Capacitive Page Count Sensor

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The sensor bases on the measurement of the voltage across the capacitor consisting of two metal plates with regular paper in between. The sensor uses a RC (Resistor-Capacitor) circuit where a voltage in form of a sine wave is connected to. The physical effect we are using is described using two formulas:
(explanations of the symbols are given at the end of the document)

$$Q = C * U$$

and

$$C = e_0 * e_r * \frac{A}{d}$$

For paper: $e_r = 5..6$
The capacity C decreases if the distance between two plates d increases. However, the charge Q of a capacitor stays constant, which implies an increase in the voltage U across the capacitor plates.

Conclusion 1: *If the distance d decreases the voltage U across the capacitor increases.*

(in the next section the voltage across the capacitor U is named U_c)
The voltage U_c is given by the resistor of the capacitor. This resistor is Z. In AC circuits Z is given by the formula: $Z = \frac{1}{w * C}$
This resistor can also be written as $Z = \frac{U_c}{I}$
The current I in this circuit can be described using the overall resistor of the circuit:
$R_0 = \frac{U_0}{I}$, whereby $R_0 = \sqrt{R^2 + \frac{1}{(w * C)^2}}$ (standard formula for the resistor of a RC circuit).
Using the formula of R_0 and Z the voltage U_c can be written as follows:

$$U_c = U_0 * \frac{1}{\sqrt{R^2 * w^2 * C^2 + 1}}$$

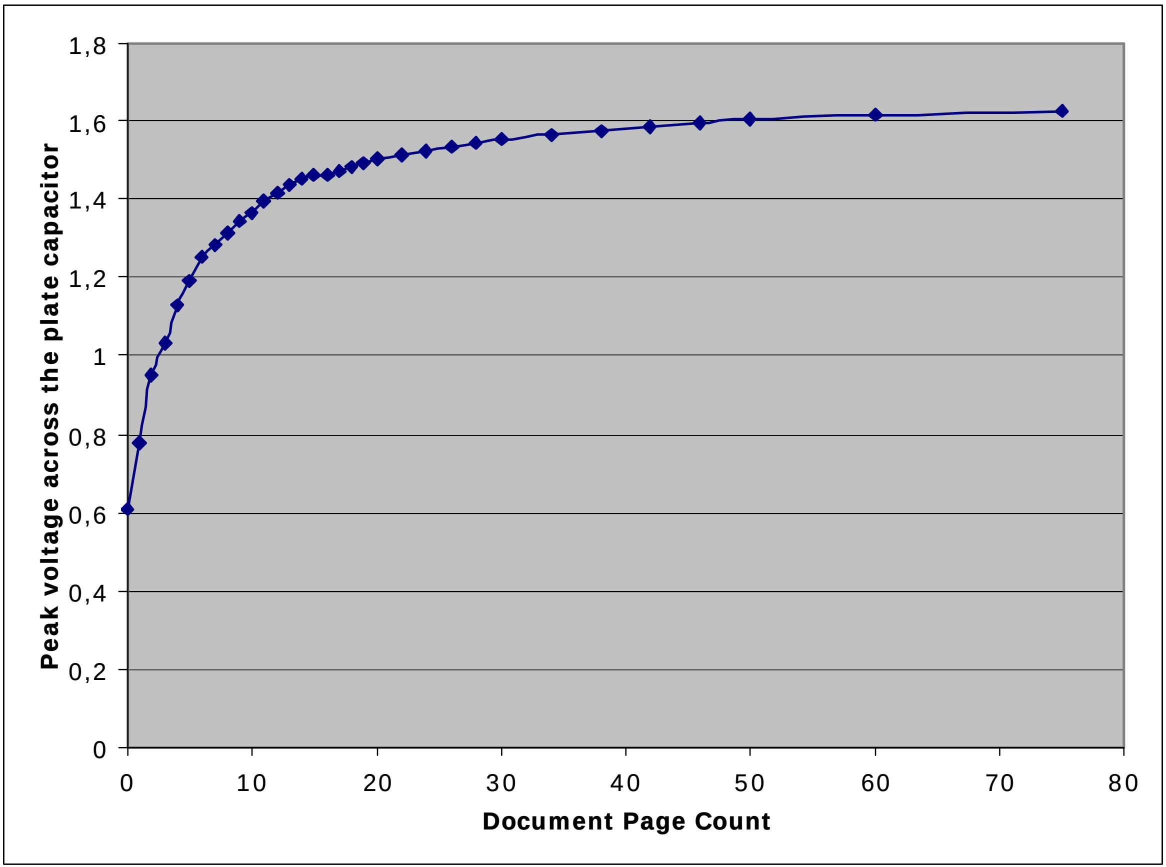
The distance d is contained in the term of C.

$$U_c \propto \frac{k_1}{\sqrt{\frac{1}{d^2} + k_2}}$$ (k_1, k_2 are constants)

Conclusion 2: *The formula* $U_c = U_0 * \frac{1}{\sqrt{R^2 * w^2 * C^2 + 1}}$ *describes the voltage* U_c *across the capacitor based on the distance* d *between the capacitor's plates.*

In our experiments we used
$U_0 = 1.65 Volts$
$R = 20k\Omega$
$f = 100kHz$

Measuring the voltage U_c lead to the following correspondence:



The Document Page Count determines the distance d between the capacitor's plates.

Note: The formula given in Conclusion 2 leads to the same correspondence.

Explanations:

U_c - voltage across the capacitor

d - distance between the capacitor plates

U_0 - input voltage of the RC circuit (same as V_{IN} in the patent draft)

R - resistor in the RC circuit

Q - charge on the capacitor

C - capacity of the capacitor

w - angular frequency ($w = 2 * Pi * f$)

f - Frequency of the input voltage U_0

Z - resistor of the capacitor

R_0 - overall resistor of the RC circuit

I - current in the RC circuit

e_0 - dielectric coefficient

e_r - relative dielectric coefficient, material specific (for paper $e_r = 5..6$)

A - surface area of the capacitor’s plate