IEEE Region 5 2008 Conference
Student Circuit Design Competition
April 19, 2008

General Problem Description — Lights Off Control

I.E.E.E., thinking “green”, desires to be energy conscious. To focus on conservation of electrical energy use in a residential environment, the I.E.E.E. proposes to have an electronic device designed and prototyped that will automate turning off lights upon the absence of humans in the room. To ascertain this absence of humans, audible sound (A), net entry into/out of the room (O), human body heat (H), and movement (M) are to be detected. Power to the light is to be continued whenever sound and any one of the other three things being sensed are detected. In addition, power to the light must continue if sound is absent but all three of the other things being sensed are detected. If the sensors indicate that the room is unoccupied for 60 seconds, then the light is turned off. The automatic turn-off circuit may automatically turn the light back on if the room becomes occupied again, but is not required to do so.

Your design team’s task is to design the audio (A) detection part of this system and a control that processes it and the other three (O, H, M) sensor inputs to automatically turn off the light when the room is unoccupied.

General Specifications

Detection of audio must result in TTL compatible voltages. The other three detection systems have already been designed and verified to operate and meet specifications. A power supply to produce +5v and +/-12v with enough current capability for the complete circuit has already been designed.

Available Test Devices and Components

- Power supplies with voltages of +5 volts and +/-12 volts are available.
- Multi-meters, oscilloscopes, and signal generators.
- A component package of standard 5% tolerance resistances.
- A selection of ICs, capacitors, and miscellaneous parts

Resources

- Data Sheets are provided.
- Application Notes are provided.
- Use of computers or the Internet is not allowed.
- Team is allowed two (2) electronic calculators (in non-programmable mode)
- Each Team is allowed unlimited clarification questions.
- Each Team is allowed one (1) technical question without penalty.

Performance Requirements for Digital/Output Circuit Design

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1. Input Signals
   a. The logic variables are: A=audio, O=optical, H=heat, M=motion.
   b. Assume all inputs are at the ideal TTL voltages of 0v and +4v.
   c. Only "True" logic variables are available as inputs (no complimented variables).
   d. Assume that these signals come from system outputs capable of driving (sinking/sourcing) typical LS-TTL input currents of up to ten (10) LS-TTL gate inputs.

2. Power Supply Voltages — Assume that an appropriate TTL voltage source has been designed to provide +5v.

3. Digital Section Constraints
   a. The input logic section must use only 2-input NAND and 2-input NOR gates to implement any combinatorial design.
   b. ROOM UNOCCUPIED CONDITION DURATION — 60 seconds +/-5 seconds.
   c. Any "storage" of information circuitry must be designed from D flip-flops.

4. Output Section Constraints — An LED is to be turned ON to indicate that a signal is present to turn OFF the light.

Performance Requirements for Analog Circuit Design

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1. Audio signal source characteristics
   a. "Speech," audio simulated by either a 500 Hz or 3 kHz tone individually
   b. Microphone output impedance = 1 kΩ
   c. Audio output of microphone superimposed on nominal 2.0-2.1 VDC bias

2. Noise source — 60 Hz at 60 mVpk, max.

3. Amplifier requirements
   a. Audio pass band — Attenuation ≤ 1 dB from maximum response for 300 Hz ≤ f ≤ 3.0 kHz.
   b. Noise rejection — 60 Hz must be attenuated by at least 18 dB with respect to 500 Hz. The objective is to reject noise at 60 Hz adequately to prevent falsely indicating audio presence or significantly altering the threshold for 'audio present' from the level without 60 Hz noise.
   c. Input impedance — loading of microphone source < 20 %

4. Audio threshold
   a. Threshold for Audio Not Present: < 50 mVpk, audio threshold for change from 'audio present' to 'audio not present' condition in room without 60 Hz noise.
   b. Threshold for Audio Present: ≥ 70 mVpk audio threshold for change from 'audio not present' to 'audio present' condition in room without 60 Hz noise.
   c. Threshold for Audio Not Present with 60 Hz noise: Not more than 20% below threshold in paragraph 'a' above.

