THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

SECOND SEMESTER EXAMINATION – 2021

EE452: ADVANCED POWER ELECTRONICS

BEEP4
TIME ALLOWED: 3 HOURS

INFORMATIONS FOR STUDENTS

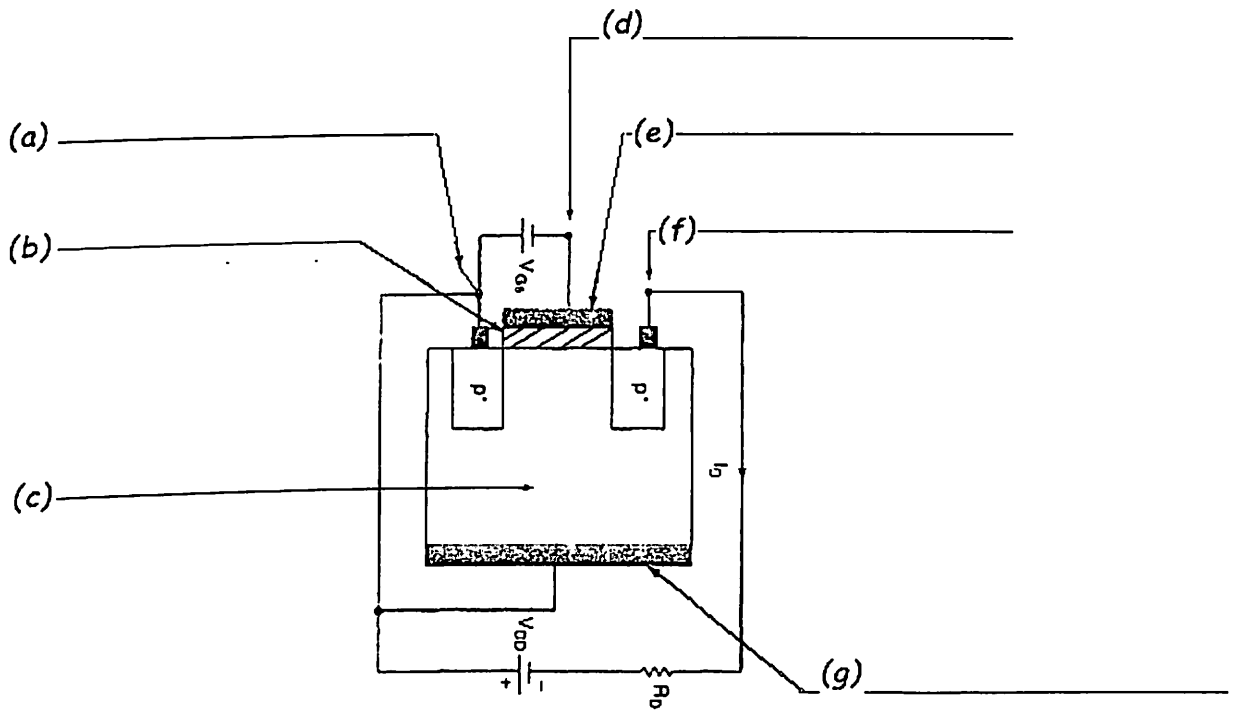
1. You have **TEN [10] MINUTES** to read through the paper. You must not begin writing during this time.
2. Answer **FOUR QUESTIONS**. Attend to **all the Examination Questions** in **any order**.
3. All Answers must be written in the **ANSWER BOOK** supplied.
4. Make sure that you have a data sheet at the final page of the Exam Paper.
5. **COMPLETE THE DETAILS REQUIRED ON THE FRONT COVER OF YOUR ANSWERBOOK – DO THIS NOW.**
6. Only the drawing instruments and the calculators are permitted on your desk. Text books and notebooks are **NOT** permitted.
7. If you are found cheating in the Examination, the penalties specified by the University shall apply.
8. A **Basic FORMULA SHEET** is provided at the final page **(Pg.8/8)** of the examination question paper.
9. **TURN OFF** all **Mobile Phones** and place them on the floor under your seat before the start of Examination.

