2013

Introduction

360° Test Labs has been retained to examine, analyze, and estimate the battery life of supplied wireless interactive dolls. Featured as Mr. Red, Mr. White, and Caribou, the dolls are called "THE BAND", pictured below. Requested tasks include:

- Identify distribution of battery drain between different components of display.
- Determine activation estimates based on in–store demo scenarios from 3 AAA cells power source.
- Check for issues in electronic circuitry that may reduce battery life.
- Provide suggestions to increase battery life.

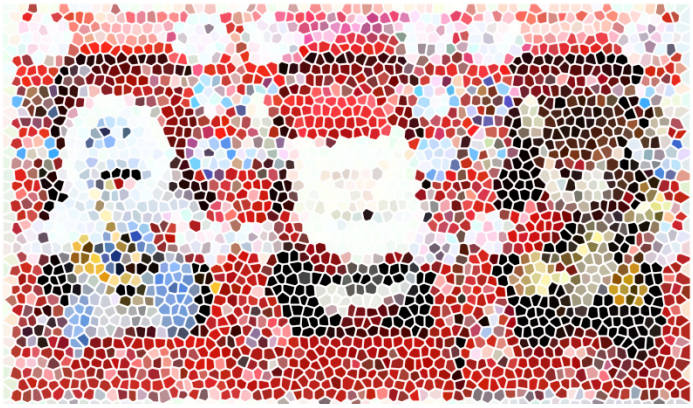


Figure 1: THE BAND

360° Test Labs received three from the set of four dolls: MODEL-A (Caribou), MODEL-C (Mr. White) and MODEL-D (Mr. Red). According to the picture shown on the packaging back side, the fourth doll is MODEL-B, is a different caribou.

360° Test Labs believes that the dolls received in Wal-Mart shopping bags were shipped to 360° with replacement Duracell batteries installed. This belief is due to the packages having been previously opened, and the customer having noted that Duracell battery replacements had been made to inventory found in Wal-Mart stores.

In each box, each doll is typically secured to the box with 3 plastic lines: in the back, and on each of the left and right feet. The plastic tie in the back was removed from all dolls and the attachment on the left foot of MODEL-D (Mr. Red) was also removed. MODEL-D (Mr. Red) did not have the yellow battery protection strip but MODEL-A (Caribou) and MODEL-C (Mr. White) did. This strip had been removed from Caribou's and Mr. White's battery boxes. The strip is to keep the batteries from powering the doll during shipping.

All three dolls arrived with Duracell AAA 1.5VDC batteries and the switches in the battery box were in the "Try Me" position. Upon receipt by 360, the batteries were removed and labeled with their location in the battery box, and then their initial voltage, as-received, was measured. The measurement was taken ... at about 12:00 p.m. MODEL-A (Caribou) and MODEL-D (Mr. Red) models had depleted their batteries completely, but MODEL-C (Mr. White) had not; MODEL-C (Mr. White) measured an average of 1.39 volts for all three batteries.

Doll Model:	MODEL-C	MODEL-D	MODEL-A
Battery 1	1.399	**0.110**	**0.019**
Battery 2	1.397	**0.078**	**0.950**
Battery 3	1.398	**0.943**	**0.947**

Table 1: Duracell AAA Battery Voltages As Received

Initial Battery Status:
The batteries in both Mr. Red (MODEL-D) and Caribou (MODEL-A) were depleted when received at 360°; only the Mr. White doll (MODEL-C) batteries had usable remaining power—the average voltage of these batteries was 1.39 VDC. Resultantly, 360° Test Labs used new batteries from our lab supply to perform initial familiarization tests of the Mr. Red (MODEL-D) and Caribou (MODEL-A) dolls. However, the original batteries received with the Mr. White (MODEL-C) were used for that doll in the familiarization tests.

Current Draw Behavior:

- Mr. Red (MODEL-D) **initially** drew about 300 mA constantly (standby, or "idling" current) with the switch in either the "Try Me" or "On" modes, but 0 mA in "Off" mode. After switching Mr. Red (MODEL-D) to "On" mode, the doll drew 300mA to 900mA while singing and moving the mouth but a constant 300 mA between performances. The first of the following two images shows Mr. Red drawing about 320 milliamperes while idling (no talking, singing or movement, which causes the voltage of the three new batteries to drop to about 3.99 volts total as seen on the leftmost meter).
- Caribou (MODEL-A) drew about 60 mA constantly with the switch in either the "Try Me" or "On" modes, but 0 mA in "Off" mode. After switching Caribou (MODEL-A) to the "On" mode, it drew 200mA to 350mA while singing with the red LED in the nose twinkling, and the body moving.
- While idling, Mr. White (MODEL-C) could be seen to draw about 2 mA with a short 12 mA peak every 2 seconds with the switch in "Try Me" and "On" modes, and 0 mA in "Off" mode. After switching the Mr. White (MODEL-C) to "On" mode, Mr. White, like Caribou, drew 200mA to 350mA while singing with the body moving. Note that the 12 mA peak is the wireless transceiver listening for the activate signal from other dolls; all dolls exhibited this.

