EVALUATION of the COVER GIRL PROFESSIONAL COLOR MATCH COMPUTER

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1. General

The proposed *Color Match Computer* is a very simple system with a required complexity far beneath that needed for the *Clarion Computer*. The latter took many customer inquiries and produced a large variety of alphanumeric responses; the Cover Girl criteria result in the illumination of three lamps. The Clarion system clearly needed a microprocessor; it is not necessarily essential for the Cover Girl Computer.

As in many design areas, implementation choices are influenced by individual preference and experience. This includes the selection of particular components, architectural layout, hardware and software tradeoffs, system flexibility, and software design philosophy. There are a multitude of design choices which would satisfactorily meet the imposed constraints.

It is not the intention here to debate an individual engineer's preferences, but rather to evaluate the proposed system's design consistent with the following goals:

(1) would a hardware-only design be preferable?

(2) if a microprocessor based design is to be used, is there an overpowering reason to select a different processor?

(3) given the selected architecture, are any design flaws evident in the particular implementation?

(4) within the chosen framework, can improvements be made?

Within these guidelines, the hardware and firmware are analyzed.

2. Hardware

It is feasible to implement the Computer with random logic elements. This would require parts to scan the keyboard, perform logical interpretation of the customer input, and flash the output lamps. Timing and control circuitry would be required. The result would definitely require more board components than the proposed scheme; it is doubtful that the parts cost would be less with such a design, though possible. The low cost of the microprocessor selected ($2.35) gives little room for price reduction. The increased number of components would result in a higher assembly cost and reduce reliability.

Although the Cover Girl Computer is most likely thought of as a one-time, single use device, the possibility exists that some future requirement for Cover Girl cosmetics, or even a completely different product line, could make use of the existing computer. Any requirement which uses 16 keypad buttons and three lamps can be handled with a microprocessor based design with the change of a single component (the microprocessor itself). This would necessitate the retrieval of the deployed units, removal of the processor (desoldering) and replacement with another identical chip programmed for the new application. The housing lettering and design would be replaced with new labeling. This reuse would not be possible with a random logic design. Whatever the likelihood of this scenario, at least the microprocessor based design provides the possibility. If it is believed that this is a likely situation, then the systems should be built with a socket for the processor chip to facilitate upgrades; updates could potentially be done by field representatives replacing the part and pasting new escutcheons on the box.

For all of the above reasons a microprocessor based design is preferable to a hardware-only approach. The selection of the processor is primarily dependent upon cost and power consumption. The low power requirement mandates a CMOS processor; the low cost necessity means that a mask programmed chip must be used.

Description of Types of Program Storage

For small systems such as the Cover Girl Computer, microprocessors with three types of program storage can potentially be used:

Separate Program Store. The control program can be stored in a separate memory part -- this must be nonvolatile so that the program is permanently a part of the system. A ROM, PROM, EPROM, or EEPROM can be used for this purpose. This means that at least two parts must be used: the microprocessor itself and the memory; this requires more board space unless a *piggyback* processor is used (the memory plugs on top of the processor, so the printed circuit board mounts only the processor). The main advantage of separate program store is that program updates can be made with the replacement of a memory chip (assuming that the processor is relatively expensive), or to store programs which are too large to fit into single-chip processors. [This is the method used for the Clarion Computer].

Programmable Single Chip Processor. The control program can be stored in a *single chip processor* which is programmable by the computer product manufacturer. Two varieties of this type are available: one-time programmable, and reusable. The reusable devices permit the previously stored program to be erased and a new program installed. One-time programmable devices cannot be erased, and must be discarded when program updates are needed. Reusable processors cost more than one-time programmable processors, and are appropriate when it is likely that the program will be changed and the part's cost is significant compared to the other update costs.

Mask Programmed Single Chip Processor. The control program can be stored in a single chip processor which is programmable only at fabrication time by the *semiconductor manufacturer*. A *mask* is defined by the control program provided to the manufacturer; such devices are made specifically for the end user, and cannot be changed or used for any other purpose. Control program errors cannot be corrected. Mask programmed processors are appropriate for high volume (the semiconductor manufacturer charges a mask fee [in this case $3500] to create the first device) applications where a program change is not anticipated. Mask programmed processors generally result in the lowest part cost for high volume requirements.

