

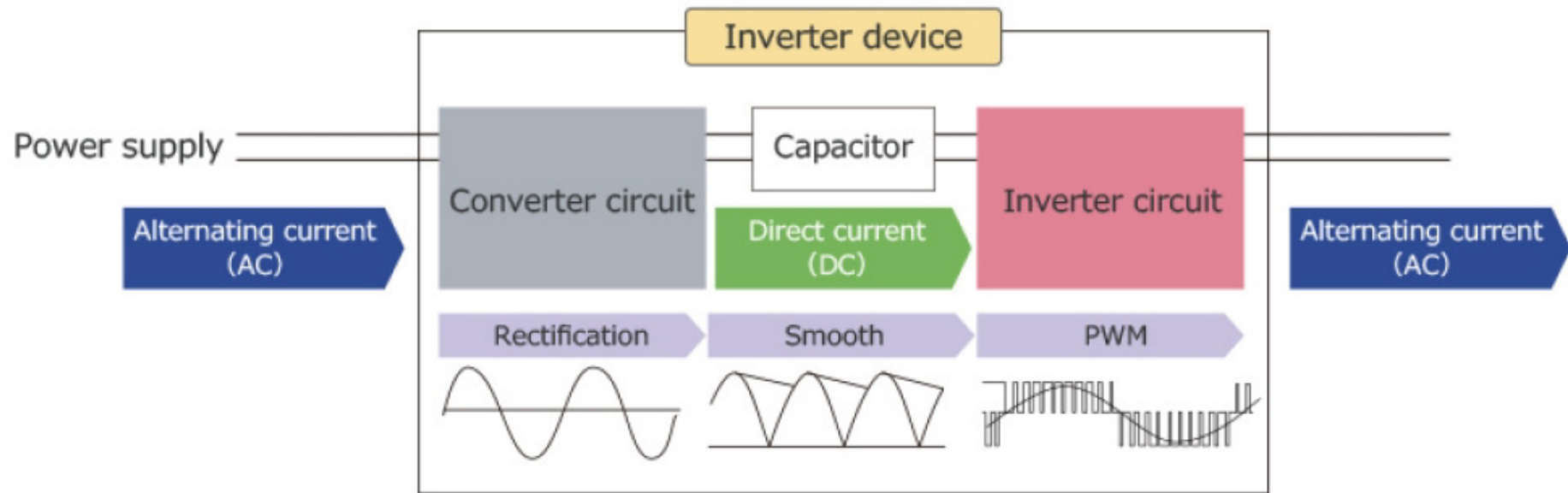


An introduction to inverters

[Fuji_inverters,TI_tiduay6e,TI_tidub21d]

