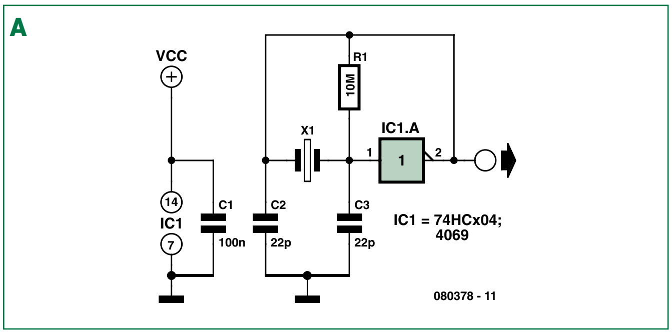
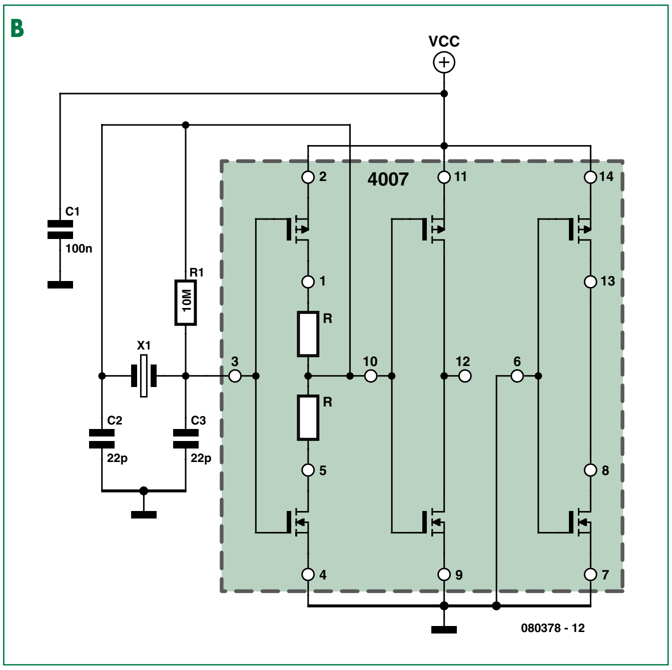
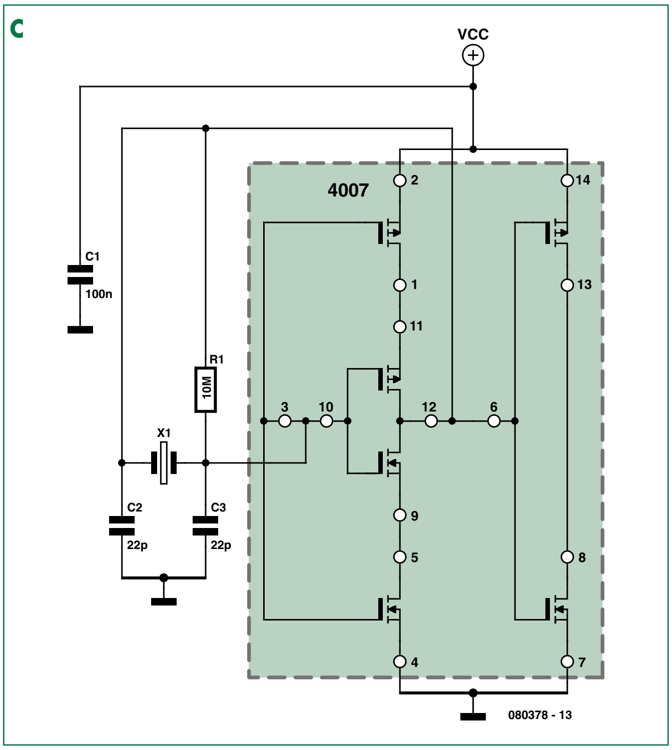
Low-power crystal oscillator







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Digital CMOS integrated circuits in the 74HC and 4000 series dissipate almost no static power. Using one inverter, for example from a 74HC04 or a 4069, it is easy to construct a crystal oscillator (**Circuit A**). Unfortunately the current consumption of the device rises considerably. Not, we hasten to add, to rainforest-threatening levels: just to a few milliamps. This could be a significant draw if the circuit is to be powered from a (rechargeable) battery. Two questions naturally arise: what accounts for this increased current consumption, and whether there are differences in this regard between the various logic families.

It is well known that current consumption rises with frequency of operation. Here, however, that is only part of the answer. The other part is due to the fact that in the oscillator circuit we are abusing the CMOS inverter as a linear amplifier. The input and output voltages are on average approximately half the supply voltage, which means that both transistors in the complementary output stage are conducting. This suggests the idea of building the complementary output stage using discrete components and limiting the current flow with resistors. The CMOS 4007 integrated circuit includes three such stages, in two of which the drain connections are brought out separately. **Circuit B** shows how this oscillator is constructed. Because the output is sinusoidal rather than rectangular, a second stage is added to square up the waveform.

We can take the idea of using drain resistors further: instead of drain resistors we can use a further complementary stage. **Circuit C** shows a practical configuration.

The current consumption of each circuit was measured using a 4 MHz crystal and a 16 MHz crystal, with a power supply of 5 V. Various drain resistor values were tried in the 4007-based circuit. The **Table** shows the results. It is apparent that at 5 V the 4000 family devices have difficulty coping with the 16 MHz crystal, with resultant unreliable start-up characteristics.

The best results were obtained using an MC14069UB (i.e., a 4069UB), but unfortunately the circuit did not start reliably at 16 MHz. The 4007-based circuit also gave good results. Increasing the value of the drain resistors reduced the current consumption, although the effect is perhaps not quite as significant as hoped. Furthermore, there is an upper limit to the value that can be used, dependent on crystal frequency and supply voltage.

Circuit C gave the same results as Circuit B with 1 kilo-ohm resistors, and there is also only a relatively low dependence of current consumption on temperature.

One final note: the values in the table should be taken only as a guideline, as in practice results will vary from device to device.

(080378-I)

Table

Circuit	Integrated circuit, drain resistor (if any)	4 MHz	16 MHz
A	74HC04	1.47mA	4.9mA
A	74HCU04	1.99mA	3.5mA
A	74HCT04	1.50mA	5.2mA
A	4069UBE	0.56mA	1.4mA
A	MC14069UB	0.37mA	0.7mA *
B	4007 / 0 Ω	0.95mA	1.8mA
B	4007 / 100 Ω	0.93mA	1.7mA
B	4007 / 470 Ω	0.86mA	1.4mA
B	4007 / 1 kΩ	0.79mA	(no operation)
C	4007	0.79mA	(no operation)

* unreliable start-up