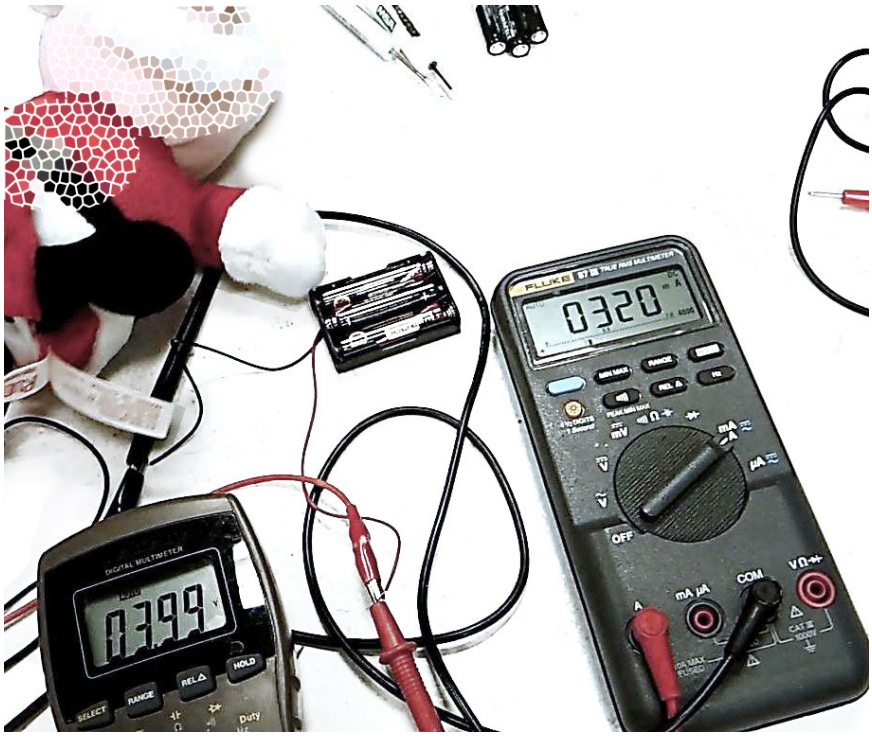


Figure 2: MODEL-D (Mr. Red), when switched to "Try Me" mode but not yet activated

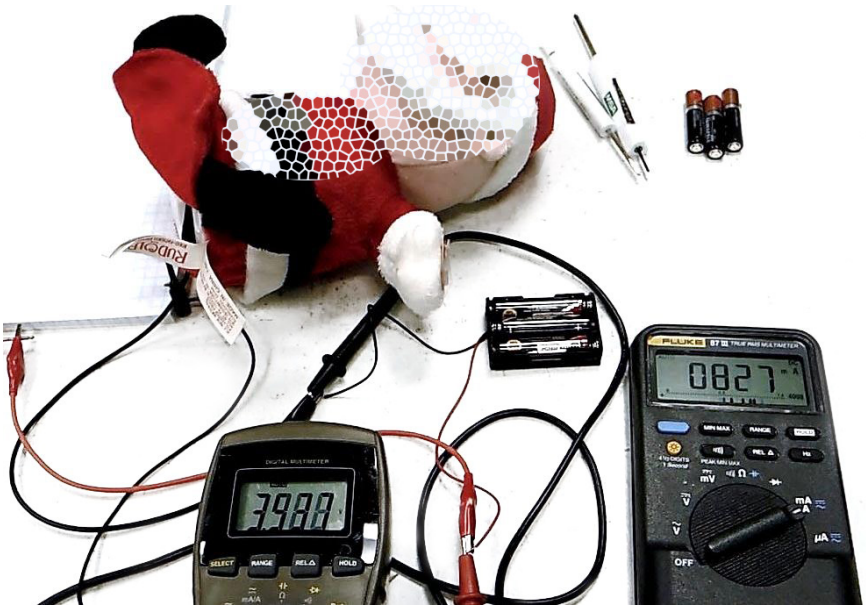


Figure 3: MODEL-D (Mr. Red), when switched to "On" mode and after pressing the Activate button in the arm

The following graph shows the current draw of each doll as operated in "On" mode from a regulated 4.50 VDC power supply, plus the actual power supply voltage. From top to bottom, the traces represent Caribou, Mr. White, Mr. Red, and the power supply voltage. The vertical scale is 0.125 amperes/division for the dolls and 1 volt/div. for the power supply, and the horizontal scale is 5.0 seconds/div.