Introduction

- General block diagram



- An important point is the harmonic content of the obtained sinusoidal voltage



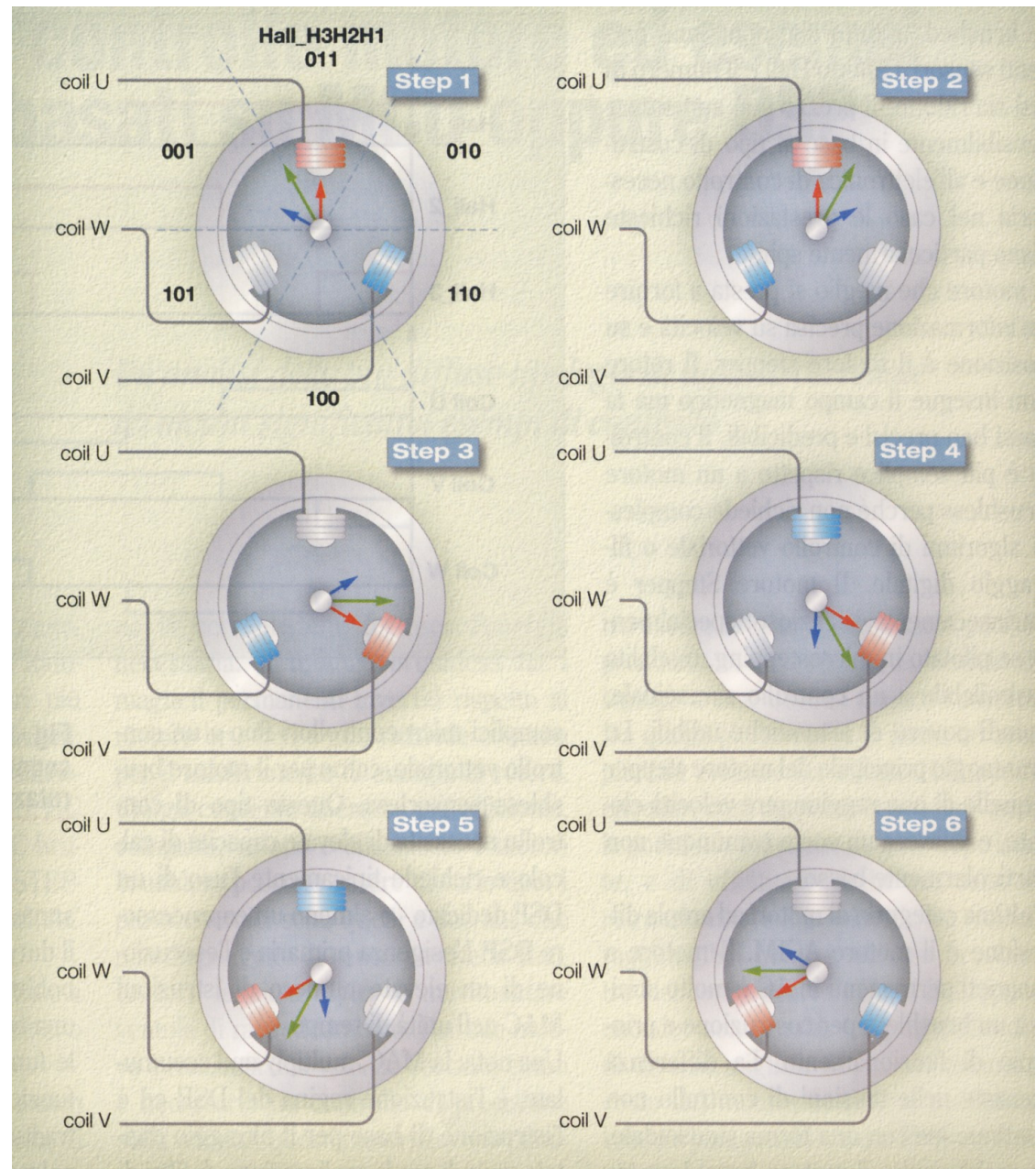
Main different types

- What is varied
 - VVVF: variable voltage and frequency
 - e.g. motors (to adjust the motor's rotation speed)
 - CVVF: variable frequency only
 - e.g. fluorescent lights (to suppress flickering)
 - CVCF: constant voltage and frequency
 - e.g. UPS (uninterruptible power supply)

- PWM
 - bipolar
 - unipolar

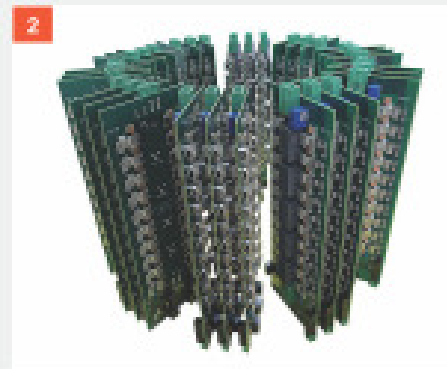
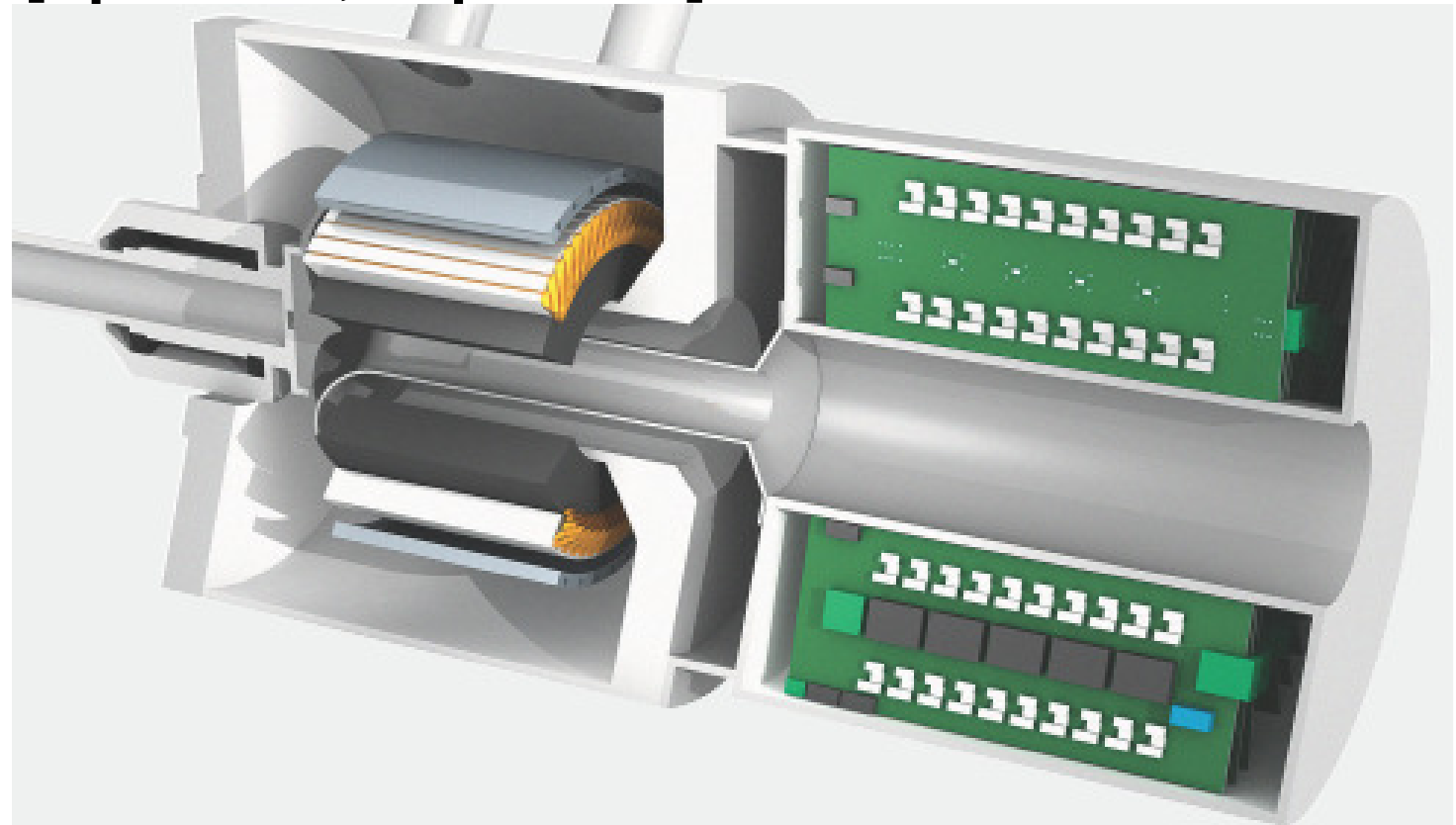
An example: brushless motor control

- The sum of two magnetic fields (red and blue) generated by the coils (excited by 120 deg delayed sines) is a rotating magnetic field (green)



