A possible inexpensive method of measuring small capacitances

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This note proposes a possible solution to a problem in identifying an economical way of measuring small capacitance values described in the final report for the following U M project:

Open-Source Linear Book Scanner

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The following are relevant quotes from the report:

Error Detection: [Page 5]

To address the more difficult problem of detecting whether multiple pages had been turned, a capacitive sensor was proposed. It was hypothesized that the voltage between a pair of parallel plates would change significantly when a piece of paper entered the space between them. This change in voltage could be measured as a signal to detect not only the presence of a page in the page turning slit, but also the number of pages. Since this sensor would have to be fabricated entirely by hand, a feasibility check was needed before proceeding with the design process. To do this, two plates were constructed and connected to a standard LCR meter. Using the capacitance measurement setting, the two plates were held loosely against the two sides of various numbers of pages. After three trials for each of one, two, and three pages for two different books, I found that the capacitance measurement was on the order of hundreds of picofarads and was roughly proportional to the number of pages. These values varied depending on the page thickness. We concluded that with a high enough resolution measurement, we could detect the number of pages between two plates.

Challenges and Successes: [Page 8]

There were several components on the device that did not perform as well as expected, the worst of which was the capacitive sensor. In order to detect the number of pages and detect if too many pages were turned, a capacitive sensor was added to the scanner. Initial testing using the plates of an LRC sensor revealed that a capacitive sensor could be used to detect the number of pages passing between two plates. However, the plates that were used in the device were not as precisely manufactured as the ones used for initial testing, which decreased the accuracy of the sensor. More importantly, the LRC sensor was too large to fit inside the scanner, so the Arduino microcontroller was used to detect the capacitance between the two sensor plates. The Arduino is not able to determine capacitances as accurately as a LRC sensor, which resulted in a signal-to-noise ratio that was too low to determine the number of pages passing through the scanner. To fix this issue, a dedicated capacitive sensor should be added.

Future Work [Page 9]

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Another module that should be added to the device is a dedicated capacitive sensor. This sensor could consist simply of a resistor and a voltmeter connected across the two capacitive plates, but the voltmeter would need to be more accurate than the one built into the Arduino. The voltmeter will need to be calibrated to detect the expected voltage drop across the capacitive plates for one or two pages, giving the sensor enough of a signal-to-noise ratio to distinguish the pages, without outputting more precision than can be registered by the 8 bit analog pins of the Arduino. An alternative approach would be to use a high precision capacitive sensor, but this system would be very large and expensive, requiring a significant increase in both the budget and the volume of the scanner.

The proposed solution

The proposed solution would utilise one or more integrated circuit monostable multivibrators, standard electronic components that are readily available and inexpensive, probably used in conjunction with an Arduino or similar microcontroller module.

A 'monostable' i.c. when triggered produces an output voltage pulse of duration determined by an external resistor and capacitor, the timing elements. The capacitance to be measured would be one of the timing elements, or could be in parallel with a fixed capacitor, if required.

The advantages of the above arrangement are that a monostable circuit can be designed to produce a useful output pulse width even with very small capacitance values, and that the width of the output pulse can be measured with fine resolution by counting cycles of a reference timing oscillator, enabling even small changes in the duration of the monostable output pulse to be measured accurately. A microsecond is a long time in modern electronics.

That is the basic idea, and an electronic engineer supplied with the requirements for a future capacitance measurement system should be able to propose suitable circuitry.

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At a more detailed level, the natural solution would probably be use the microcomputer module utilised in the scanner project to trigger the capacitance-measuring monostable, measure the duration of the output pulse, and then compare that value to reference pulse duration values to detect page feed error conditions.

If an Arduino is used, suitable standard software modules could probably be found in the software library, and an active forum has both software and general electronics sections.

If the resolution of the on-board microcontroller timing software were found to be insufficient, a simple solution might be to use an external counter i.c. driven by a faster external oscillator i.c., and then to read the counter value into the microcomputer periodically.

An alternative to interfacing the monostable circuit to a microcomputer might possibly be to simply compare the output pulse width from the capacitance sensor monostable to the output from one or more reference monostables with pre-set output durations, probably using simple logic i.c. circuitry to derive the error signal required by the scanner control microcomputer.

An example typical i.c. monostable is the 74HC123, go Google...