A THREE CHANNEL INTEGRATING PHOTOMETER

Eugene J. Brach
Engineering Research Service
Research Branch, Canadian Agriculture
Ottawa, Ontario

G. F. St. Amour
Engineering Research Service
Research Branch, Canadian Agriculture
Ottawa, Ontario

W. J. Mason
Engineering Research Service
Research Branch, Canadian Agriculture
Ottawa, Ontario

INTRODUCTION

For experimental work in apple breeding it is important to know the relative amounts of certain band-width of radiant energies reaching the fruit. Instantaneous measurements which are recorded with different light meters are laborious and unless a large number of readings are made throughout the growth season the records have a limited value. In the study of color formation in apples it has been found by different authors (1, 2, 3, 4) that the blue (450 nm), green (550 nm) and red (6600 nm) wavelengths are of prime importance. Other wavelengths have little effect in color development. Therefore the amount of energy in an integrated form received separately at these three wavelengths during a growth season can simplify evaluation of their effect.

An instrument is described where three wavelengths are integrated electronically and the information stored by separate electromechanical counters.

DESCRIPTION OF APPARATUS

The photohead (Fig. 1) houses 3 selenium photodetectors (International Rectifier A5M) with three cinemoid filters (Strand Cinemoid filters No. 14, No. 20, No. 39). The bandwidth of such filters are ±25nm. The filters are protected by clean acrylic covers. The photohead is connected to the integrating spectrophotometer (Fig. 2) which consists of two operational amplifiers (TOA2741), an integrator (TOA-2741), pulse-shaper Q_5, clock pulse generator Q_4, $IC_1 - IC_3$, shift 3 multiplexer and decoder $IC_4 - IC_6$, relay driver and relays $Q_6 - Q_{11}$ with memories $Mem_1 - Mem_3$.

The photodetector outputs are connected sequentially to the input of the first operational amplifier where they are amplified by 20. A second amplifier with a gain of 5 increases the total amplification to 100. The output of the photodetector is 10 mV at a light intensity of 1 gr Cal. cm^{-2}, min^{-1}, this is amplified to 1V. The amplified signal charges the integrating capacitor, through an input resistor. When the voltage across the capacitor reaches 10V, the M4L3052 PNPN four layer diode turns "ON", discharging the capacitor to zero. The integrating frequency of the integrator at 1 gr.Cal.$cm^{-2}min^{-1}$ is 100, and it depends only on the applied voltage since:

$$f = E_{in} \frac{1}{R\ C\ \Delta E_0} \quad \text{where}$$

E_{in} = applied voltage, R = 100 K input resistance C = 0.1 uF feedback capacitor ΔE_0 = 10V output voltage swing, R, C and ΔE_0 are constant. Thus "f" the frequency of integration varies linearly with photodetector output. The output of the integrator is a ramp which is squared by the zener diode and Q_5 transistor. The transistor will turn "ON" at the 5.5 volt point of the ramp and stay ON till the four layer diode discharges the capacitor.

One amplifier and integrator is used for the integration of the three wavelengths, therefore a multiplexer is required to switch the photodetectors (λ1, λ2, λ3) sequentially to the amplifier, and the proper memory (Mem_1, Mem_2, Mem_3) of the integrator. The clock pulse generator uses the line frequency as a standard. The 60 Hz 110V line voltage is stepped down to 3.5V. Q_4, a 2N4401 transistor squares the 60 Hz sine wave. IC_1, IC_2 are SN7490 TTL integrated circuit (IC) decade dividers, IC_3 is a SN7492 TTL IC divide by 12 counter.

Since each counter is ON for 20 sec, the clockpulse generator must provide a pulse at its output, after $20 \times 60 = 1200$ pulse from the line. For multiplexing by three, a SN7473 dual flip flop is used (Fig. 3A). The truth table of the flip flop is shown in Fig. 3B, and the logic diagram in Fig. 3C.

At the first pulse of the clock pulse generator Q_1 output of FF_1 will be LOW and $\bar{Q}_1$ HIGH. The Q_2 output of FF_2 will be LOW and $\bar{Q}_2$ HIGH. The negative going edge of the second pulse will change state of the outputs, Q_1 and Q_2 will be HIGH $\bar{Q}_1$ and $\bar{Q}_2$ will be LOW. The third pulse of the generator will put Q_1 and $\bar{Q}_2$ to LOW, Q_2 and $\bar{Q}_1$ to HIGH. The signal from the multiplexer is decoded by 3 two input NAND gates SN7400. The truth table for a two input NAND gate is shown in Fig. 4. To the number one gate, input Q_1 and Q_2 are connected. At the first pulse $\bar{Q}_1$ and $\bar{Q}_2$ have HIGHS, the output of the gate will be LOW. This