An example [Spectrum, Sept. 2023]: 1 MW motor control

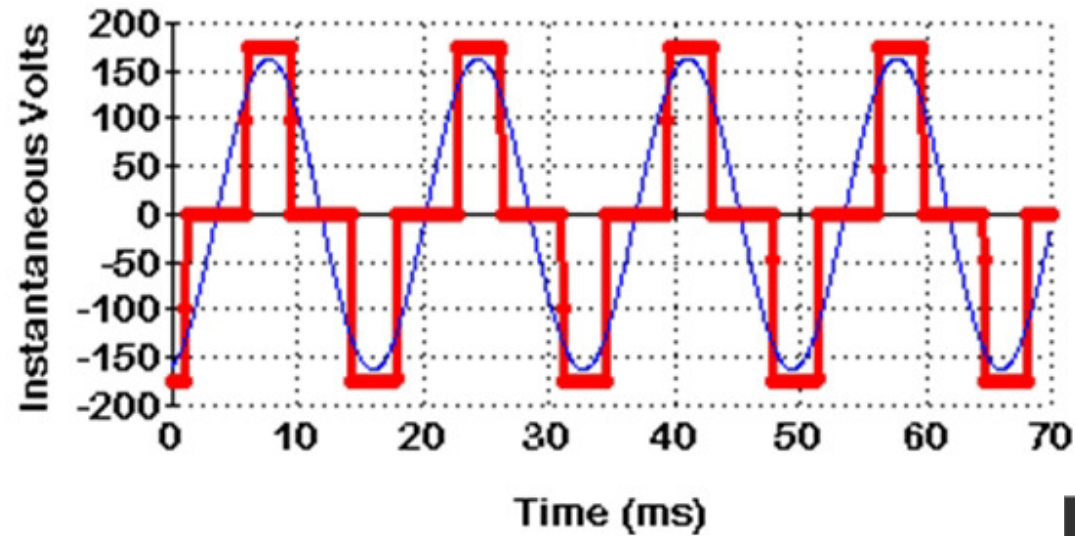
- This motor has a very special application: commercial airliners



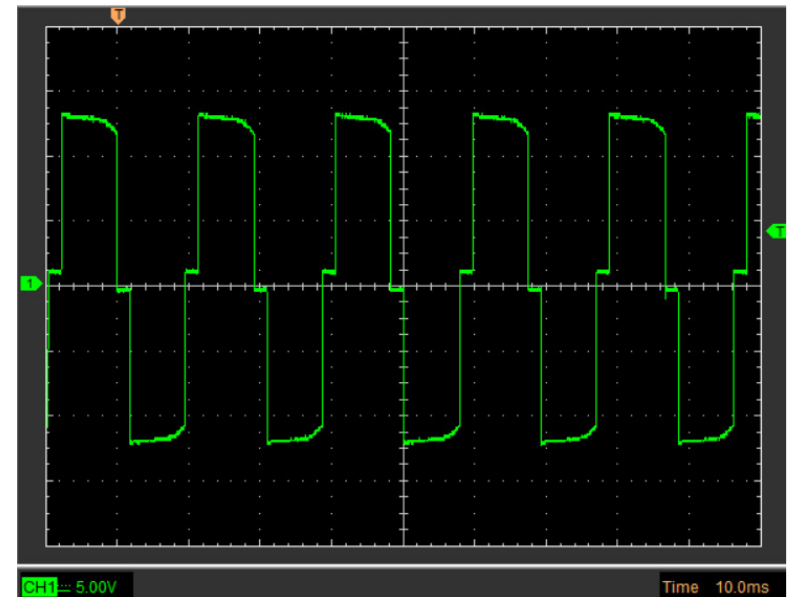
Researchers at MIT have developed a 1-megawatt electrical motor that could help electrify commercial airliners and lead to new types of hybrid or fully electric aircraft. At top is the demonstrator prototype, including (1) a low-loss, tooth-and-slot stator surrounded by a thermal management system, and (2) 30 custom-built, high-speed power-electronics boards that enable high-frequency alternating current in the stators, thus increasing the motor's rotating speeds.

Without PWM

TS-500 Inverter



Very poor harmonic performance



Bipolar PWM

Name bipolar is given as voltage switches in both directions throughout the cycle

