Home-Rolled Flame Detectors

During a period of indecisiveness over whether to buy a commercially made flame sensor, such as Acroname's IR flame sensor or Hammatsu's Ultraviolet flame sensor, I experimented with some IR phototransistors to see if it would be feasible to design our own. The first tried was a Radio Shack part. Unfortunately the ambient overhead flourescent lighting had more effect than a candle flame on this device. It was evident that both optical filtering and focusing would be required to make this feasible. I ordered every photo device in the Electronic Goldmine catalog along with some mirrored flashlight type reflectors and some Kodak 87C IR filter material. I also salvaged the IR lens material out of an old passive IR motion detector.

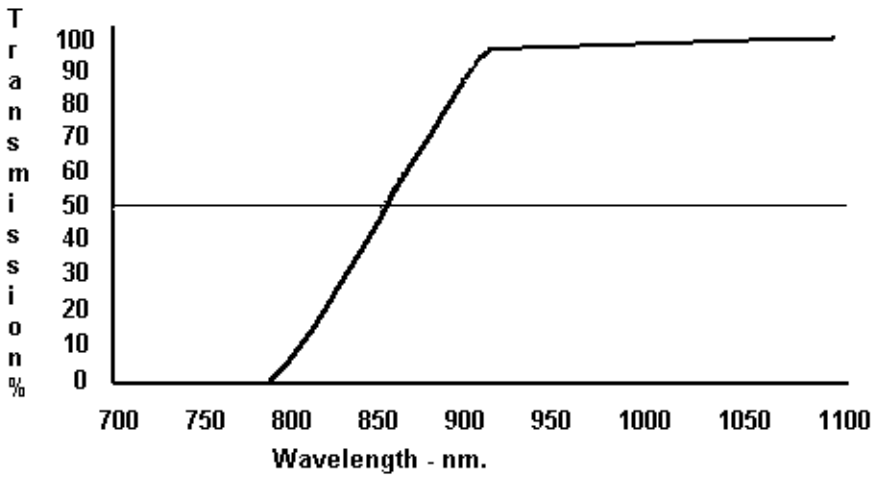
The photo devices from the Electronic Goldmine arrived mid-March, about 1 month from the Trinity Fire-Fighting Robot Contest date. With little time to spare, they were experimentally tested in the Ward College lab, and within a few days, it was determined one set of devices performed better than all the rest in our IR-noisy environment (energy-saving electronic ballast flourescent lighting). These were unmarked Honeywell IR phototransistors in a tiny black rectangular package. The Electronic Goldmine part# for these is G9412. Even with a reasonably high value collector resistor of 27K, the overhead lighting did not even begin to turn on the device. Yet a small flame at a foot or more distance easily saturated the collector. The only problem was the omni-directional pickup pattern: it would pick up a flame in almost any direction, making it impossible to determine what direction it was coming from. Some experimentation with flashlight type silvered reflectors was tried. This idea was discarded when it became apparent the increased optical gain was too much, and had higher gain at visible 500-750 nM. light wavelengths than at the desired 900-1000 nM. Infra-Red region. While scouring the junkboxes, a better solution for a narrow aperture housing was seen: Black plastic Waldom WN-10 Wire Connectors for twist splicing AWG-10 house wiring. After removing the springs from several of these, 2 small holes were drilled to allow the phototransistor leads to exit, and the devices were glued about halfway into these "housings". Three were mounted on the underside of the robot's upper deck at approximately 7.5" height above ground using tie-wraps and adhesive backed clamps, facing to the front, right, and left sides at a slight downtilt angle. Rather than run the phototransistor outputs directly into the Basic Stamp II, it was decided to add comparator circuitry with a small amount of hysteresis. A threshold reference of 1/2 Vcc would be employed, which should reduce false triggering.

The home-rolled flame detectors worked very well. The values of R4, R5, and R9 were adjusted so that the the left and right sensors could spot a flame 2 feet away but the front sensor would have less gain (for zeroing in on the candle) and would only toggle when within 12 inches.

The sodium lighting swamped our flame sensors. Luckily we had some Kodak 87C IR lowpass filter material with us. This material passes 900-1000 nM and longer wavelength IR light but rejects all visible light under 800 nM.