QUESTION1 [20 Marks]

This is a short answer question. PartA (1 to 6) is short answer Questions and PartB (7 to 11) is True or False Questions.

PARTA: SHORT ANSWERS

(1) Provide the labeling for Power MOSFET structure provided below with appropriate names of the parts. [7 marks]



(2) The MOSFET in (2) does not have physical channel, what is the name of this type of Power MOSFET?

_____[1maek]

(3) List four examples of Controlled Power Static (Semiconductor) Switches. [4marks]

(a)_____ (d)_____

(b)_____

(c)_____

(4) What is the name for the Power MOSFET that has physical channel?

_____ [1mark]

(5) In one paragraph provide description of the operation of the "Power MOSFET without physical channel"? [3marks]

(6) What influences the "Steady-state Transfer characteristic" of a power MOSFET?

_____ [2 marks]

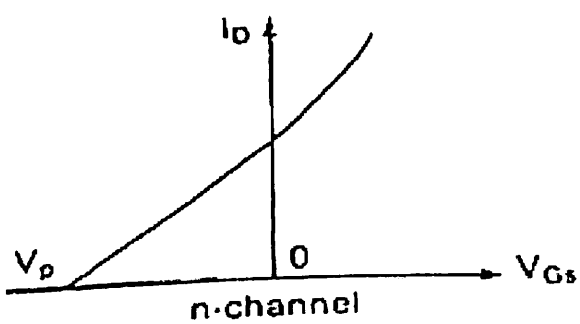
PARTB: TRUE OR FALSE

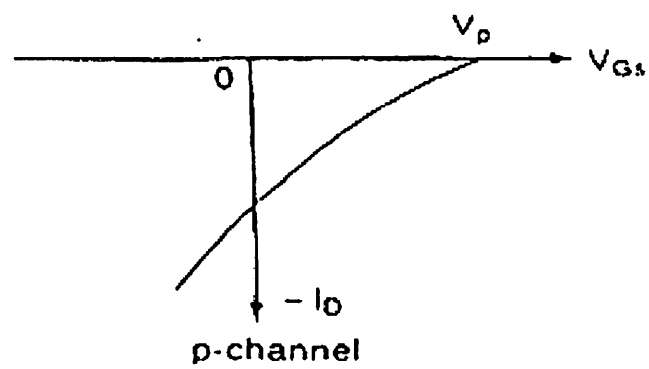
Write "TRUE" if you think the statement is correct or write "FALSE" if you think the statement is not true. [5 marks]

(7) Two regions of the steady-state characteristics are Saturation and linear region.

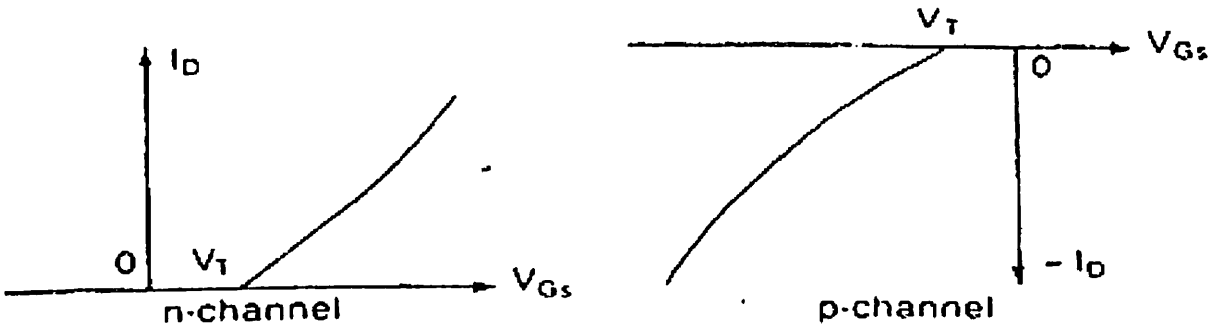
(8) Power MOSFET is utilized as a static switch in the saturation region.

