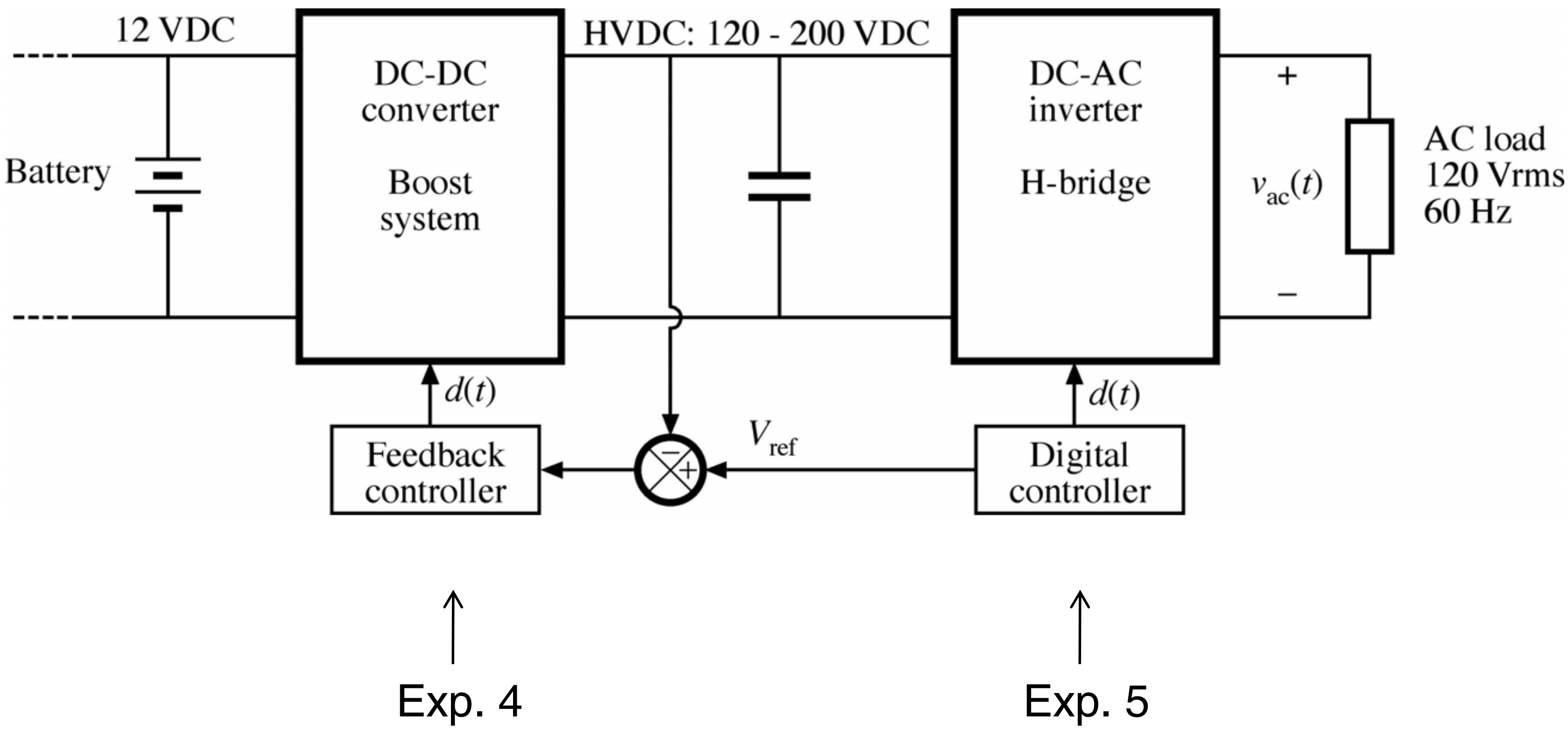
# Lecture 10

ECEN 4517/5517

## Experiment 5

Inverter system



# Schedule

This week: finish Lab 4

Exp. 5 prelab due via D2L by next Tuesday 4/10 12pm

Exp. 4 report due via D2L by Friday, April 20, 5 pm

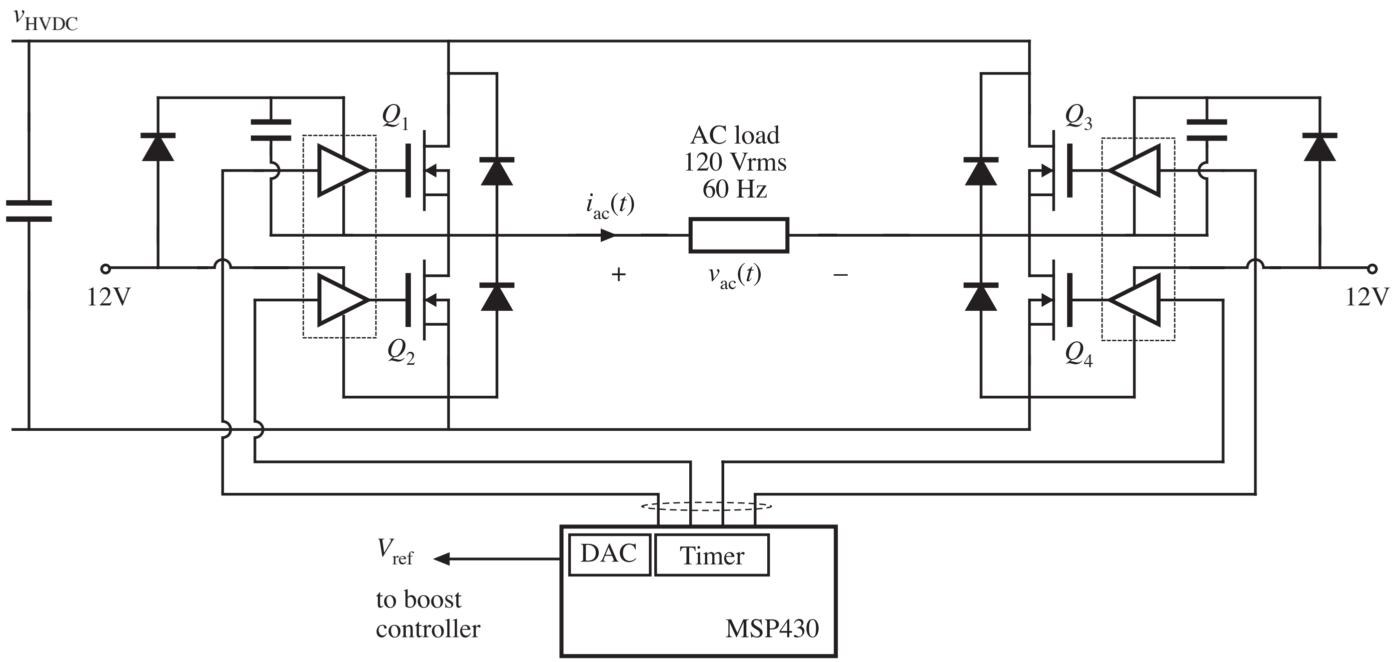
Final demo: complete PV system working outside, the morning of Thursday May 3 (Expo)

# Exp. 5
## H-bridge inverter, off grid

+

HVDC
from Exp. 4

–