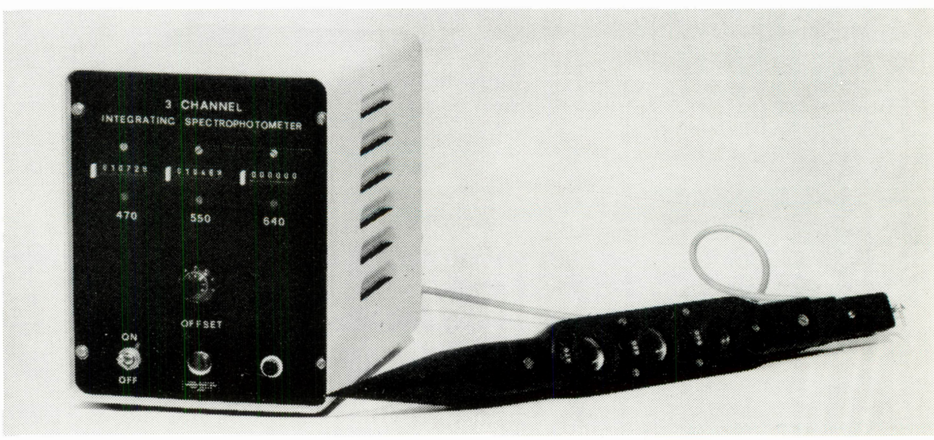

Figure 1. The three channel integrator and photohead

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is inverted by CD2310 inverter to a HIGH turning ON Q_6 a 2N4401 NPN transistor which energizes relay RY_1. When RY_1 is pulled in its two switches (1) will connect λ_1 the photodetector to the amplifier, and the output of Q_5 (2N4401) transistor to the input of Q_9 (MFE521) power transistor, when relay switch (1) is closed Q_9 turns ON and $Memory_1$ an electromechanical counter counts and stores the pulses from the integrator. $Memory_1$ will count till the second pulse from the clock pulse generator changed state of IC4. Q_1 and $\overline{Q_2}$ have HIGHS, so the output of the second gate will be LOW, this is inverted by IC6, which turns ON Q_7 energizing RY_2. One of the RY_2 switches (2) connects λ2 to the amplifier, while the second RY_2 switch (2) connects the output of Q_5 to the input of Q_{10} which drives $Memory_2$, till the third pulse puts HIGHS at $\overline{Q_1}$, Q_2 output of the multiplexer which are connected to the third gate inputs switching it to LOW, inverted by IC6 will turn ON Q_8, RY_3 will pull in placing through its switches λ3 to the amplifier, and Q_5 output to Q_{11} which drives $Memory_3$.

The instrument is powered by a regulated power supply, which supplies 5 volts for the IC circuits, and 12 volts to drive the relays and memories.

CALIBRATION

To calibrate the photohead, a Sylvania 300W flood lamp was used. The voltage and current for the lamp was kept constant. The emission curve of the lamp was taken with a Bausch & Lomb monochromator. It has been found when assuming the relative emission (RE) for the wavelength 640 nm 100, that at 550 nm the R.E. was 95.5 and at 470 nm 91.

The transmission factor of the filters were established by measuring the output of the photodetector with or without the filter. The light from the flood lamp entered into the monochromator, and was picked up by the photohead at 470, 550 and 640 nm. The transmission factors were found to be 31% for 470 nm, 64% for 550 nm and 59% for 640 nm. The bandwidth of each filter was established