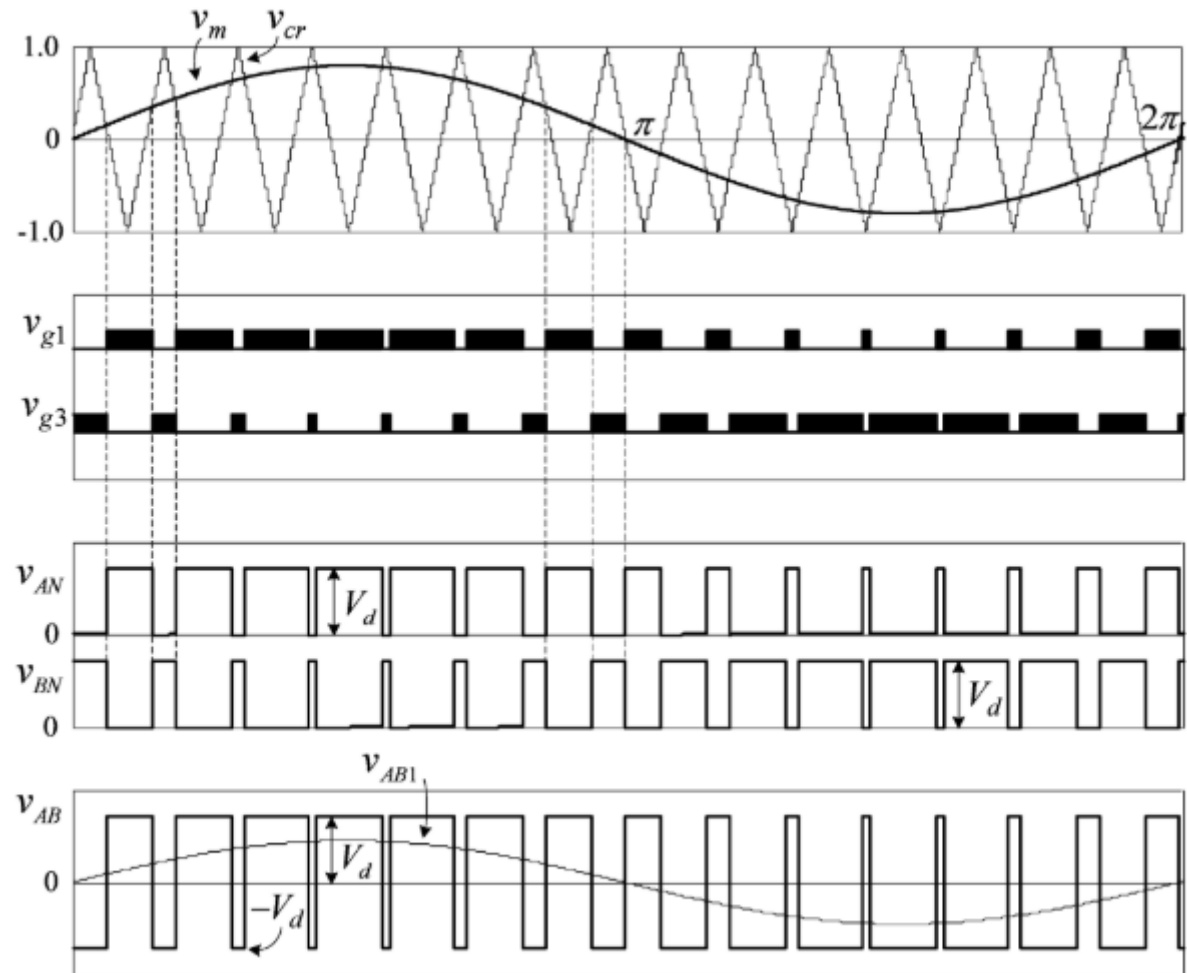


Fig. 3: Waveforms of Bipolar Modulation Scheme

Unipolar PWM

Name unipolar is given as voltage applied to the load remain positive during positive cycle and negative during negative cycle.