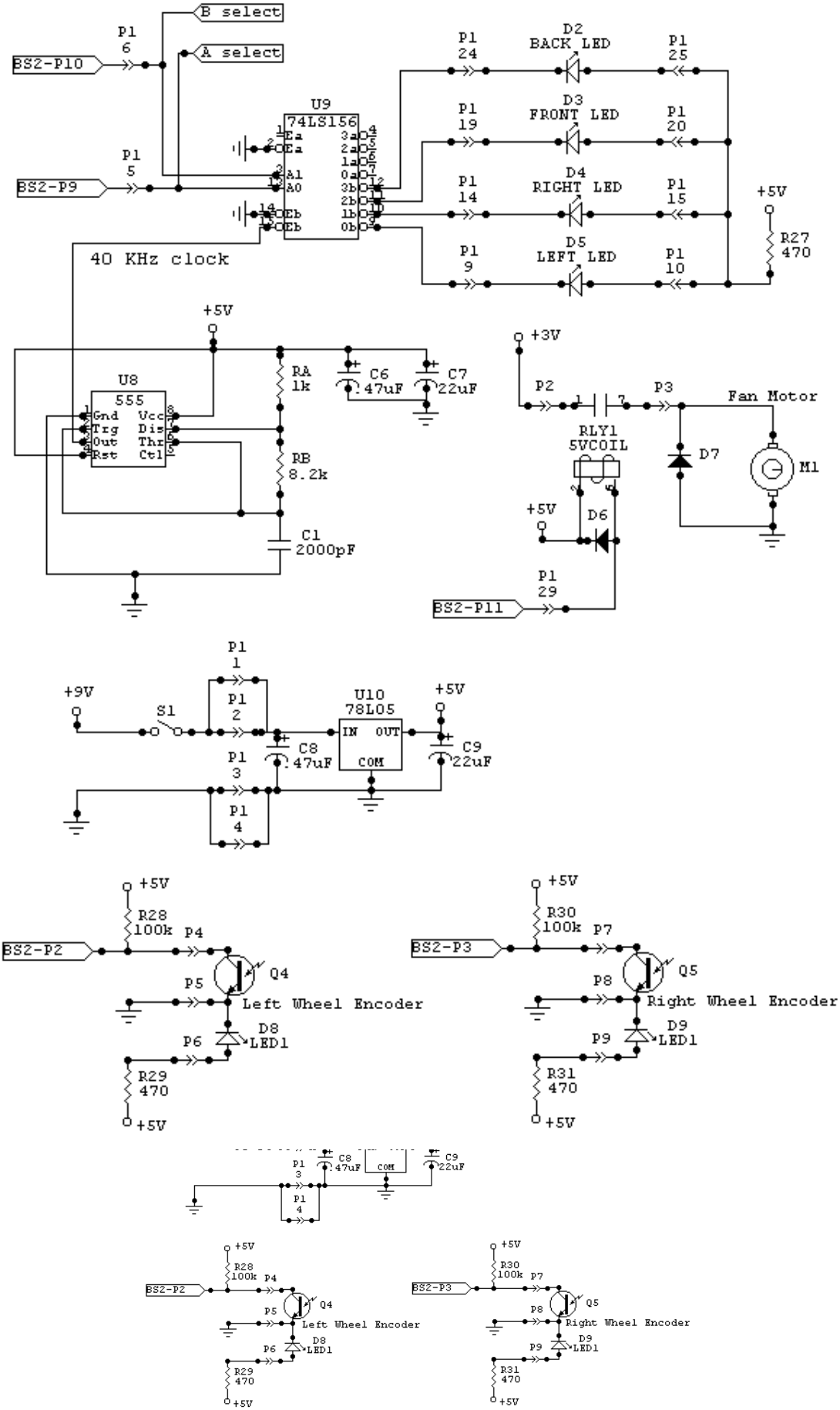
We glued small pieces of it over all our sensors, the flame sensors and the object proximity sensors. After hours of fine tuning, we finally got "Willitrun" to complete a qualifying run - finding and extinguishing a candle - we were in!