This graph shows the dolls sequentially playing all six songs/performances, and the beginning seconds of a second set of six songs on the right edge of the graph.

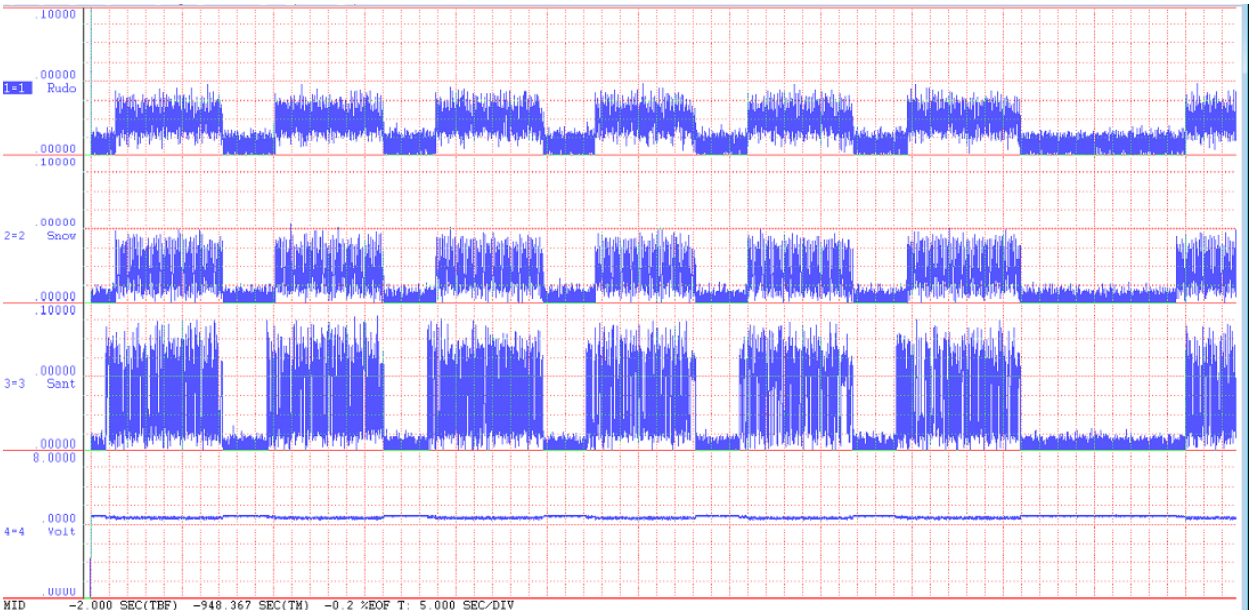


Figure 4: Current draw of each doll as operated in "On" mode from regulated 4.5 VDC

As seen above, Mr. Red is drawing the highest peak current, followed by Mr. White, then slightly lower than Mr. White is Caribou. This graph was created after Mr. Red had stopped drawing 300 mA during the idling state (discussed later).

Button and Sound:
All three models function correctly when the "Activate" button in the arms are pressed in either "Try Me" and "On" modes. No current was drawn by any doll in "Off" mode. When activated in the "Try Me" mode, any doll will first give a short introduction speech lasting about 13 seconds and then will begin playing a song. Regardless which doll is first initiated, the other two dolls will then synchronize to the first doll within 2 seconds then all dolls play in synchronization. Regardless which doll was first initiated, all dolls can be stopped instantly by any one of the others at any time by pressing an Activate button.

360° Test Labs tested one doll in the "On" mode and two others in "Try Me" mode. Any doll can "lead" the others in either "On" or "Try Me" modes. If the first doll starts in the "Try Me" mode, all three will sing together after the introduction speech and then stop at the same time. In the "Try Me" mode, only one performance is given, then the dolls stop in idling mode until triggered by an Activate button again. If the second trigger is less than 30 seconds from the ending of the performance, all dolls will then sing a second song and stop. However, if the trigger occurs more than 30 seconds after the ending of the last performance, then all the dolls will reset to the introduction speech and first song; i.e., the triggered doll will first give the introduction speech, begin the song for 2 seconds, then the other two dolls will join in, in synchronization.