Better harmonic performance and lower switching losses wrt bipolar

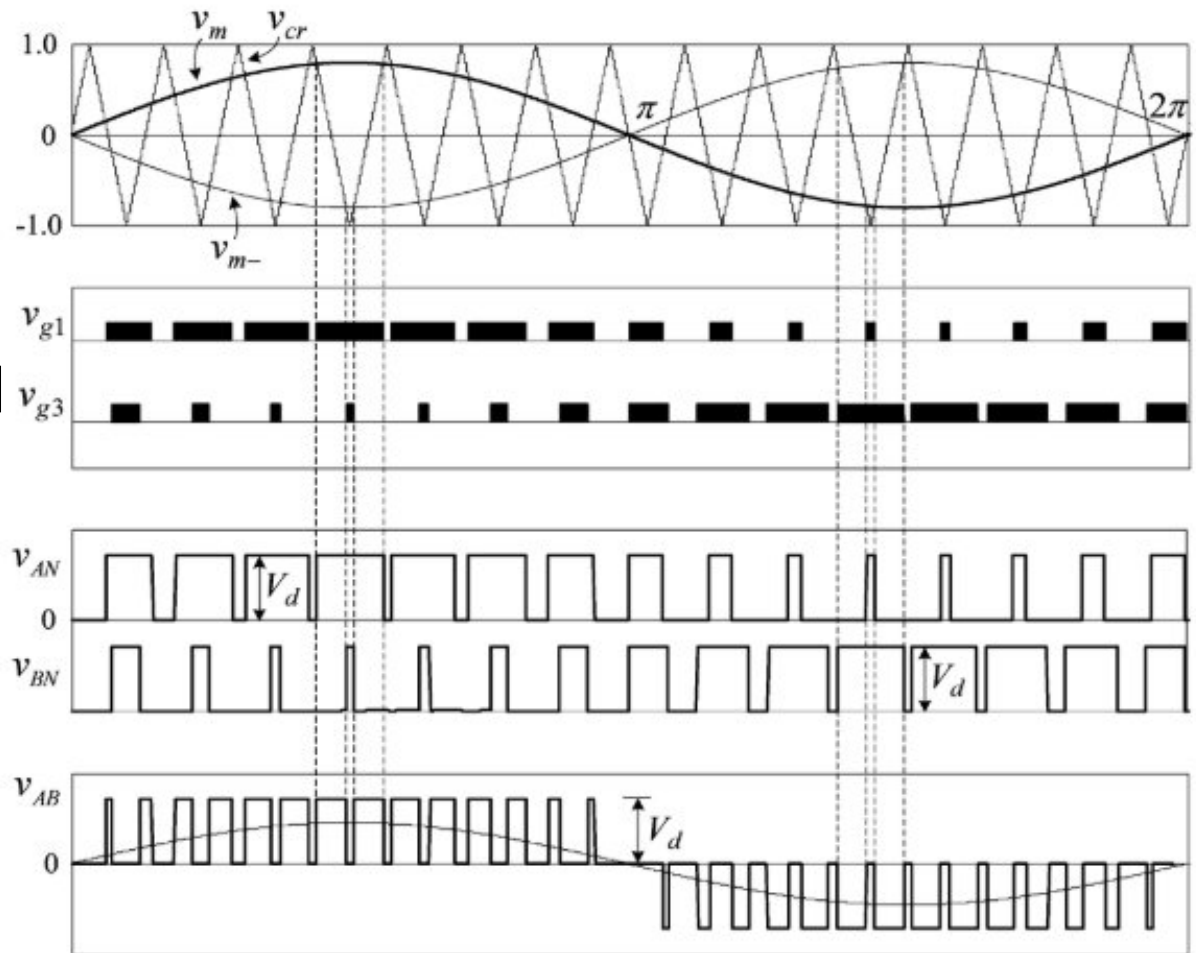


Fig. 4: Waveforms of Unipolar Modulation Scheme

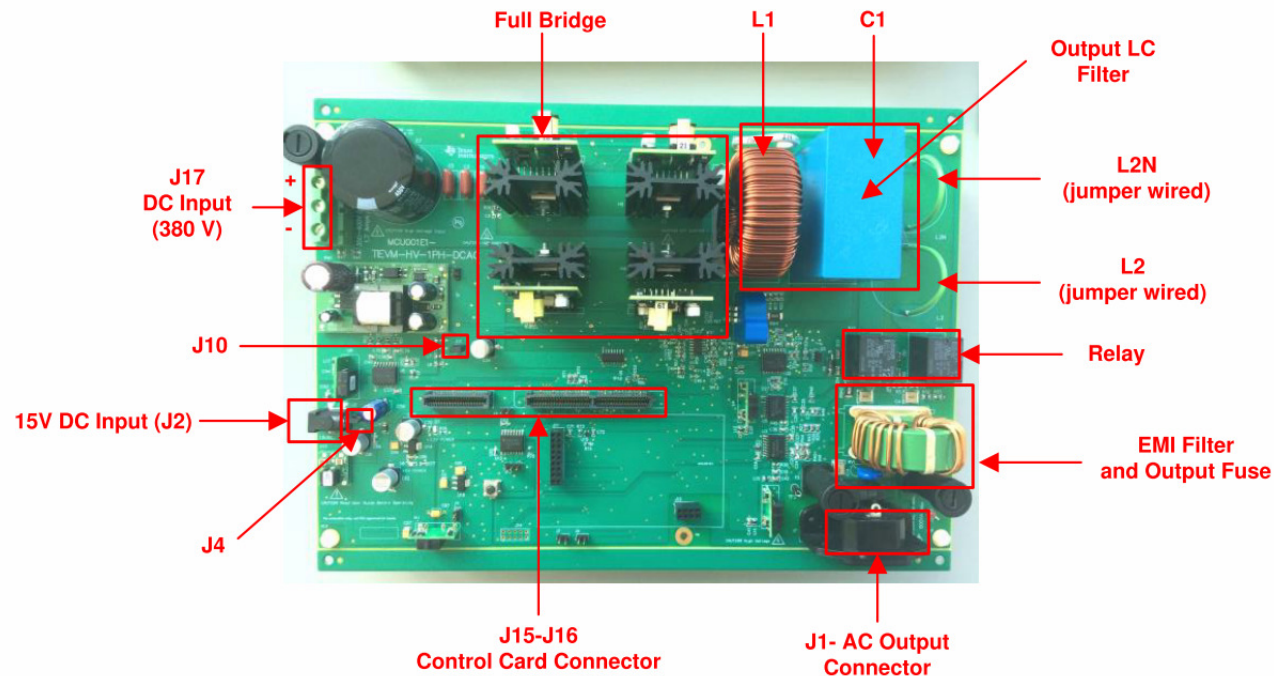


DC/AC example

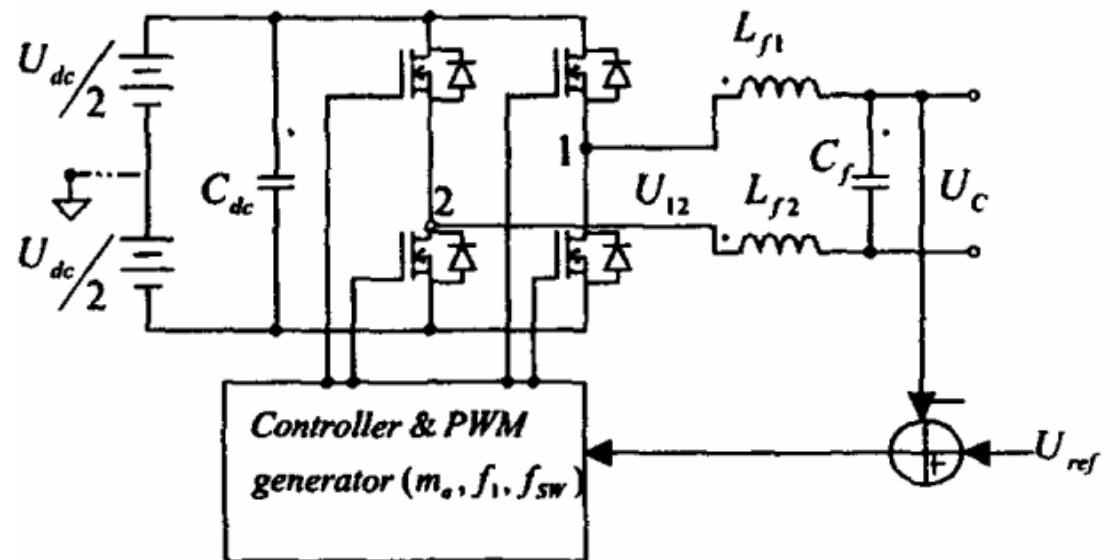
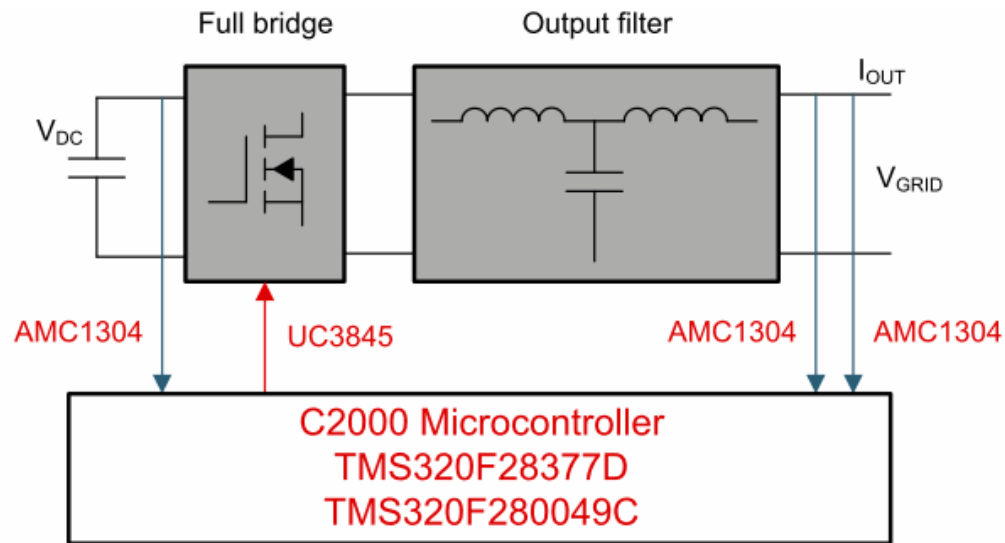
- Example of a single-phase inverter (DC/AC) control using a C2000™ microcontroller (MCU)
- The design supports two modes of operation for the inverter:
 - a voltage source mode using an output LC filter, and
 - a grid connected mode with an output LCL filter