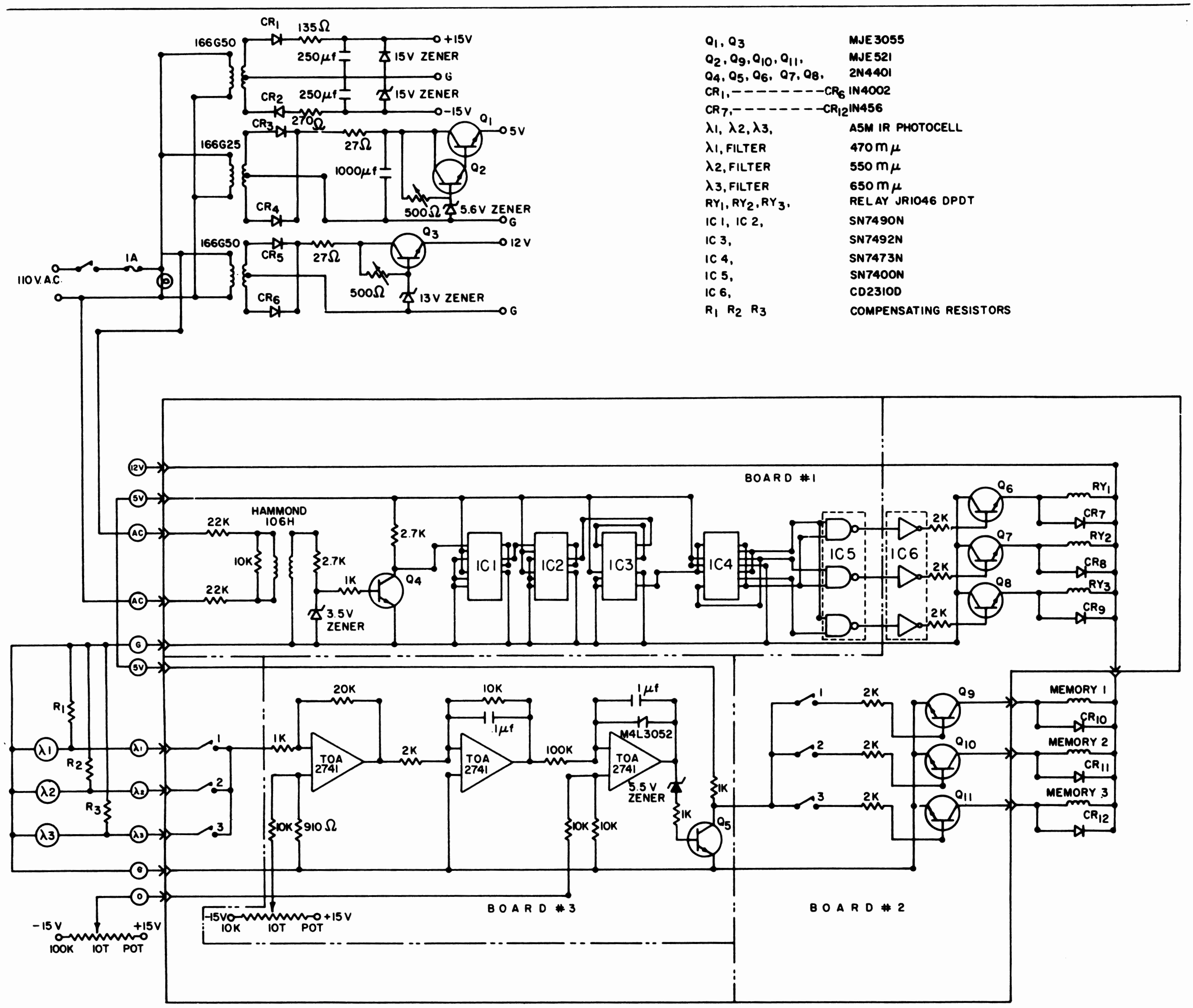


Figure 2. Circuit diagram

by the monochromator by choosing the 1% transmission as the cut-off point. The results showed that each filter was within ±25nm of the center wavelengths. To correct the disparity of the R.E. at different wavelengths of the lamp and for the differences of transmission factor of the filters, a 100 ohm resistor was placed in parallel with λ2 and a 95 ohm resistor in parallel with λ3.

The instrument is calibrated to read 100 digits per gr.cal.cm^{-2} min.$^{-1}$. The memories are each ON only 0.333 minute, therefore the final reading must be multiplied by 3. The deviation of the instrument due to ambient temperature changes was ±2% within the range 40-100°F.

CONCLUSION

A compact unit (Fig. 1) to integrate light energies at three different wavelengths is discussed. The three channel integrator uses an electronic multiplexer to switch the sensors of the three wavelengths sequentially into the circuit, so that only one amplifier is used. This simplifies calibration of the instrument and improves its accuracy. The instrument is a useful research tool in areas where color effect is an important factor.

A	B	C
H	H	L
H	L	H
L	H	H
L	L	H

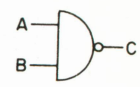
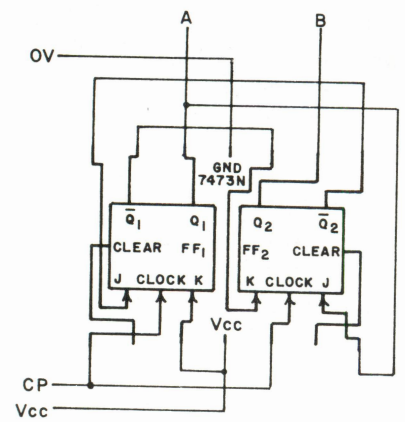


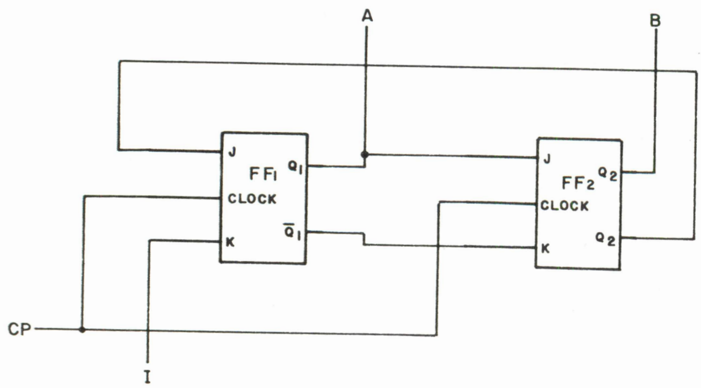
Figure 4. Truth table for a 2 input NAND gate



A

	SN7473 POSITION				GATE INPUTS			GATE OUTPUTS		
PULSE NO.	Q_1	$\bar{Q}_1$	Q_2	$\bar{Q}_2$	1	2	3	1	2	3
1	L	H	L	H	$\bar{Q}_1 \bar{Q}_2$			L	H	H
2	H	L	L	H		$Q_1 \bar{Q}_2$		H	L	H
3	L	H	H	L			$\bar{Q}_1 Q_2$	H	H	L

B



C

Figure 3. A. Multiplexer B. Truth Table C. Logic Diagram

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