(9) Following is the characteristic curve for steady-state transfer characteristic for depletion type power MOSFET.





(10) Following is the characteristic curve for steady-state transfer characteristic for induction type power MOSFET.



(11) Three main regions of a dynamic (switching) characteristic of a pulse are Turn On, Conduction and Turn OFF.

QUESTION2 [20 Marks]

Attend to questions (a) and (b) based on information provided in figure1 and figure2 respectively. Circuit in figure1 is used as gate drive for Power MOSFET and that, PWM signal for the gate drive is generated by combining saw tooth carrier signal with a reference signal. Attend to the following questions.

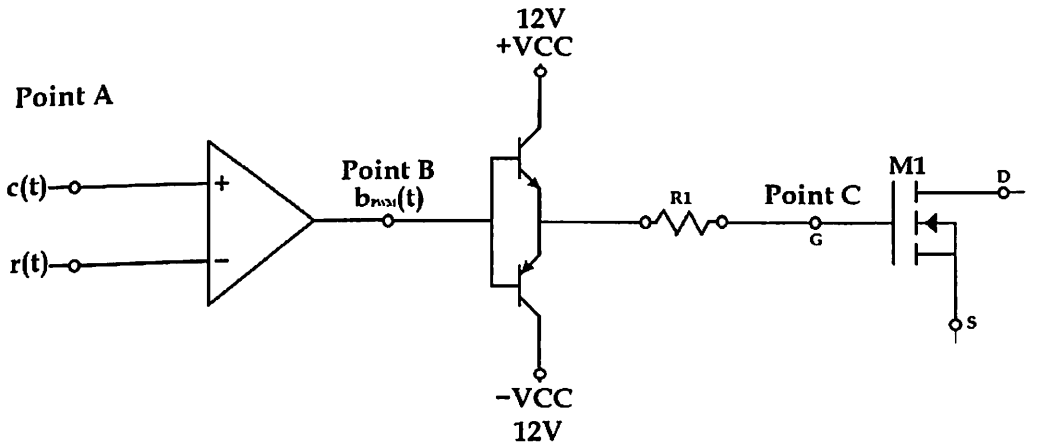


Figure 1: Gate Drive Circuit for Question2.

(a) The drive IC used in drive circuit of figure1 is capable of sinking and sourcing 1A is used to drive a MOSFET switch (C_{GS} = 1000pF; C_{DS} = 200pF; V_{th} = 4V).

(i) Find the value of R_g such that V_{GS} on turn-on reaches 10V within 500 ns.

(ii) Calculate turn on time for the circuit of figure2.

(iii) Calculate rise time for the drive circuit.

(iv) If pinch-off voltage of 9Volts is reached during discharging, find the turn off delay time t_{doff}.

(v) Calculate the fall time t_f).

(vi) Calculate maximum design frequency of PWM signal if turn on time requirement for switching is 1% of the switching period.

(b) Figure2 shows a mathematical block diagram of a basic control scheme for a permanent magnet three phase synchronous motor. A PWM inverter (DC /AC converter) with a closed loop control component is utilized to implement the speed control of the three phase motor. The two blocks with "0" in them are constant inputs. Identify the number of closed loops and determine the closed loop transfer functions in terms of *R(S), Y(S) and T(S).* Establish all constants used in place of Block Diagrams with appropriate mathematical equations. Express any conversion process with appropriate mathematical state equations.

