Resit Examination

Electronic Instrumentation (ET8017)

Tuesday, January 31 2012, 14:00-17:00

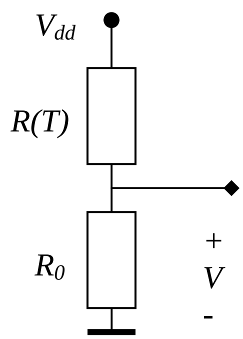
There are 6 questions in the exam
all of which should be attempted.

Please support your answers with the appropriate
explanations, drawings and circuit diagrams

Only the book and the slides
can be taken into the exam

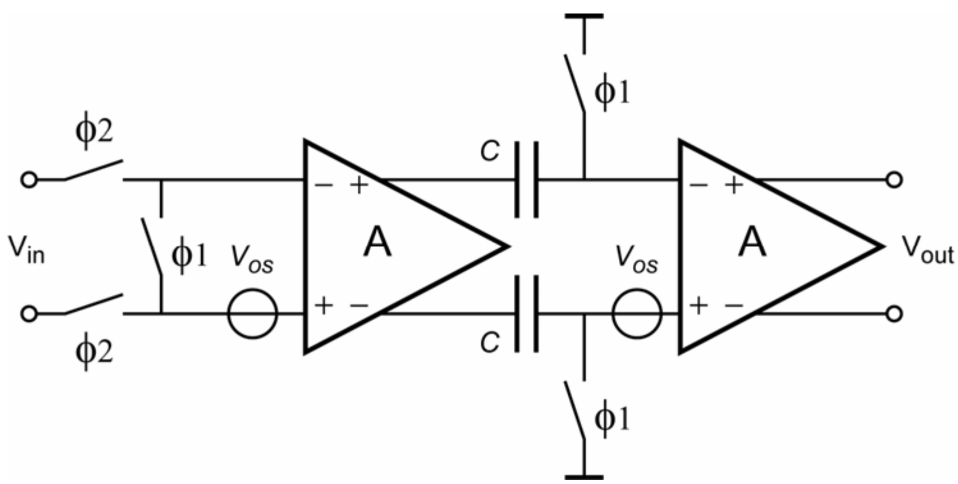
— Good luck! —

1. An on-chip resistor is to be used as a temperature sensor. Its resistance is given by: $R = R_0(1+\alpha(T\text{-}T_0))$, where T = temperature in °C, R_0 = resistance at T_0=25°C and α = 0.3%/°C. As shown below, the resistor is biased via a stable reference resistor R_0 from a noise-free supply voltage V_{dd} and the output voltage V of the resulting potential divider is measured.



If the total power dissipated in the two resistors is 15μW, calculate the detection limit in °C due to thermal noise, given that the measurement noise BW is 5Hz and the nominal temperature is 25°C. Note: $4kT \sim 1.62 \times 10^{-20}$W.

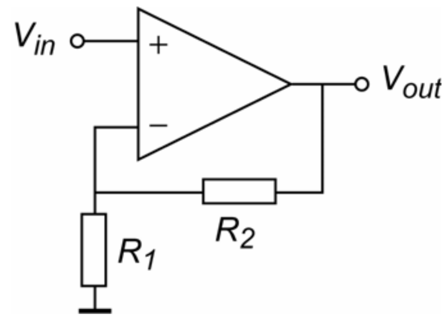
2. Consider the auto-zeroed amplifier shown below:



A) With the help of figures showing the switch configuration in the two phases of operation, explain how this circuit reduces the effect of the amplifiers' offset. .

B) Calculate the overall circuit's input-referred offset, given that the amplifiers have an initial offset of 10mV and an open-loop gain of 40dB, C = 10pF and that turning off each switch results in 10fC of charge injection (which may be assumed to be divided equally between the switch terminals).

3. Consider the amplifier shown below, where $R_2 = 2R_1$:



A) Derive an expression for the amplifier's closed loop gain as a function of the opamp's open-loop gain *A* and the resistor values.

B) Now assume that the op-amp has a finite open loop gain of A with ±10% variation. In order to keep the closed loop gain variation below ±0.1%, what should be the **minimum** open loop gain A?

C) Now again assume that the op-amp is ideal but the resistors have some spread i.e. $R_2 \neq 2R_1$. For this reason we would like to use DEM to mitigate the effect of this spread on the closed loop gain. What is your proposal for applying this technique? Draw some figures showing how your proposed circuit would look in the different DEM phases? What is the minimum number of <u>ideal</u> switches (single-pole single-throw SPST) required?

D) If the feedback network is realized with three resistors with values of, R, R and R+r, respectively, calculate the residual gain error after the application of DEM. You may assume that the amplifier has infinite gain and that r/R <<1. How does this compare with the gain error without DEM?