- Filtering of ac output not explicitly shown
- Need MOSFETs and half-bridge gate drivers
- Grid-tied: control $i_{ac}(t)$
- Off-grid: control $v_{ac}(t)$

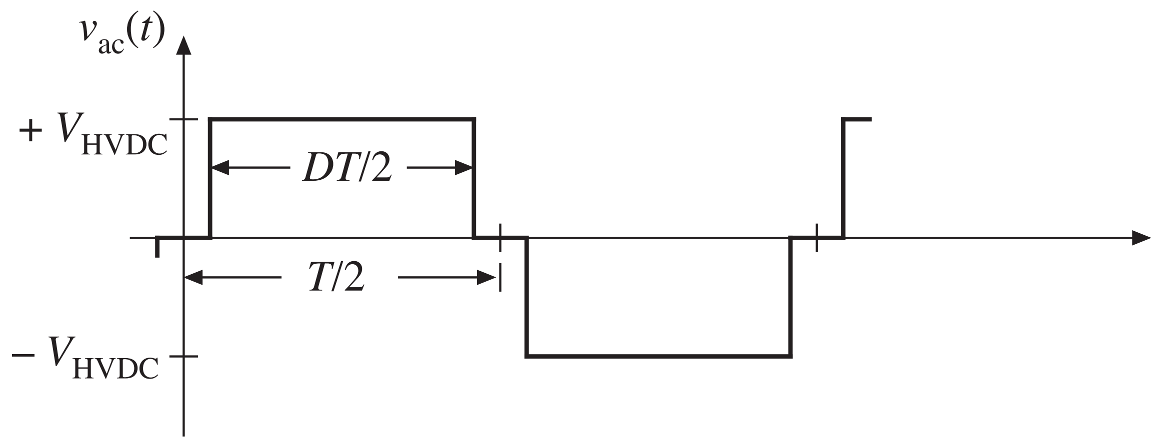
**Exp. 5: off-grid inverter**

- Demonstrate modified sine-wave inverter (required)
- Demonstrate PWM inverter (extra credit)

# "Modified Sine-Wave" Inverter

$v_{ac}(t)$ has a rectangular waveform

Inverter transistors switch at 60 Hz, $T$ = 8.33 msec




RMS value of $v_{ac}(t)$ is:

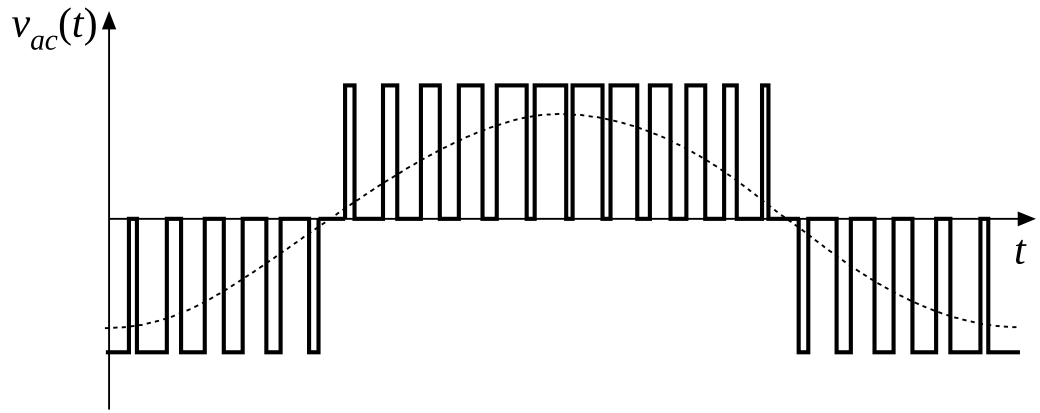
$$V_{ac,RMS} = \sqrt{\frac{1}{T}\int_0^T v_{ac}^2(t)\,dt} = \sqrt{D}\,V_{HVDC}$$

- Choose $V_{HVDC}$ larger than desired $V_{ac,RMS}$
- Can regulate value of $V_{ac,RMS}$ by variation of $D$
- Waveform is highly nonsinusoidal, with significant harmonics

# PWM Inverter

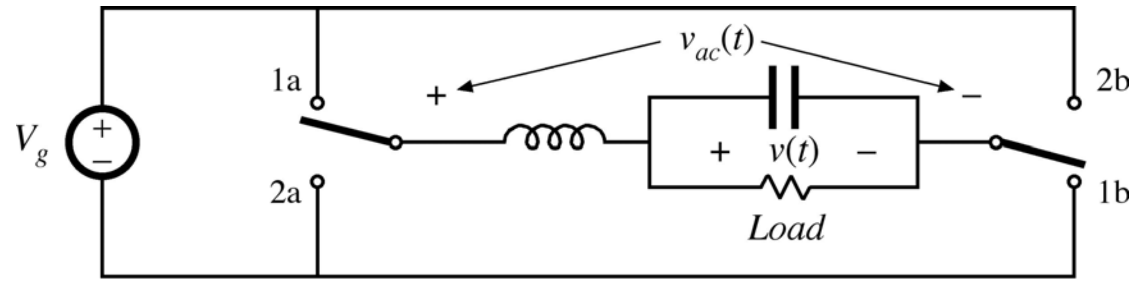
Average $v_{ac}(t)$ has a sinusoidal waveform

Inverter transistors switch at frequency substantially higher than 60 Hz



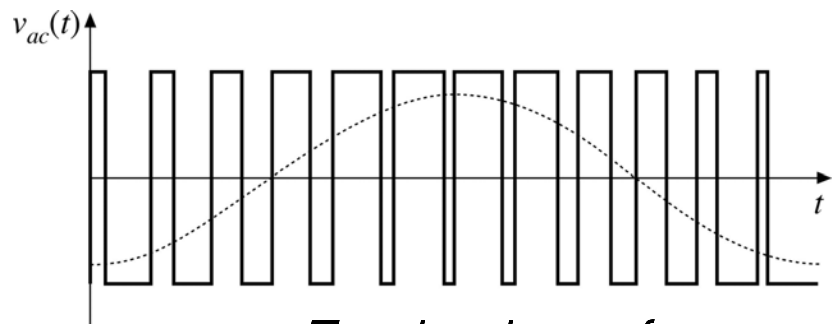

- Choose $V_{HVDC}$ larger than desired $V_{ac,peak}$
- Can regulate waveshape and value of $V_{ac,RMS}$ by variation of $d(t)$ (programming inside microcontroller)
- Can achieve sinusoidal waveform, with negligible harmonics
- Higher switching frequency leads to more switching loss and need to filter high-frequency switching harmonics and common-mode currents
- For the same $V_{ac,RMS}$, need larger $V_{HVDC}$