Specifications

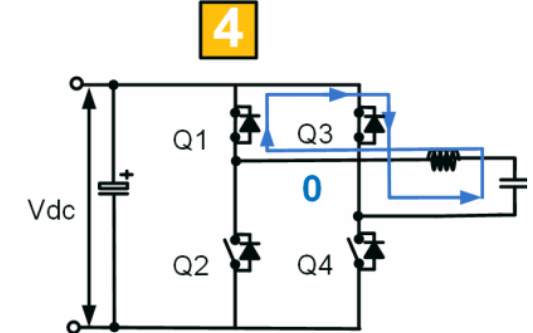
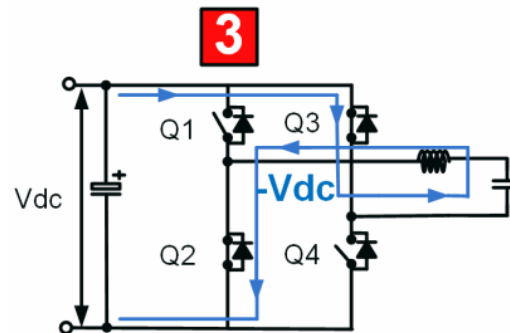
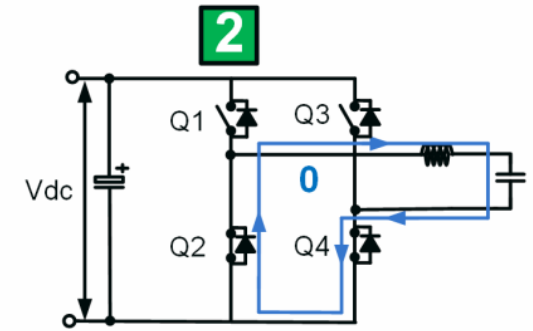
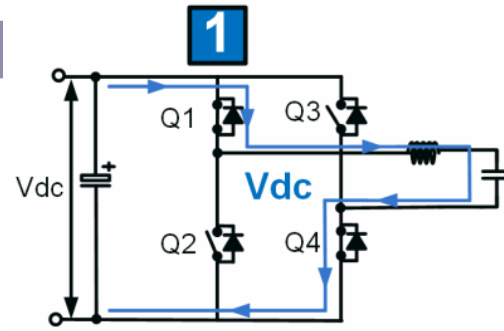
- $V_{IN} = 380$ DC, $V_{OUT} = 110/220$ V_{RMS} , 50/60 Hz, 400 VA max
- $f_s = 20$ kHz
- ~ 97% efficiency
- <2% Total Harmonic Distortion at >50% rated power



