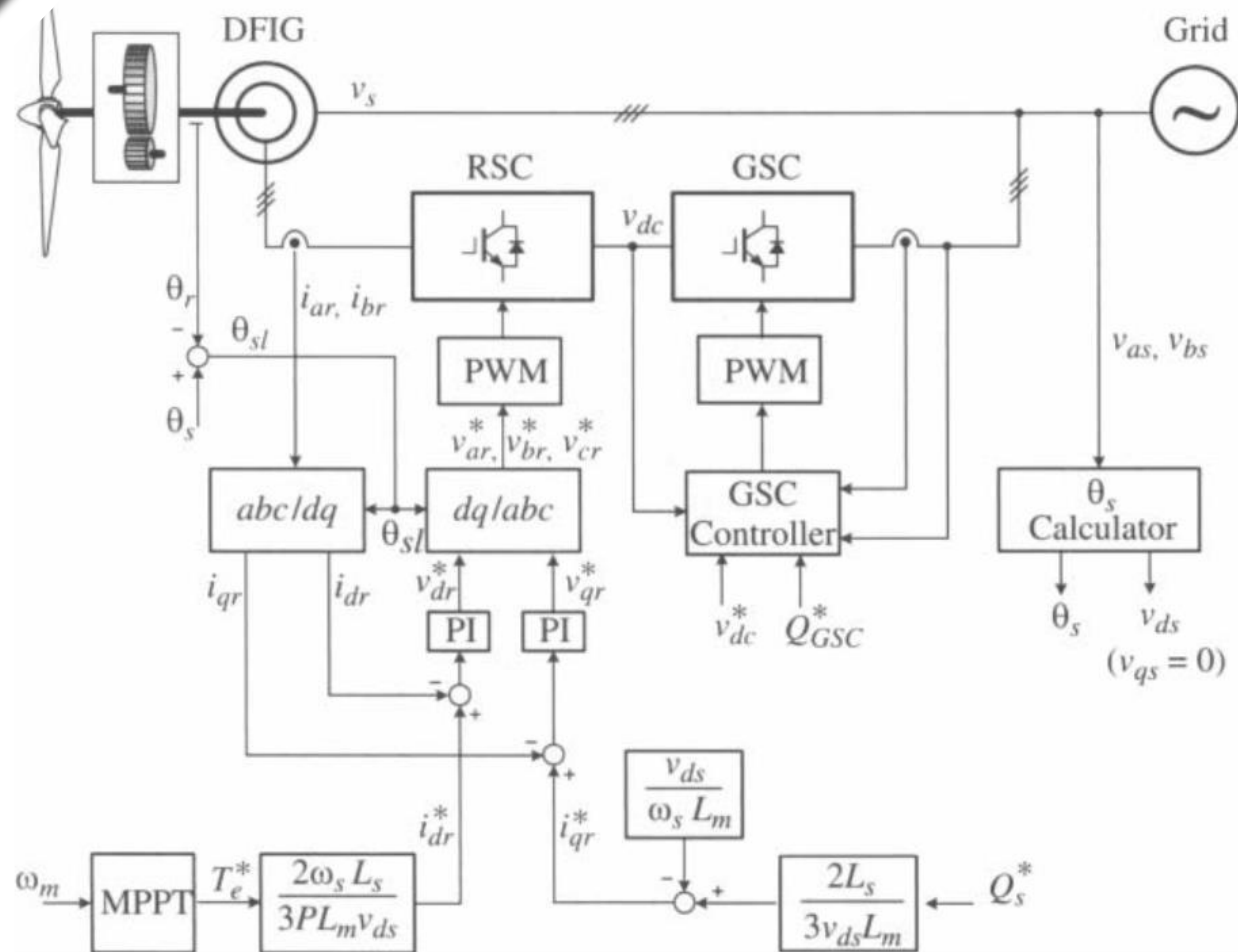


# MICROCONTROLLER & SOFTWARE



# DFIG ROTOR SIDE CONVERTER

- ▶ Similar idea to vector control of a motor
- ▶ Controlled by torque and slip commands
- ▶ Feedback from stator
- ▶ Rotor position



# DFIG CONTROLLER & SOFTWARE

- Overview of software blocks
- Details on prominent sections
- Requirements of a microcontroller
- Microcontroller choice
- Electrical Isolation

Sensor Inputs,  
Command Values



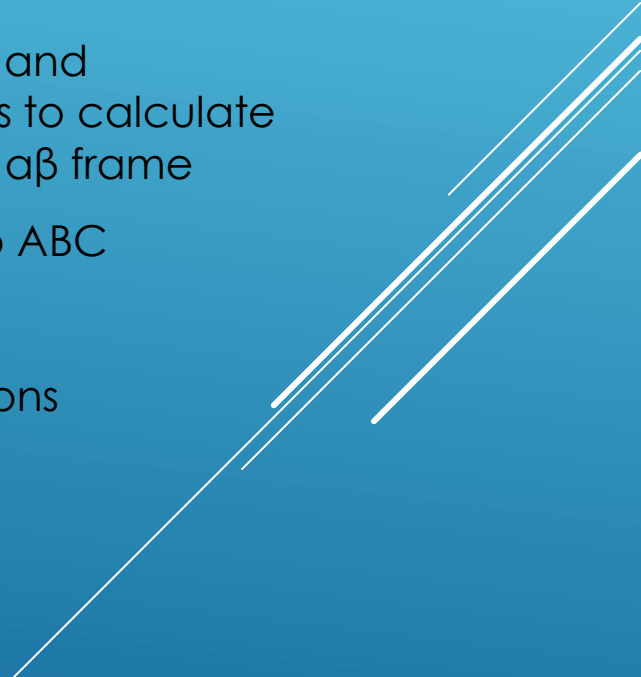