# Two ways to generate a PWM sinusoid




(a) Operate left and right sides with same (complementary) gate drive signals

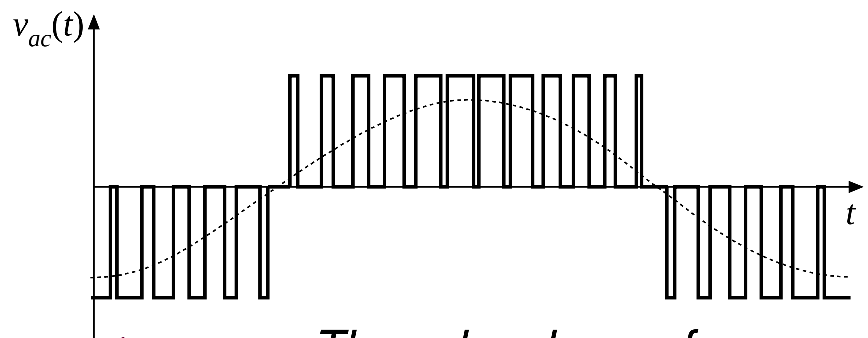
$$v(t) = (2d(t) - 1)\ V_g$$




*Two-level waveform*

(b) PWM one side, while other side switches at 60 Hz

$$v(t) = \pm\ d(t)\ V_g$$

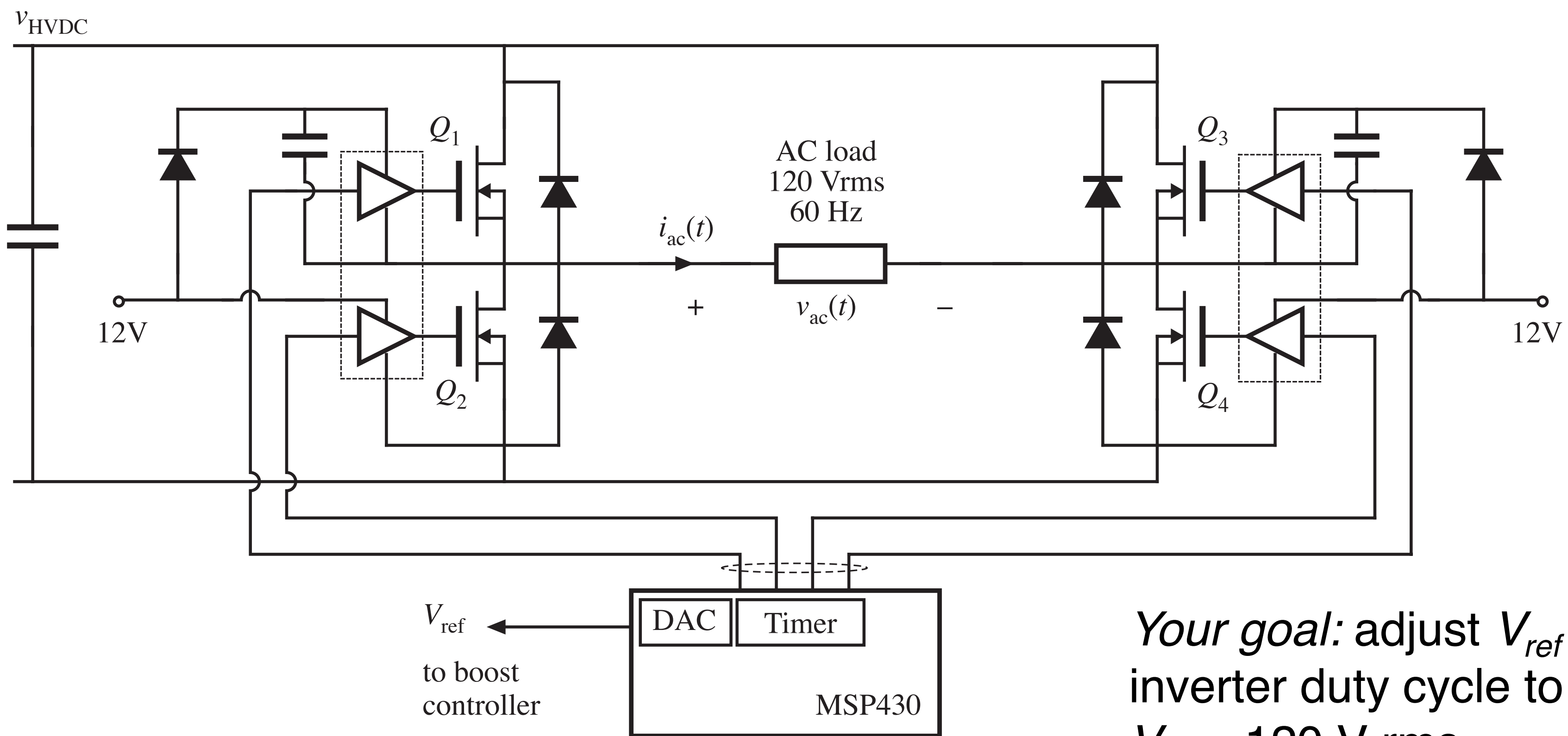



*Three-level waveform*

# Controlling the inverter

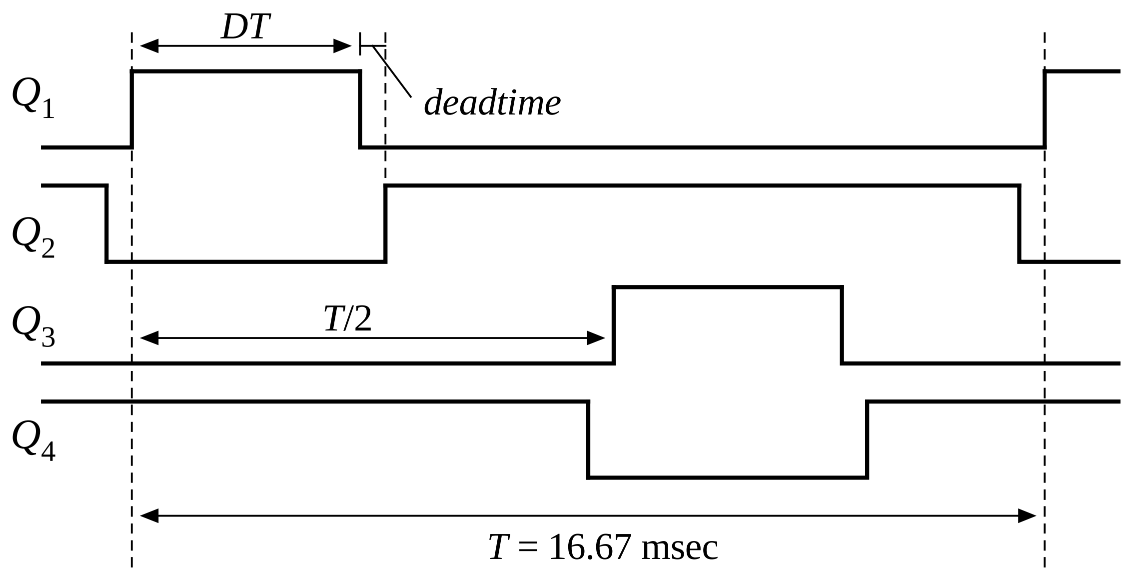
MSP430 generates logic signals to control the four gate drivers

- Control MSP430 timer (you could use A or B or simply use logic outputs) to generate MOSFET drive signals




*Your goal:* adjust $V_{ref}$ and inverter duty cycle to obtain $V_{ac}$ = 120 V rms

# Gate drive timing




- For modified sine wave inverter: switch once per ac half cycle. Adjust duty cycle to control rms voltage.
- You decide how to do this / which timer to use
- Require deadtime > (switching/delay times of MOSFETs plus gate drivers); otherwise, simultaneous conduction of $Q_1$ and $Q_2$ causes “shoot-through” current that can damage MOSFETs.

# Half-bridge Gate Drivers

## example: FAN 73832

Contains two MOSFET drivers:

- Low side driver
- High side driver

High side driver includes

- Level-shifting circuitry
- Provisions for bootstrap power supply

Undervoltage lockout circuitry holds MOSFETs off when driver power supply is below threshhold