The selection of the particular mask programmed single chip processor is somewhat dependent upon subjective preference. The Cover Girl Computer requirement necessitates a CMOS (low power consumption) low cost device. The selected part is CMOS and relatively low cost -- to achieve significant cost reduction requires higher volume (for example, part cost around $0.50 is possible for some processors at volumes of one million). Of greater concern is that the selected Motorola processor is a new part, and is in fact not available yet in its final form. However, the processor is a variety of a large line of processors, and Motorola is a most reputable semiconductor manufacturer with a great deal of experience in this area. There is a slight possibility of delay because it is a new part; Motorola is currently quoting a 12 week lead time (mask production included).

The proposed Computer uses a very small number of parts beyond the obviously essential ones: processor chip; keyboard; buzzer; LED lamps; and battery assembly. It might be possible to reduce some of these parts, but the cost difference would be measured in pennies.

3. Battery Life

The power consumption analysis provided by the supplier is conservative. The operating current drain figure used for battery life calculation (17 ma) is greater than both the amount measured in the prototype (12 ma at 6.25 volts) and the maximum current specified for the components (10 ma at 5.0 volts). The standby power figure (20 ua) is much greater than the component specification for typical current drain (2 ua), somewhat less than the maximum stated in the specifications (30 ua), and much less than the amount measured (< 1 ua) in the prototype. The current specifications for the prototype microprocessor and the production microprocessor are close, and in fact the production unit should draw less current than the prototype.

The supplier's estimated battery life of five years is reasonable; however, no actual battery specifications for the very low rate of discharge to be encountered exist. As a result, some guesswork is involved in the estimate and it is possible that the battery life may differ from that predicted.

4. Firmware

The control program is written in 6805 assembly language. A line-by-line examination of the program would be a time consuming and costly process. However, reasonably close inspection of all of the source code shows that it is well written. Independent verification that all of the responses for the user inputs are as desired should be made.

A cursory glance may give the impression that there is a lot of code to perform essentially very little functionality. The listings include sections which are duplicated, and cross reference information which is not part of the program itself. A considerable portion of the code space consists of the diagnostic functions, which are comprehensive.

A small difference exists in the assembly language between the processors used in the prototype unit and the production units. This has been carefully handled in the firmware in a logical fashion, which should result in no problems when the mask is made.

The firmware uses about 80% of the available internal memory. In comparison to the Clarion Computer, the code is cleaner and more maintainable (though there is no intention of future changes).

5. Testing

The diagnostic tests included in the firmware test all functional aspects of the Computer. Possibly a device bake and burn-in test may be desired; however, the Computer is quite a simple system and this may be overkill. Results from such tests as conducted for the Clarion Computer could be useful in indicating the necessity for the Cover Girl Computer.

Static discharge is of some concern. Although the microprocessor has some protection built-in, there are no external protection components provided on the keypad interface lines. Some limited high voltage testing should be performed to verify that any potential spark jumping between the finger and the keypad does not make it through the keypad insulation to the conductors. Induction of voltages into these lines is also possible. The ability of a spark to jump to the LEDs should also be checked. These tests can only be performed in the production housings.

6. Cost Estimate

The following parts costs are estimates for a production run of 35,000 units.

Item	Quantity	Cost Each	Description
C1, C2	2	.04	.1 mf bypass capacitor
D1, D2, D3	3	.33	LED
D4-D8	5	.015	1N4148 diode
P1	1	.178	Amp connector
P2	1	.11	Molex battery connector
Q1-Q3	3	.22	2N2222A transistor
R1-R6	6	.007	1/4 watt 5% carbon film
R7	1	.015	1/4 watt 1% carbon film
RA1	1	.114	9-element resistor SIP pack
U1	1	2.35	Motorola microprocessor
Z1	1	.50	Piezo buzzer
	1	1.36	Printed circuit board
	1	2.50	Keypad
#1	4	.72	Alkaline "D" cell
#2	1	.20	Fuse
#7	2	.06	Crimp terminals
#8	1	.11	Molex connector housing
	1	3.00	Contract board assembly
Total per piece cost		$ 15.28	

The above material and assembly cost does not include some inexpensive items such as heat shrink tubing and electrical tape, or functional testing of the Computer, so an estimate of $16 or $17 per piece can be used to cover these costs. Fixed charges (mask charge and printed circuit board setup fee) have been built into the per piece price, amortized over 35,000 units.

The cost of the housing and cover plates is not included in this cost estimate.

7. Conclusion

The Cover Girl Professional Color Match Computer is a well designed unit. Intelligent choices have been made in component selection, and the firmware is written in a professional state of the art fashion. Tests similar to those conducted for the Clarion Computer can be performed to a lesser degree. Hardware costs are estimated at $17 per unit.