5. Output to digital circuitry – Output must be LS-TTL compatible.

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Other instructions

1. Logic inputs (O, H, M) must be simulated by DIP switches and pull-up or pull-down resistors, not loose wires.
2. The students must construct the Simulation Circuit for Input Microphone Sensor. Schematic is provided.
3. Audio input signals from signal generators to Simulation Circuit for Input Microphone Sensor are higher than actual specified audio input to the analog circuit in order to make measurement easier and more accurate.
4. Laboratory notebooks must include:
   a. Title page
      i. Team Number
      ii. Title of the Project
      iii. Date
      iv. Do not include the team members' names or their school name
   b. Analysis of specifications and design computations
   c. Block diagram of circuit
   d. Circuit schematics, logic diagrams, and timing diagrams as needed
   e. Include IC pin numbers on schematics
   f. Component locator diagram with designators such as U1, R1, C1.
   g. Test results used to verify performance to specifications
   h. Discussion and conclusions
5. Signal Generators
   a. For 500 Hz sinusoidal signal, students may use B&K 3011B, Global Specialties 2002, or Leader LAG-120B.
   b. For 60 Hz sinusoidal 'noise,' use either a Leader LAG-120B or B&K 3011B signal generator. Do not use the Global Specialities 2002.

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HINTS & SUGGESTIONS

1. If op amps show cross-over distortion, connect a nominal 1.8-2.2kOhm resistor from output to low power supply.
2. Rejection of 60 Hz noise can be implemented by DC blocking capacitors; however, the students are encouraged to examine whether the passband loss and 60 Hz rejection will be met.
3. If the students want to use a more sophisticated to approach rejection of 60 Hz noise, a guide to design of active filters is provided.

SIMULATION CIRCUIT FOR INPUT MICROPHONE SENSOR
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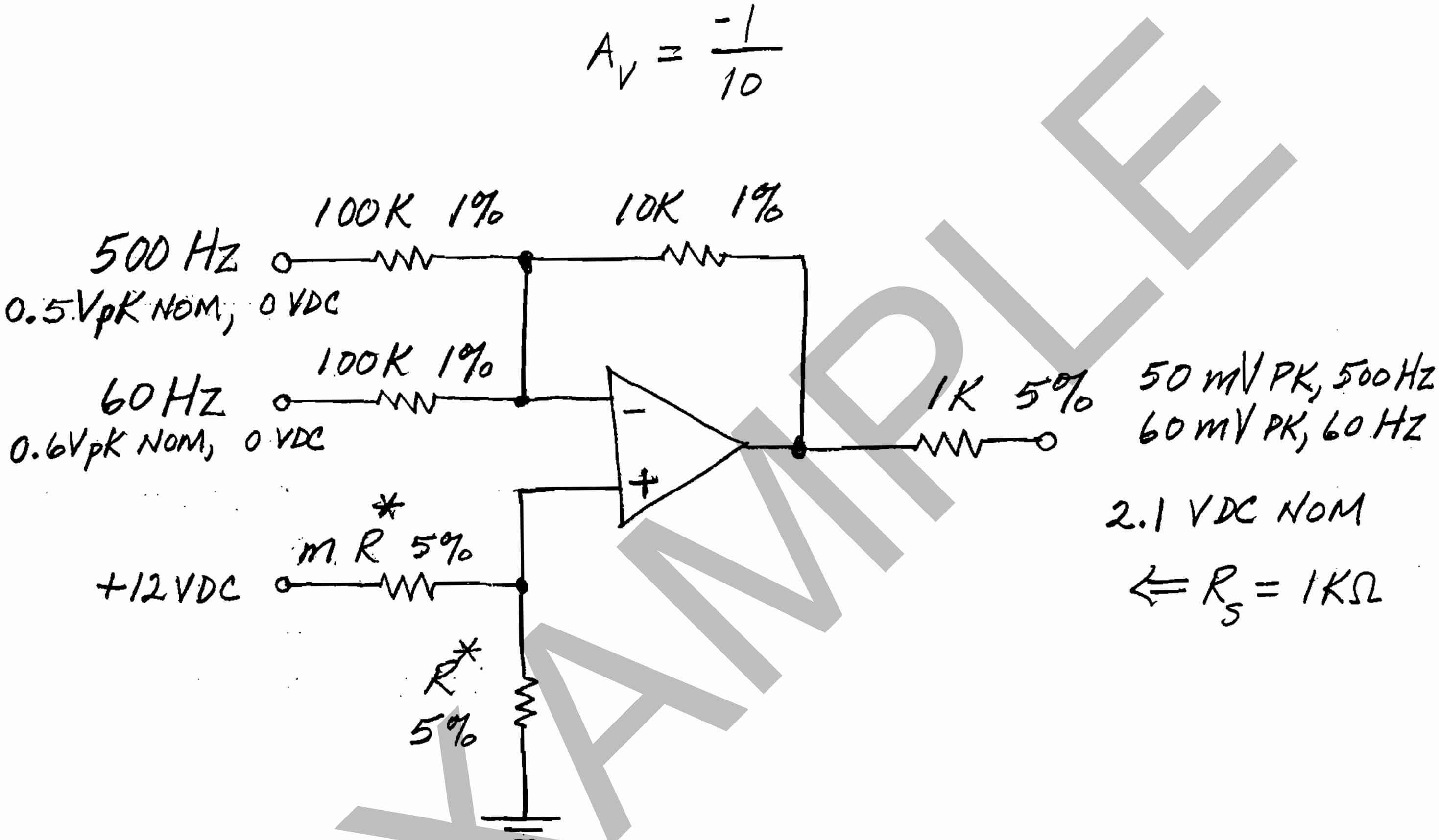