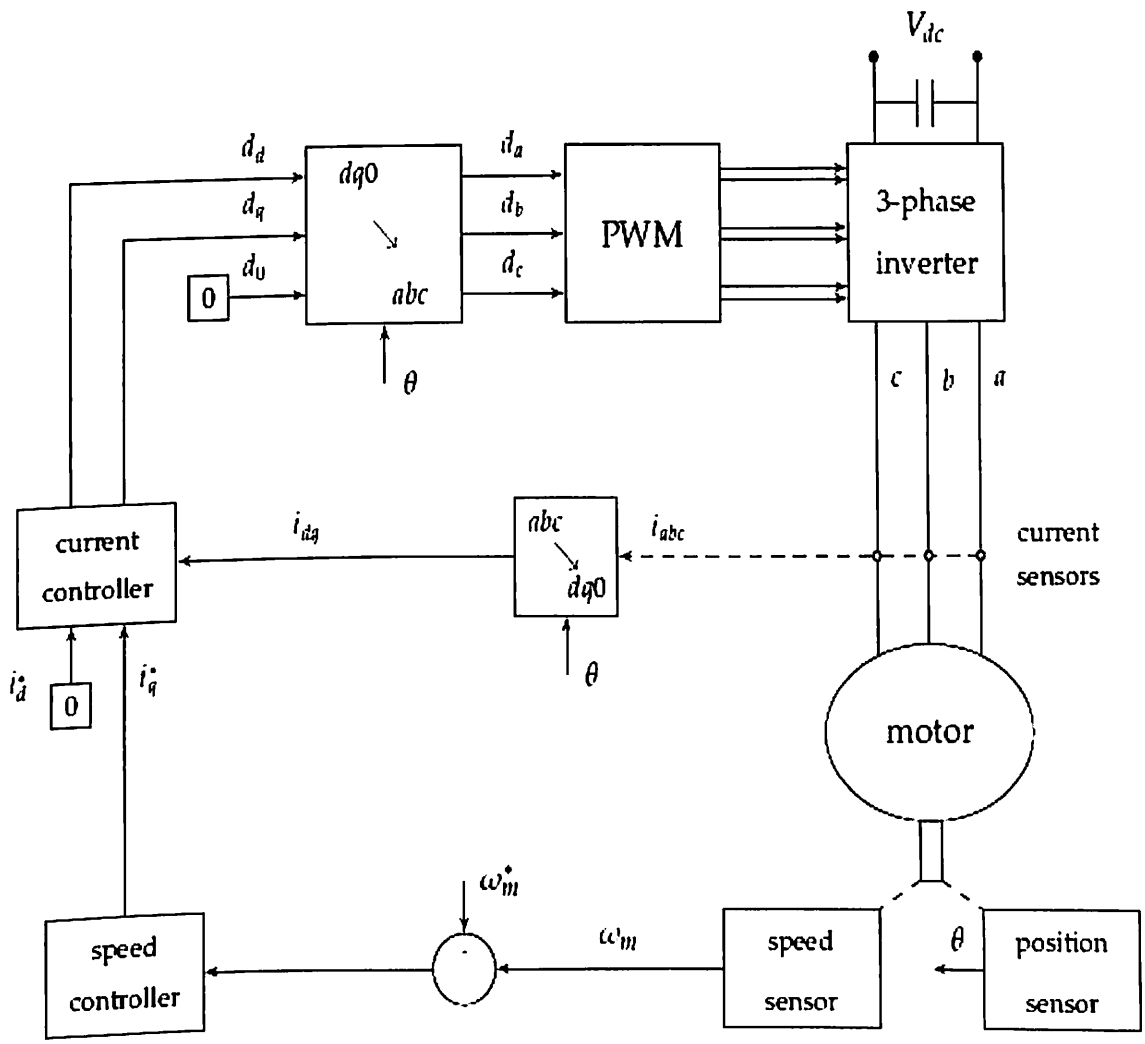


Fig.2. For Question2(B).

QUESTION3: [20 Marks]

A MOSFET is used as a switch operating at f_s = 50 kHz. If R_{DS} = 28 mΩ, the drain source leakage current (I_{DSS}) is 250μA, the threshold voltage (V_T) is 5 V, voltage required to drive the MOSFET into linear region (V_{GS}) is 35 V, the over drive voltage (V_1) is 400 V, I_D = 350 A, the effective input resistance of the gate and drive circuit is R_1 = 10 Ω and the input capacitance to the power MOSFET is 0.01 μF. The duty cycle is k = 75%. Assume that the turn off time (t_{toff}) is half the turn on delay time (t_{don})

(a) Calculate;

- ***i.*** Conduction time t_n;
- ***ii.*** Off time t_o.
- ***iii.*** Calculate the value of saturation voltage V_{DSS}.