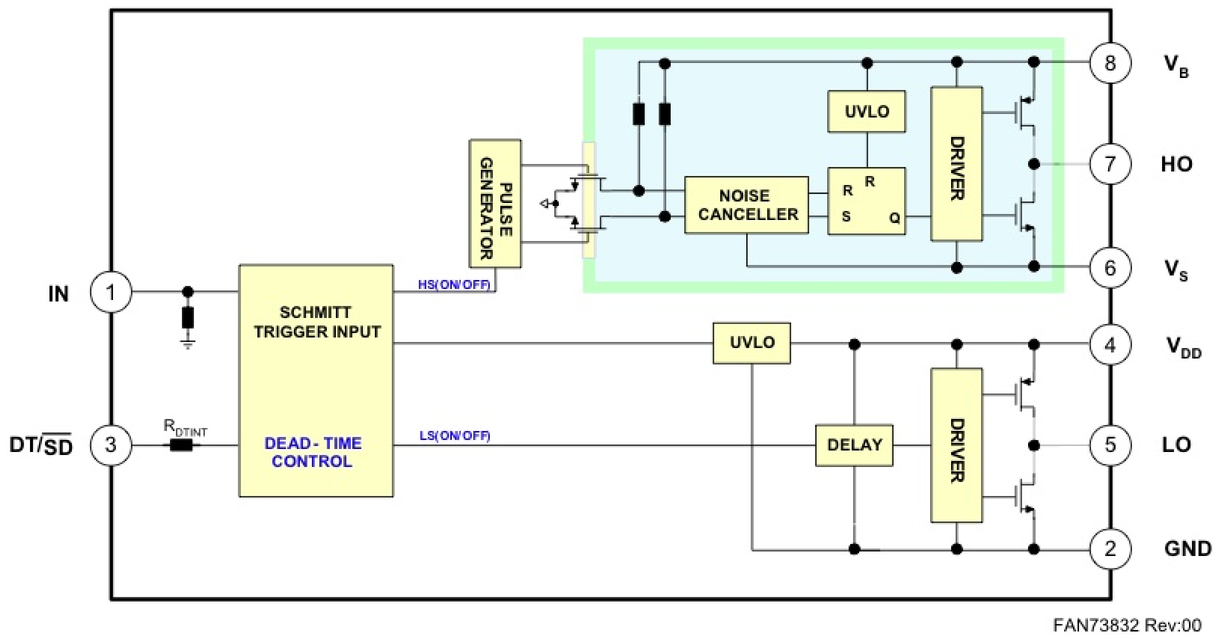



Figure 3. Functional Block Diagram of FAN73832

# Half bridge gate driver circuit example

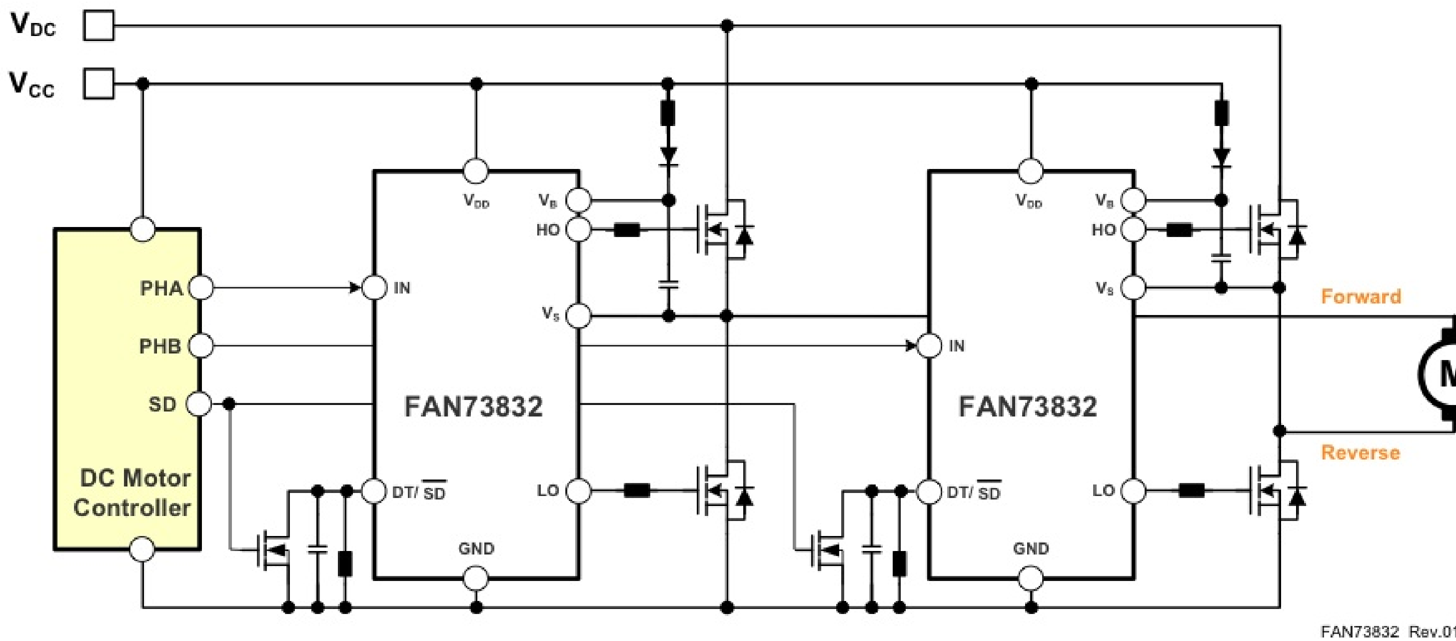


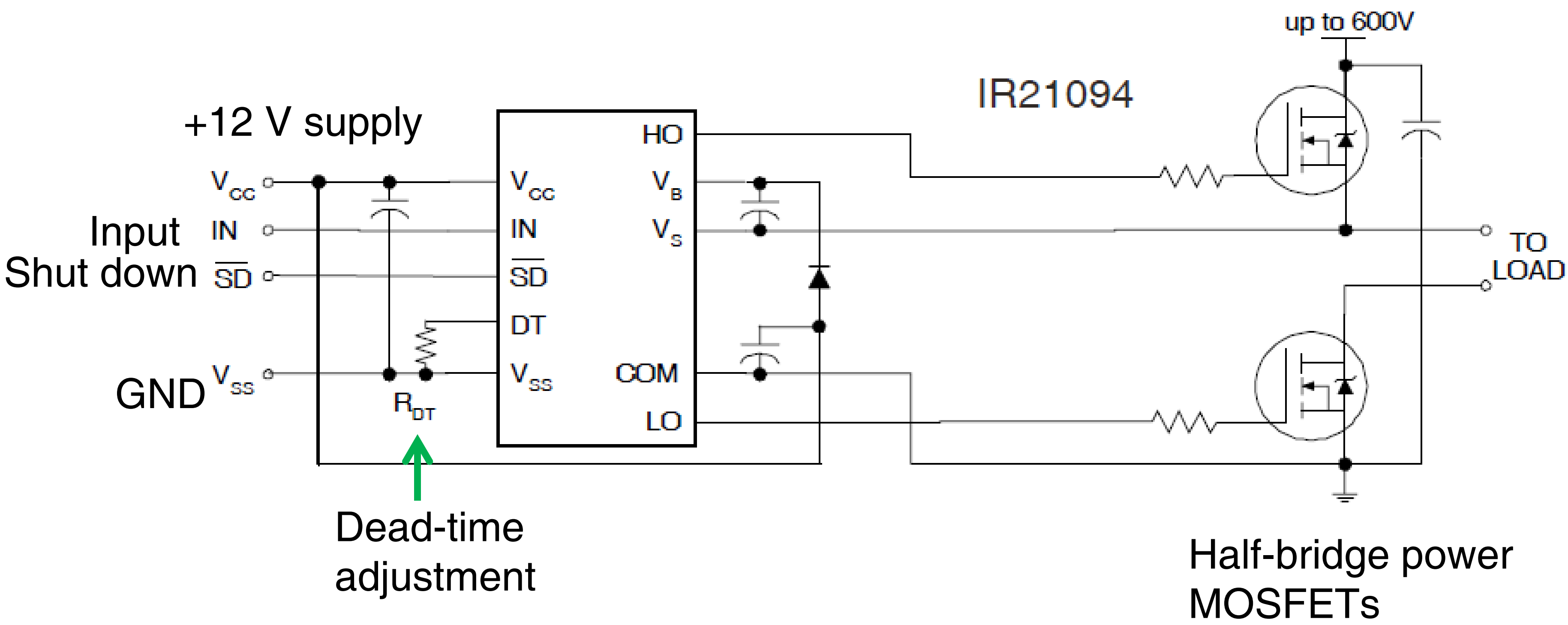