* CHOOSE R, e.g. R = 10KΩ

m = 4.7, NOM ± 10%

Components in bag	Quantity
LM324AN	2
LM339AN	1
74LS74	1
74LS00	3
74LS02	2
LM741	1
74LS123	1
74LS86	1
74HCT4538	1
MC14541BCP	2
74HCT4040	1
LM358AN	2
555	1
74LS04	1
LED	2
DIP Switch	1
1 kΩ potentiometer	1
10 kΩ potentiometer	1
100 kΩ potentiometer	1
1N914	3
2N3904	1

Separate

Potentiometer adjustment tool

Resistor pack

Data Sheets

2% resistors

Lab notebook

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Highlights and Page Key for Active Filter Design Techniques

1. Normalized frequency
   a. Filter responses for design purposes are normalized to the cutoff frequency or corner frequency, f_c.
   b. The cutoff frequency for the accompanying chapter is the frequency for which the amplitude response is -3 dB.
   c. The normalized frequency is represented by Ω, where $\Omega = f/f_c$. **See note on page 16-3.**

2. All filters are based upon transformation of a low pass filter prototype transfer function.

3. A high pass filter is made by transforming the low pass filter amplitude response with the substitution $\Omega_{HP} = 1/\Omega_{LP}$. See **page 16-21** for the transformation.

4. Filter transfer function
   a. See **page 16-5**. The key point is that transfer functions that approach an ideal vertical boundary between passband and stopband ("brick wall response") are a product of one or more second order transfer functions and possibly one first order transfer function.
   b. **Page 16-6** lists two transfer function approximations to the brick wall that are preferred over Bessel for this design competition.
      i. Butterworth
         (1) Has flat passband
         (2) But transition past cut-off frequency is not as steep as Tschebyscheff
      ii. Tschebyscheff
         (1) Has steepest transition in the stopband beyond the cutoff frequency for about the first half decade or decade
         (2) But the steep response in the stopband is gained at the expense of ripple in the passband.
         (3) Passband ripple is a chosen parameter. Higher passband ripple yields steeper slope in the stopband region just above the cutoff frequency.
         (4) For a given order, Tschebyscheff will give more rejection margin than Butterworth for equal cutoff frequency.
      iii. At frequencies a decade or two beyond cutoff, all types of filter approximations asymptotically approach the same slope of rejection, i.e. (n poles) x (20 dB/decade).
   c. Order of transfer function
      i. The higher the order of a filter transfer function, the steeper the transition between passband and stopband. See **pages 16-6 & 16-7**.
      ii. To implement higher order transfer functions, one or more second order active filter stages are cascaded for even order transfer functions and are cascaded with one first order active filter stage for odd order transfer functions. This implements the product of second order and first order transfer functions mentioned above in 3.a. See **paragraph 16.2.5 on page 16-10**.

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ELECTRONIC FILTER DESIGN HANDBOOK

Arthur B. Williams

Manager of Research and Development
Coherent Communications Systems Corp.

McGraw-Hill Book Company

New York St. Louis San Francisco Auckland
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Panama São Paulo Hamburg
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