(b) Determine the power losses of the Power MOSFET due to the drain current ($I_D = I_L$) . To enable you solve the problem start by sketching the switching waveform with complete switching details.

- ***i.*** during turn-on ($t_{on} = t_{d(on)} + t_r$;)
- ***ii.*** during conduction period (t_n,)
- ***iii.*** during off time ($t_{off} = t_{d(off)} + t_f$,)
- ***iv.*** during off time (t_o,) and
- ***v.*** the total average power loss (P_T).

QUESTION No4 [20 Marks]

The analysis in this particular question will be based on the three Phase Bridge PWM Inverter given in the **Fig.3** below.

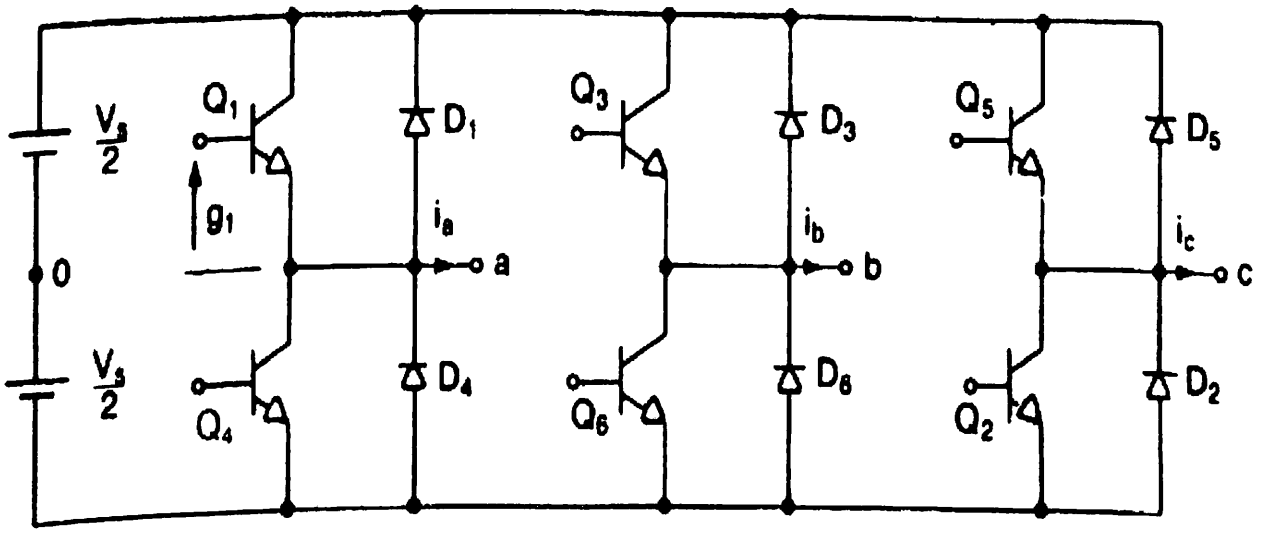


Fig.3. For Question3.

The full bridge converter in **Fig.3** has a wye-connected resistive load of R = 5 Ω. This time the inverter frequency is f_o = 60 Hz and the dc input voltage, Vs = 220 V. Determine;

(a) the expression of the instantaneous line-to-line voltage $v_{ab(t)}$ in Fourier series.
(b) the expression of the instantaneous line $i_{a(t)}$ in Fourier series.
(c) the load current (I_L)
(d) rms currents of the transistors (I_R)
(e) average currents of the transistors (I_A)
(f) peak currents of the transistors (I_P)
(g) Determine the total harmonic distortion (THD) of the load current.