**Figure 2. Application Circuit for Full-Bridge DC Motor Driver**

High side circuitry includes external diode and capacitor for bootstrap power supply

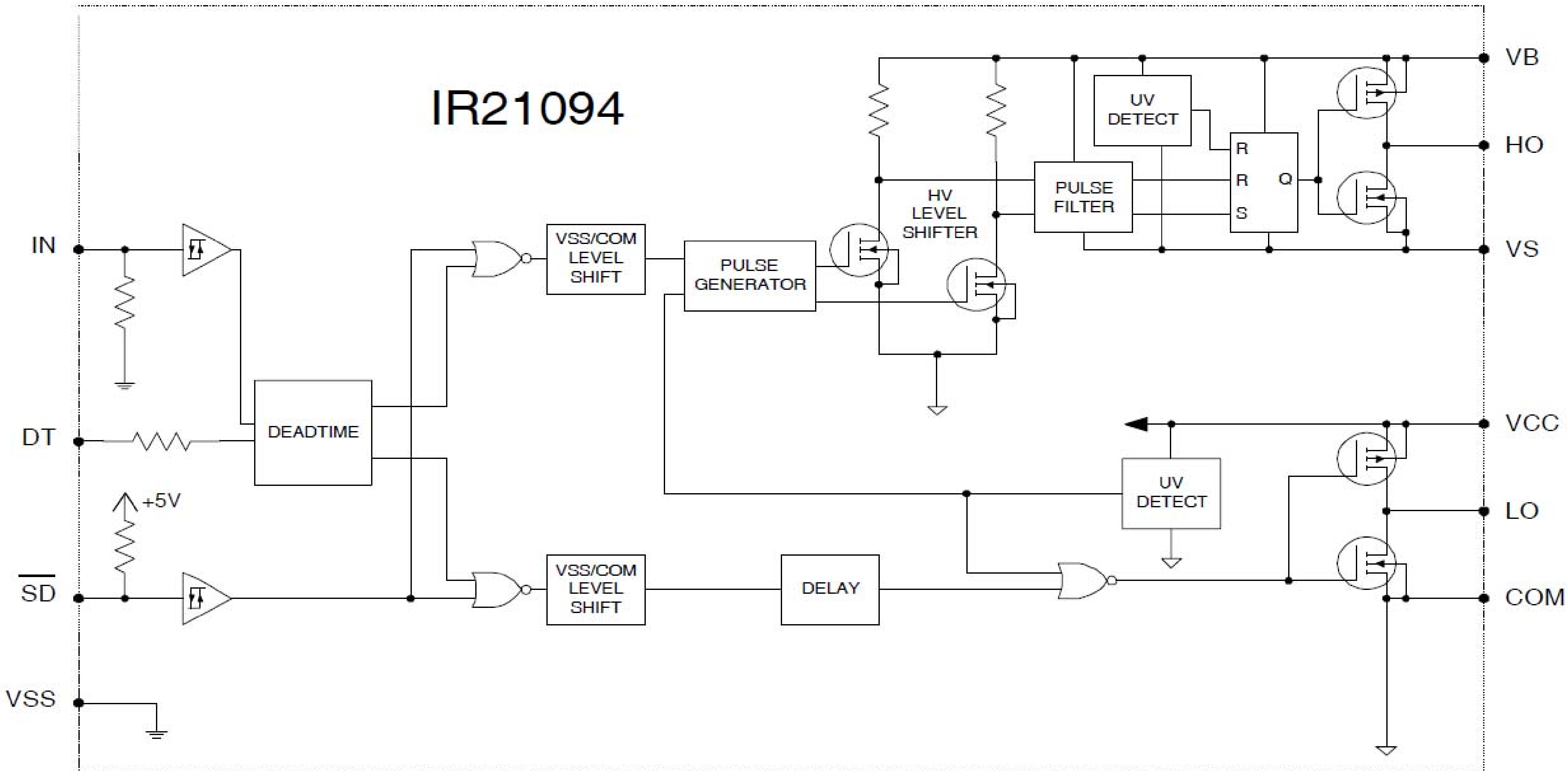
To charge bootstrap capacitor, low side MOSFET must conduct