KODAK WRATTEN INFRARED FILTER No. 87C:



reproduction from Edmund Scientific Industrial Optics catalog, p.61

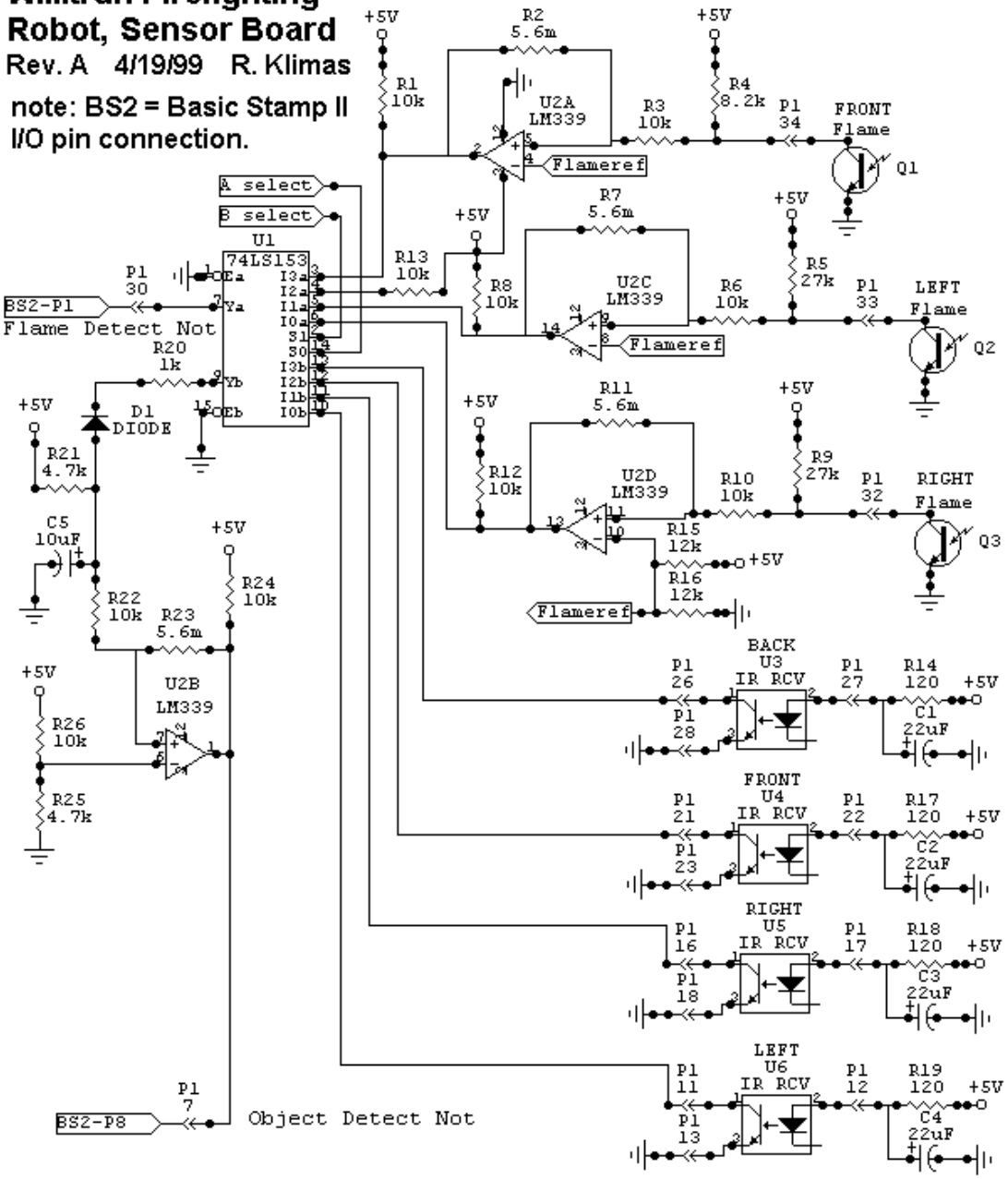
The home-rolled flame detectors worked so well, we had a couple of people in the business ask about our design. The Kodak filter film really helped cut the ambient light interference. The modified AWG#10 splicing connector housings provided about a 30 degree aperture, wide enough to sense a flame by passing by it in motion, and narrow enough to zoom in on it off the front sensor. The home-rolled flame detectors worked so well, I'd use them again. Perhaps some added circuitry for programmable stepping.