QUESTION No5 [20 Marks]

Two of the three phase full wave converters used in Question 1 are combined "back to back" to implement three phase dural converter of figure4. Provided that the load resistance is 15 Ω circulating inductance is 50 mH, and the delay angles are α_1 = 60° and α_2 = 120°. Perform the following calculations in relation to analysis of converter of figure4.

(a) Calculate the ***peak circulating current*** of converter,
(b) ***Peak current*** of converter1
(c) ***Peak current*** of converter2

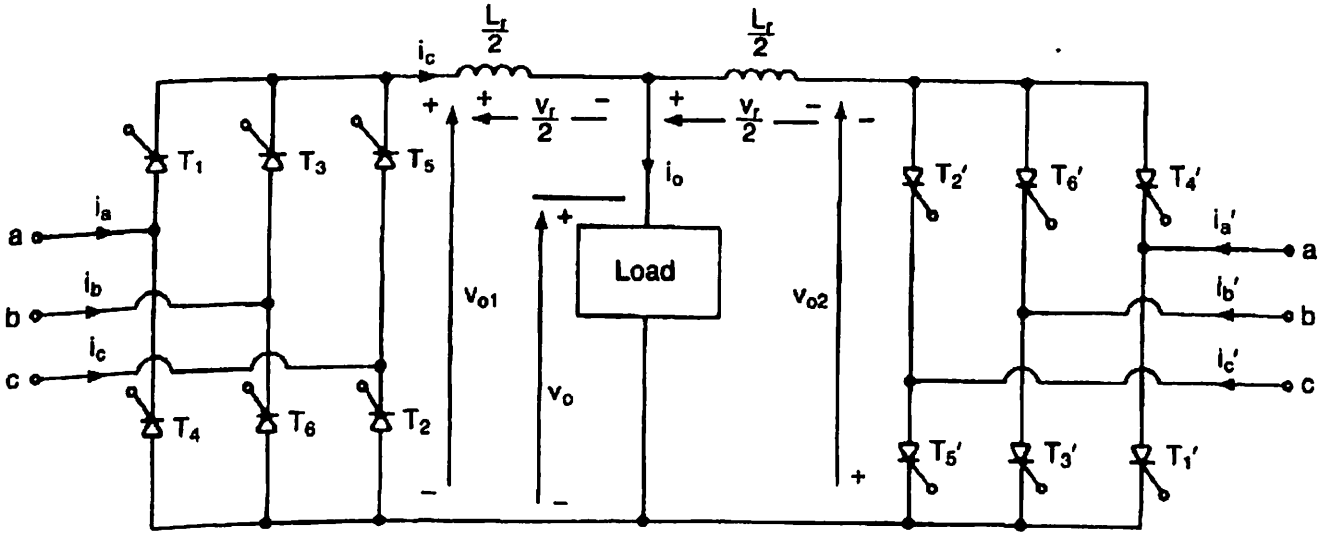


Fig. 4: Topology of three-phase Dual Converter for Question4.

LAST PAGE OF EXAM QUESTIONS

FOURIER FUNCTIONS FOR CONTROLLERS OF INTEREST

3-PHASE FULLWAVE PWM INVERTER

- Line –to-line voltage in Fourier series

$$v_{ab} = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_s}{n\pi} \cos\frac{n\pi}{6} \sin n\left(\omega t + \frac{\pi}{6}\right)$$

- Line instantaneous current in Fourier series

$$i_a = \sum_{n=1,3,5,\ldots}^{\infty} \left[\frac{4V_s}{\sqrt{3}\, n\pi \sqrt{R^2 + (n\omega L)^2}} \cos\frac{n\pi}{6}\right] \sin(n\omega t - \theta_n)$$

where $\theta_n = \tan^{-1}(n\omega L/R)$.

- Total Harmonic Distortion

$$\text{THD} = \frac{(I_{m}^2 - I_{m1}^2)^{1/2}}{I_{m1}}$$