Block diagram



Modulation scheme

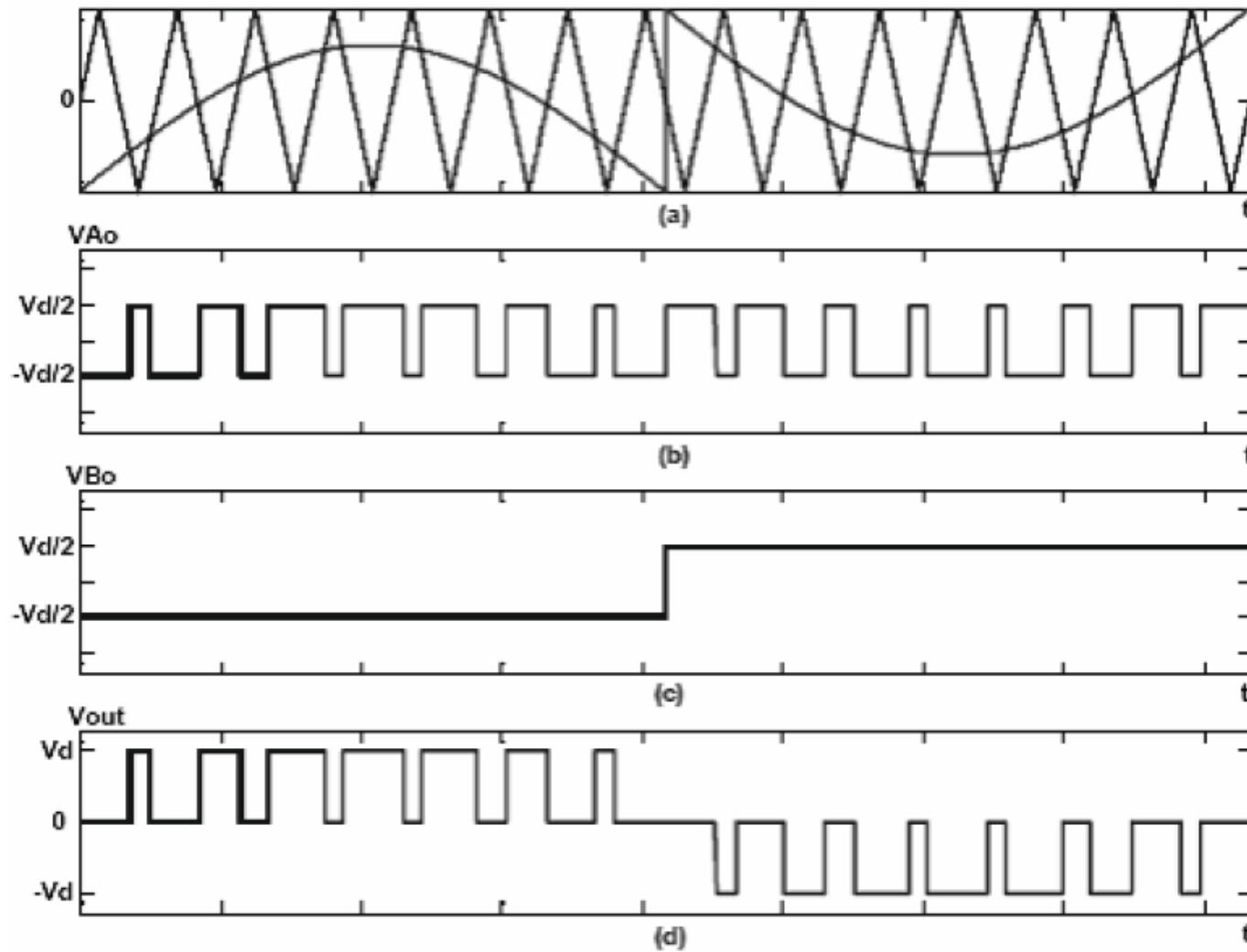


- (Modified) unipolar modulation in which
 - switches Q1 and Q2 are switched at high frequency
 - switches Q3 and Q4 are switched at low frequency (frequency of the grid)

CYCLE	Q1	Q2	Q3	Q4	VOLTAGE AT BRIDGE OUTPUT	STATE
Positive half cycle	ON	OFF	OFF	ON	V_{DC}	1
	OFF	ON	OFF	ON	0	2
Negative half cycle	OFF	ON	ON	OFF	$-V_{DC}$	3
	ON	OFF	ON	OFF	0	4

Modulation scheme

This modulation scheme has reduced EMI



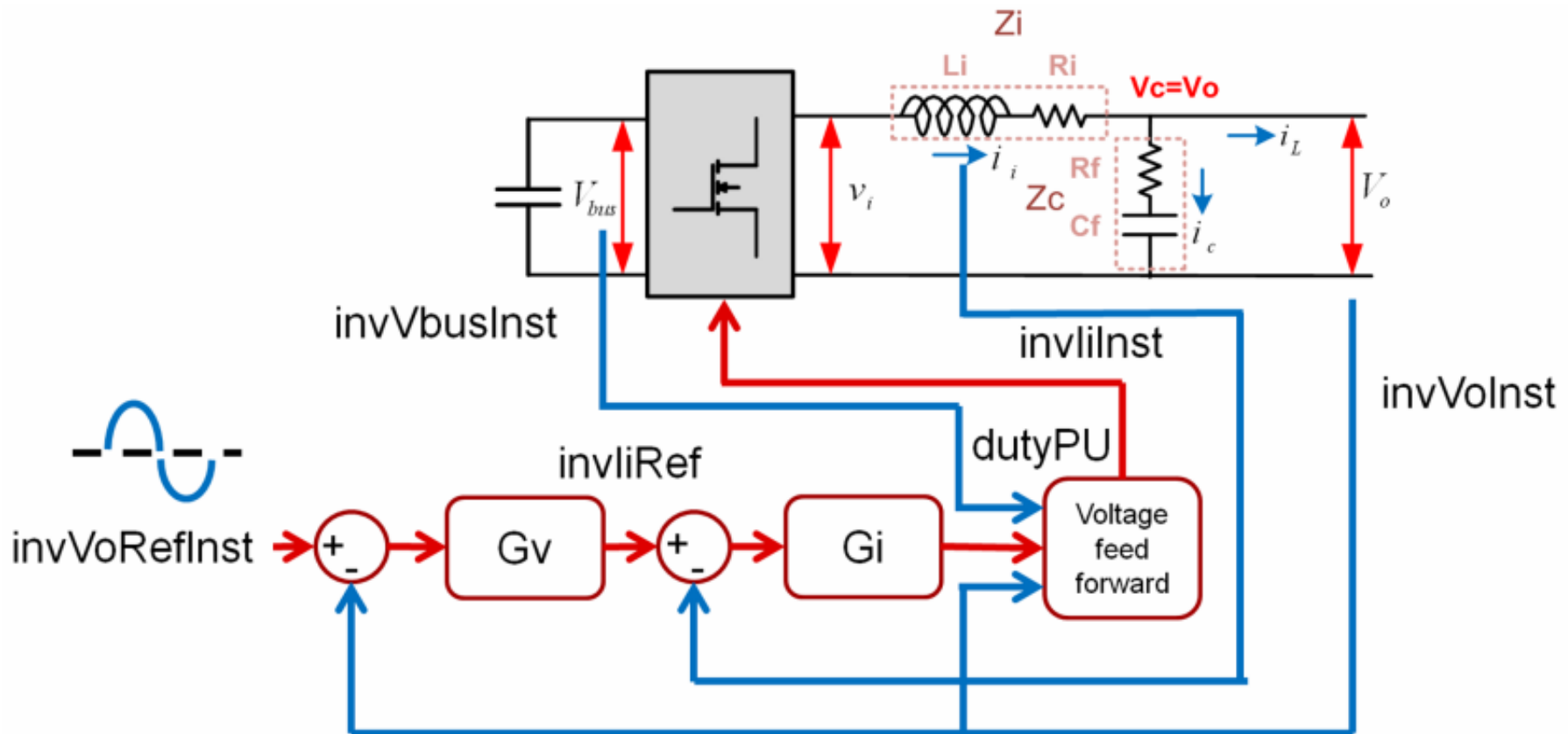


Voltage and current sensing

- To control the inverter stage for desired operation, voltage and current values are required to be sensed for processing by the digital controller
 - DC bus sensing
 - AC output voltage sensing
 - inductor current sensing
 - output current and capacitor current sensing
- Most power electronics converters need protection from an overcurrent event