B select
A select
P1
6
BS2-P10
P1
5
BS2-P9
U9
74LS156
40 KHz clock
P1
24
D2
BACK LED
P1
25
P1
19
D3
FRONT LED
P1
20
P1
14
D4
RIGHT LED
P1
15
P1
9
D5
LEFT LED
P1
10
+5V
R27
470
+5V
U8
555
Gnd
Trg
Out
Rst
Vcc
Dis
Thr
Ctl
RA
1k
RB
8.2k
C1
2000pF
C6
47uF
C7
22uF
+3V
P2
P3
Fan Motor
RLY1
5VCOIL
D7
M1
D6
+5V
P1
29
BS2-P11
P1
1
P1
2
P1
3
P1
4
+9V
S1
U10
78L05
IN
OUT
COM
C8
47uF
C9
22uF
+5V
R28
100k
P4
BS2-P2
Q4
P5
Left Wheel Encoder
D8
LED1
P6
R29
470
+5V
+5V
R30
100k
P7
BS2-P3
Q5
P8
Right Wheel Encoder
D9
LED1
P9
R31
470
+5V

Willitrun Firefighting Robot, Sensor Board

Rev. A 4/19/99 R. Klimas

note: BS2 = Basic Stamp II I/O pin connection.



Bill of Materials for Fire-Fighting Robot Sensor Board:

Item	Qty.	Label-Value	Attributes	Designations
1	6	22uF	Tantalum cap.	C1,C2,C3,C4,C7,C9
2	1	10uF	Tantalum cap.	C5
3	2	.47uF	Tantalum cap.	C6,C8
4	1	.002uF	Silver mica cap.	CT
5	1	DIODE	1N914	D1
6	2	DIODE	1N4004	D6,D7
7	1	BACK IR LED	LTE-2872, E/G G8312	D2
8	1	FRONT IR LED	LTE-2872, E/G G8312	D3
9	1	RIGHT IR LED	LTE-2872, E/G G8312	D4
10	1	LEFT IR LED	LTE-2872, E/G G8312	D5
11	1	Fan Motor	R/S 273-223	M1
12	1	Berg header	34 pin	P1
13	8	w/w header pin	single pin connector	P2,P3,P4,P5,P6,P7,P8,P9
14	1	Front Flame	detector, E/G G9412	Q1
15	1	Left Flame	detector, E/G G9412	Q2
16	1	Right Flame	detector, E/G G9412	Q3
17	1	Left Wheel	encoder, E/G G8669	Q4/D8
18	1	Right Wheel	encoder, E/G G8669	Q5/D9
19	10	10k	Resistor 1/4W	R1,R3,R6,R8,R10,R12,R13, R22,R24,R26,
20	4	5.6m	Resistor 1/4W	R2,R7,R11,R23
21	3	12k	Resistor 1/4W	R4,R15,R16
22	2	27k	Resistor 1/4W	R5,R9
23	4	120	Resistor 1/4W	R14,R17,R18,R19
24	2	1k	Resistor 1/4W	R20,RA
25	2	4.7k	Resistor 1/4W	R21,R25
26	1	180	Resistor 1/4W	R27
27	2	100k	Resistor 1/4W	R28,R30
28	2	470	Resistor 1/4W	R29,R31
29	1	8.2k	Resistor 1/4W	RB
30	1	5VCOIL	Form 1A relay	RLY1
31	1	Switch, on/off	SPST	S1
32	1	74LS153	DIP16 dual 4-1 Mux.	U1
33	1	LM339	DIP14 quad comparator	U2
34	1	Back IR RCV	module, R/S 276-137B	U3
35	1	Front IR RCV	module, R/S 276-137B	U4
36	1	Right IR RCV	module, R/S 276-137B	U5
37	1	Left IR RCV	module, R/S 276-137B	U6
38	1	555	DIP8 timer IC	U8
39	1	74LS156	DIP16 dual 2-4 Decoder	U9
40	1	7805	TO-220 5V regulator	U10
41	1	none	Kodak #87C IR filter none	
42	1	none	PC board, R/S 276-158B	none
43	8	none	16 pin w/w sockets	none
44	3	none	Waldom WN-10 wire conn.	none

notes:
1: E/G = Electronic Goldmine catalog item
2: R/S = Radio Shack catalog item
3: The Waldom WN-10 wire connectors were converted to Flame detector housings by removing the wire twist-splice spring, drilling two 0.040" holes for the detectors, and covering the aperture with Kodak #87C IR optical low-pass filter material. The same material was applied to the 40 Khz IR Rcvrs.