In this example, $V_{CC}$ = 12 V

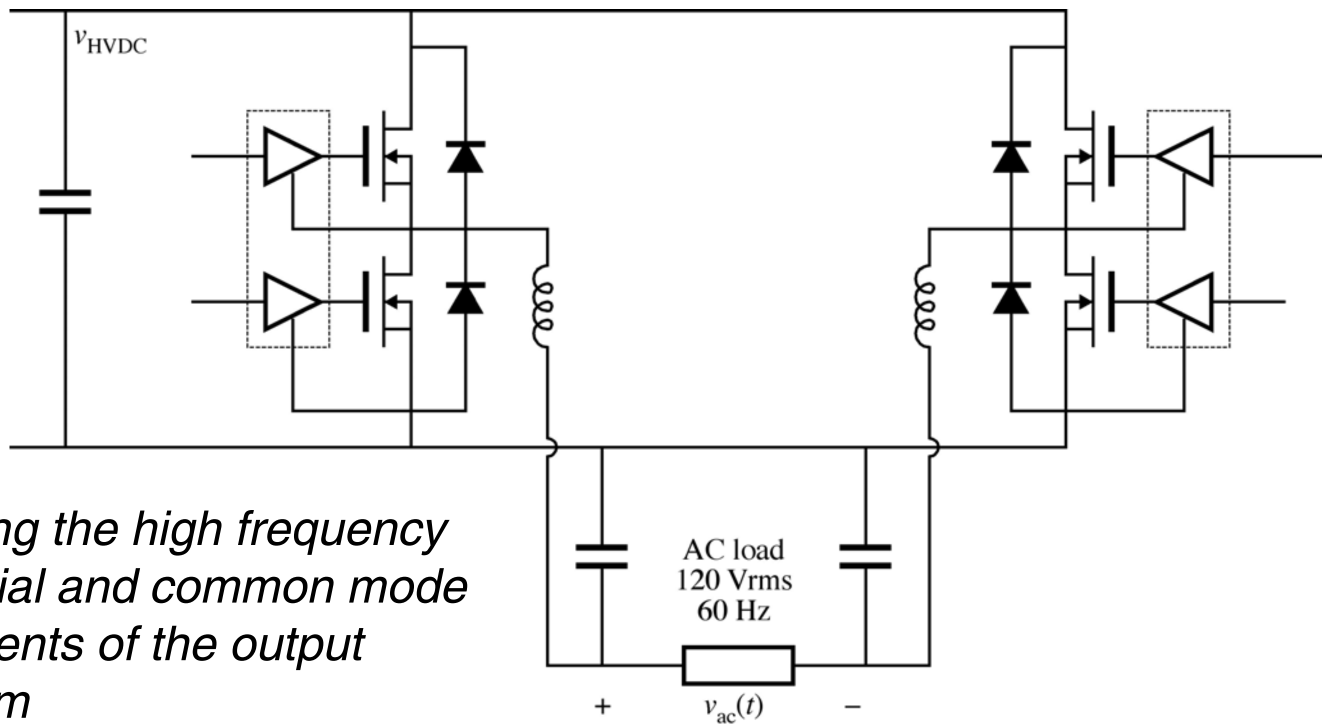
# Half-Bridge Driver Example 2: IR2019



# Half-Bridge Driver Example 2: IR2019



# Filtering the ac output




*Removing the high frequency differential and common mode components of the output waveform*

*Note:* the “Kill-a-Watt” power meters cannot tolerate high frequency components in the ac voltage waveform. Do not connect these meters to an unfiltered inverter output!