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graph TD; A[Sensor Inputs, Command Values] --> B[FOC Algorithm]; B --> C[SVM Algorithm]; C --> D[PWM];
```

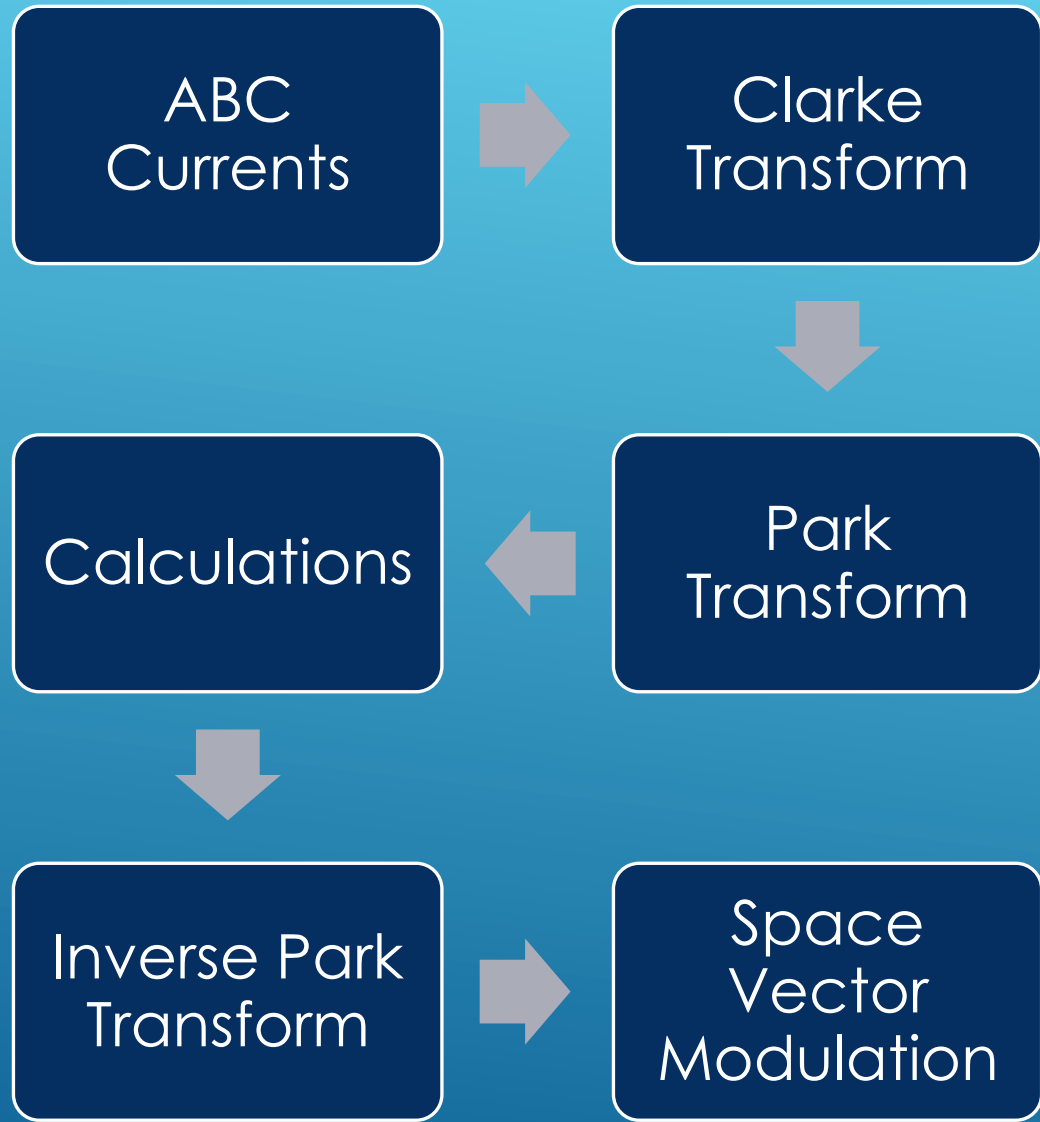
FOC Algorithm

SVM Algorithm

PWM

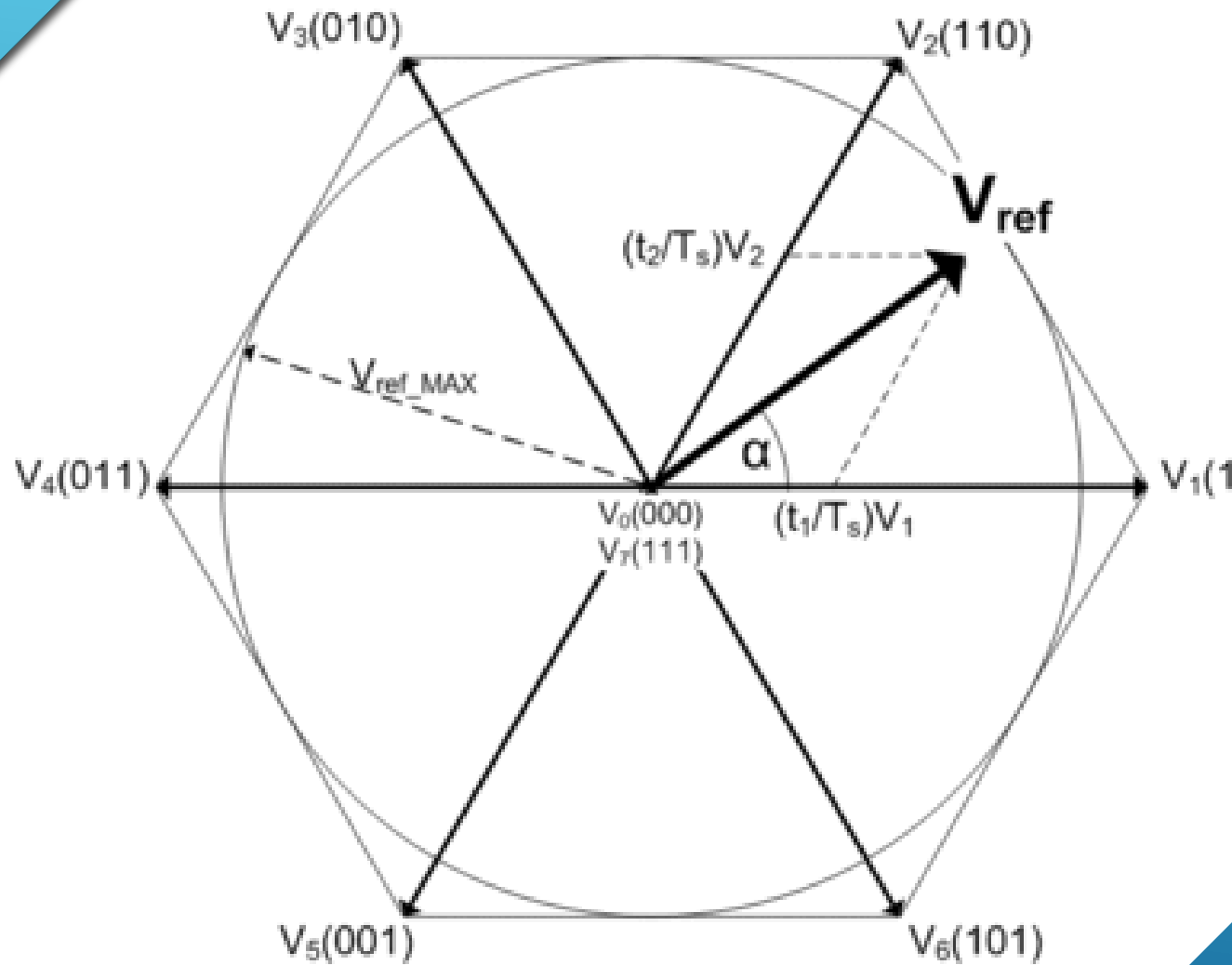
## SOFTWARE PROCESS

- Sensors: stator magnetic flux angle, rotor currents/voltages, rotor position
  - FOC: Use sensors and command values to calculate desired vector in  $\alpha\beta$  frame
  - SVM:  $\alpha\beta$  frame to ABC
  - PWM output
  - Additional functions
- 



## FIELD ORIENTED CONTROL

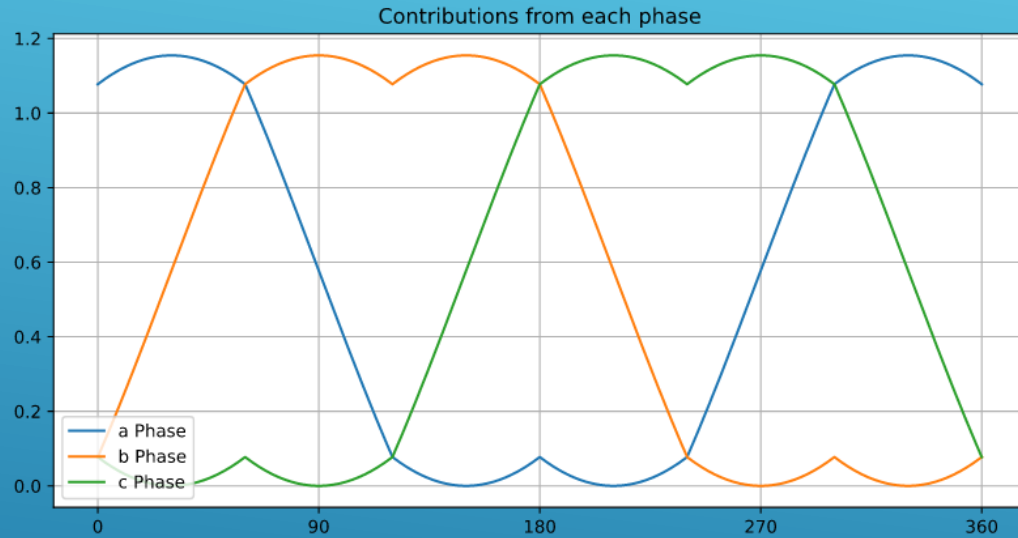