Output voltage control scheme (voltage source mode)

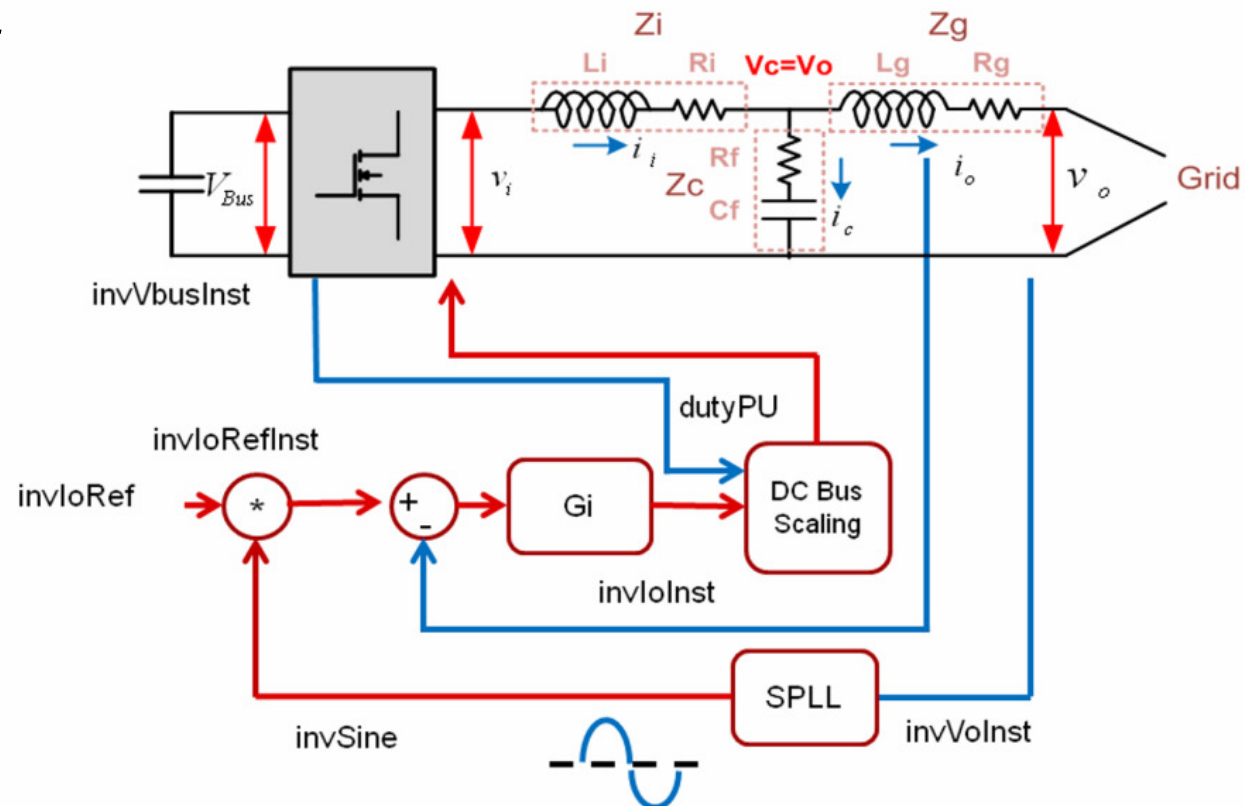
- Input (blu): V_{bus} , i_i , and V_o
- $invVoRefInst$ is the reference sinusoid



Output voltage control scheme (grid connected mode)

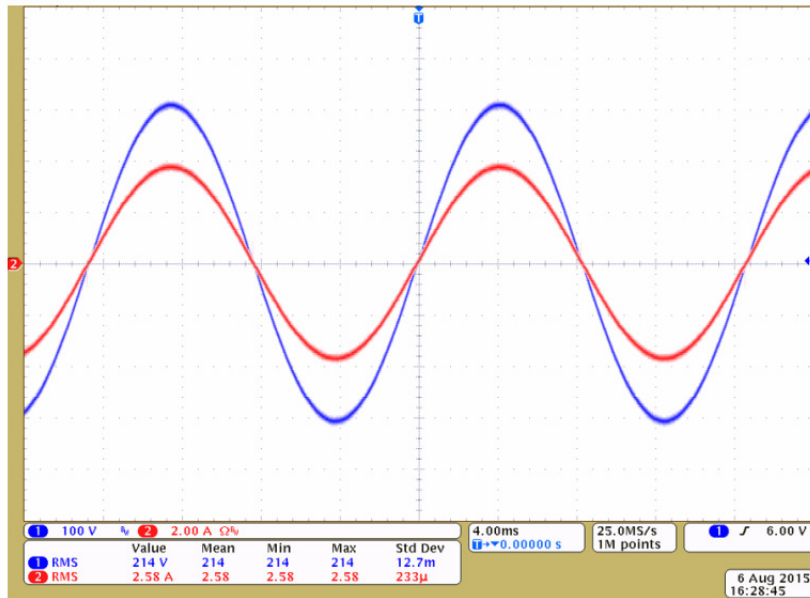
- The grid voltage, V_o , is sensed in the variable *invVolInst*
- A software PLL algorithm computes the phase of the grid, *invSine*
- *invSine* is then multiplied with the reference current command *invIoRef*, which generates the instantaneous current command reference *invIoRefInst*

- This reference is then compared with the sensed output current, *invIoInst*, and the error fed into the current compensator



Output voltages: examples

- Linear load



- non linear load (a rectifier)