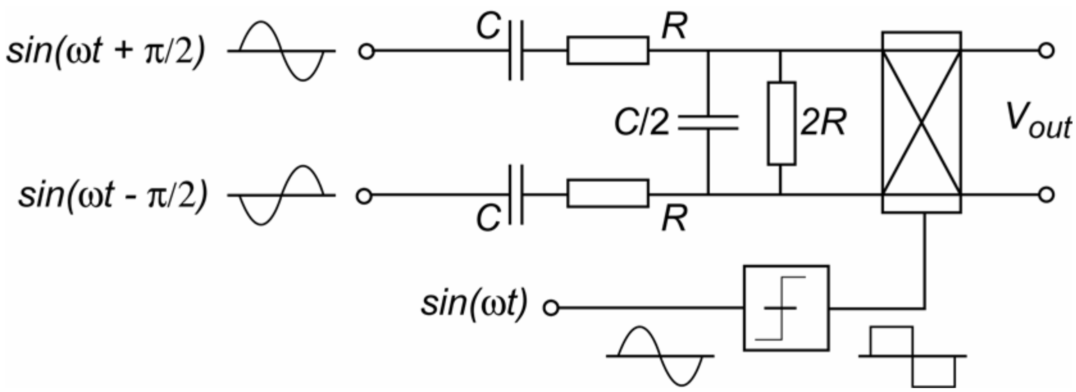
4. The output of an AC-driven Wheatstone bridge made up of four resistors with a nominal value of 10kΩ is demodulated by a lock-in amplifier that consists of a preamplifier followed by a chopper demodulator and a 3rd order low-pass filter. The preamplifier has an offset voltage of 10mV, an offset bias current of 1μA, a bandwidth of 10 kHz, a thermal noise level of 4nv/√Hz and a flicker noise corner frequency of 2 kHz.

Note: The thermal noise density associated with a 1kΩ resistor is 4nV/sqrt(Hz).

A) Calculate the input-referred noise density of the entire measurement system if the Wheatstone bridge is driven at 1kHz.

B) What is the maximum bandwidth of the lock-in amplifier's low-pass filter that ensures that the output ripple due to preamplifier offset is less than 1μVrms.

5. Consider the RC network shown below, which is driven by two sinusoids in anti-phase: $A\sin(\omega t+\pi/2)$ and $A\sin(\omega t - \pi/2)$, where $\omega = 1/RC$.



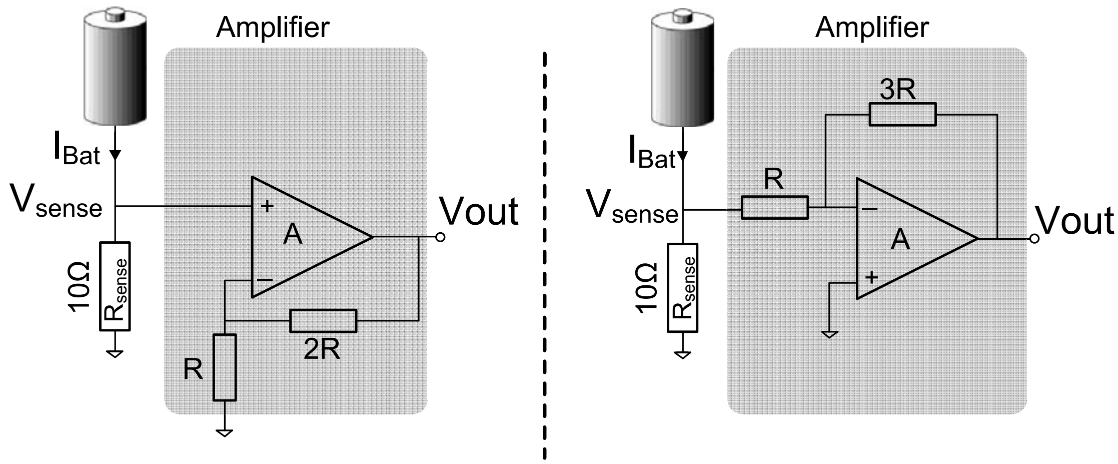
The output of the filter is then demodulated by a chopper demodulator, which is driven by a square-wave derived via a comparator from a sinewave: $A\sin(\omega t)$.

A) Derive an expression for the phase shift in the RC network. Hint: Analyze the HALF circuit.

B) What is the average DC value of the chopper demodulator's output voltage V_{out}.

C) Using the result of (A), explain <u>quantitatively</u> what happens to this DC value if the resistor values should change, e.g. due to temperature changes.

6. In a battery powered system, the current of the battery, I_{Bat}, needs to be measured. As shown in the figures below, this is done by amplifiying the voltage drop V_{sense}, across a sense resistor R_{sense} (=10Ω). Note: the same opamp is used in both circuits.



A) non-inverting B) inverting

A) Assuming an ideal opamp, and that the resistance R is poorly defined, which circuit can achieve the highest current-sensing accuracy? Motivate your choice.

B) Now assume that the value R is well defined and is much larger than R_{sense}, but that the opamp's CMRR is finite. What difference does this make to the current-sensing accuracies of the two topologies.

C) Suppose that the Op-Amp has an input offset voltage of 10mV. How does this impact the input-referred offset of the two topologies? What happens as the amplifier's closed-loop voltage gain is increased? Support your answers with calculations.