- Clarke Transform:  $ABC \rightarrow \alpha\beta$
- Park Transform:  $\alpha\beta \rightarrow dq$
- Calculations: In rotating reference, quantities are DC
- Inverse Park Transform: Rotating reference to stationary
- Space Vector Modulation



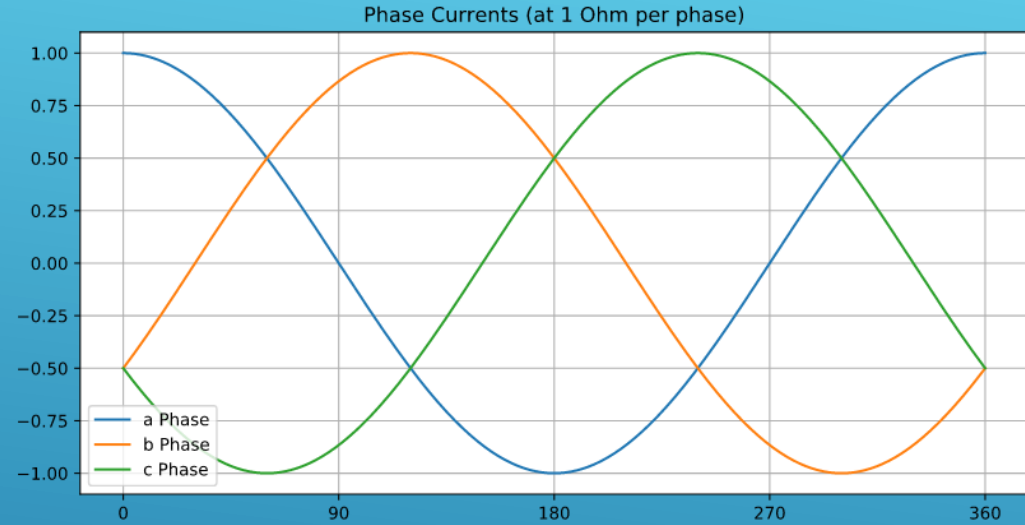
# SPACE VECTOR MODULATION

- ▶ 8 possible switch states, 6 on, 2 zero
- ▶ Calculate state contributions (inner product)
- ▶ Adjust for changing neutral voltage
- ▶ Output with PWM