If the initiating doll starts from "On" mode with others in "Try Me" mode, the first begins the song (i.e.: no introduction speech is ever given during the "On mode"), then 2 seconds later, the others join in. All three will sing together and won't stop until either all six songs are finished (with an idling break before the next performance begins of approximately 10 seconds), or the Activate button is pressed on any doll, which will immediately stop all of the singing dolls.

Each song is between about 28 and 32 seconds long; in the "on" mode, there is about 12 - 13 seconds between songs.

Interactive Distance:
Wireless RF technology provides the communications between the dolls. 360° tested the interaction between the set of three dolls in terms of both distance, and the potential ability of a single doll to act as a "repeater" between two out-of-range dolls. The claimed interaction distance of the dolls is 50 feet between one another.

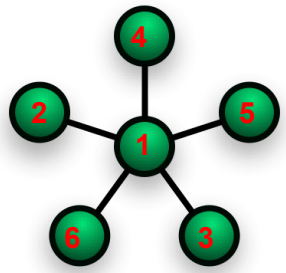


Figure 5: Star network topology

The fleet of dolls can be represented by a network topology structure. For example, in Figure 5, if a doll is in node 1, it can initiate connections to each of 2 to 5 nodes as long as they are in reachable distance. Tests found that the activation is not extendable to more than about 50 feet radius centered around node 1. Any node could be the centric of the Star network to interactive with the others.

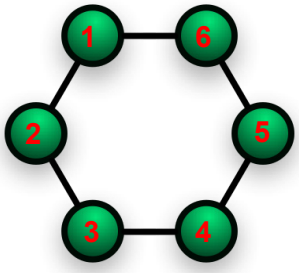


Figure 6: Daisy Chain - Ring network topology

On the other hand, if the topology between each doll is daisy chain as shown in Figure 6, node 1 could initiate others and pass the trigger to any node within 50 feet; however, no doll further away than 50 feet from the trigger will be triggered. In other words, the dolls are not capable of daisy-chaining the trigger. In the worst case, if one doll is displayed on the shelf and activated by a customer, a trigger would pass through all dolls within 50 feet. Some dolls might be displayed in multiple locations within a store, such as the cashier, store decoration, and even in the storage. As long as one doll is activated, all dolls within 50 feet might interact.

To clarify the battery depletion by being unintentionally activated, 360° Test Labs tested all three dolls in multiple topologies inside a building, with a variety of lengths in a hallway. The walls are drywall with some sheet metal vertical studs, while the ceilings are ordinary noise-suppressing tile. The floor is carpet-covered concrete. Engineers tested with different sets of straight and corner combinations. All of the three dolls interactive perfectly with each other within 50 feet, and any of the three could be the center to activate another doll on either end.

Figure 7: THE BAND Interactive Distance
(Left to right: MODEL-C, MODEL-D, MODEL-A)

Straight distance was tested by spacing out dolls between points Y and Z for any of two dolls. All of them could interactive within 50 feet. Because of signal reflection from the walls, ceiling, and/or floor, the dolls interacted erratically as the distance began exceeding 50 feet. However, none of them were able to communicate reliably with one another beyond about 55 feet in straight length. If three dolls were placed at 50-foot intervals in a 100+ foot-long hallway, a doll at one end only interacted with the doll in the center; the one at the other end was not activated.

To further confirm the result, engineers tested the distance with corners, and also by holding the dolls at different heights above ground; see the following images.