## Phase Contributions - PWM




## Phase Currents - Results



# PYTHON SIMULATION OF SVM



# MICROCONTROLLER REQUIREMENTS

- Core Clock: 100 MIPS minimum
  - Timers: 20 MHz, 6 simultaneous PWM signals
  - ADCs: At least 4, target 12-bit resolution
  - IO & Communication: Digital IO plus I2C/SPI/CAN capability
  - Hardware acceleration: FPU, MAC, usable from C/C++
  - Memory: Sufficient memory for program storage, large lookup tables
  - Development tools: Free, open source preferred, multiple options
  - Other resources: Software samples, support, forums
- 
- A series of three parallel white diagonal lines on the right side of the slide, extending from the middle towards the bottom right corner.



# MICROCONTROLLER FINAL CHOICE

- ▶ STM32G474E-EVAL
  - ▶ Motor Control Focus
  - ▶ 170 MHz, 213 DMIPS
  - ▶ 512 KB memory
  - ▶ Advanced Timer Functions
  - ▶ 3 Channel, Automatic Complementary PWM
  - ▶ Emergency Stop
  - ▶ 5 12-bit ADCs
  - ▶ Math Accelerators – CORDIC (Trig), FMAC
  - ▶ Multiple Free IDEs
  - ▶ Software Samples



- ▶ Microcontroller separated from high voltage
- ▶ Fiber optic link
- ▶ Noise shielding

# ELECTRICAL ISOLATION