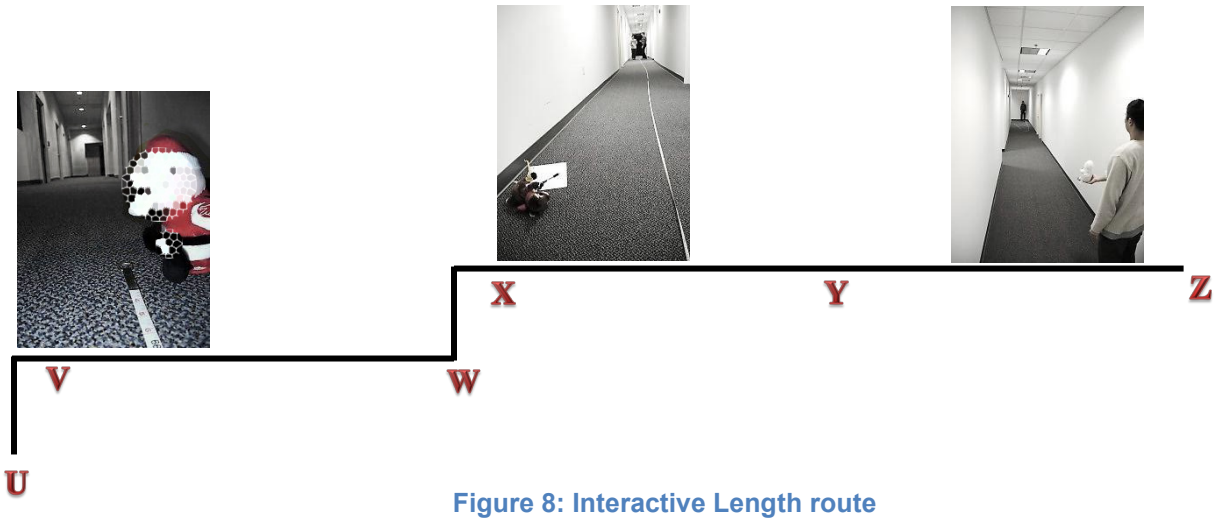


Figure 8: Interactive Length route

To test the ability to communicate around a corner, engineers put MODEL-C in between X and Y, MODEL-A at X point, and MODEL-D at W. It was found that as long as any two dolls are not further apart than 50 feet, they can interactive with each other, whether in a straight line or around corners.

However, when MODEL-A was activated on X point, MODEL-C at point Y was not activated, but MODEL-D at point W was, because the distance between X and Y is further than 52 feet. Engineers also tested the same points with different dolls, and the result was the same. As a last test, engineers put MODEL-C in U, MODEL-D in between V and W points and MODEL-A in X point. The result was the same as with earlier tests; as long as the longest distance between dolls was no further than 50 feet, all the dolls would interact.

In short, all three dolls interact with one other within 50 feet perfectly even if the communication is not straight. The topology of the last tests was to test whether a doll placed in between two dolls that are further apart than 50 feet, would act as a "repeater", allowing either widely-spaced doll to communicate with the furthest-spaced doll, or "Daisy Chain". The tests showed the distance is not extendable in this manner.

After tests of interactive distances were performed for 30 minutes, 360° Test Labs recorded the voltage of each battery pack within each doll. Caribou and Mr. Red were provided with new batteries at the beginning of these tests while Mr. White was operated with the still-usable original batteries.

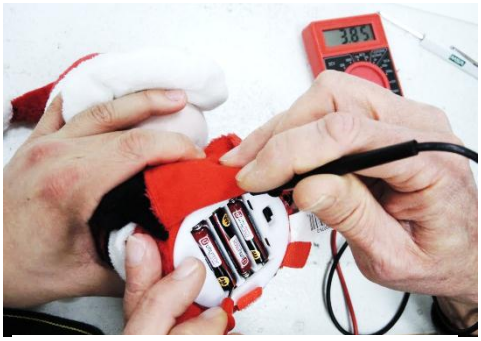


Figure 9: X240078-D Voltage reading after interactive test

Voltage(V)	MODEL-C	MODEL-D	MODEL-A
Before	3.85	4.04	4.25
After	3.22	3.79	3.85
Consumed	**16%**	**6%**	**9%**

Table 2: Voltage reading after 30 minutes interactive test

The measured voltages are shown in the preceding table; however, the dolls were not triggered or "played" equally, so this data is not entirely representative of real-world expectations.

Voltage Variation Screen:
To measure and record the current drawn by each doll, a 0.1 ohm, 5% resistor was connected in series with an Agilent 6622A regulated power supply set to 4.5 VDC. A four-channel differential voltage recorder, a DATAQ DI-158U, then monitored the voltage across each 0.1 ohm resistor, thus recording the current draw of each doll. When this setup was started, it was discovered that the standby current of Mr. Red (MODEL-D) had dropped dramatically from before the distance-activation tests were begun. The idling current of Mr. Red was now approximately that of Mr. White, around several milliamperes with the very short 5 mA peak occurring every two seconds. For a reality check, average current was measured with a FLUKE 87-III by sampling for an average reading every 100ms for 1 minute.

	MODEL-C	MODEL-D	MODEL-A
Avg. (mA)	**10.72**	**12.48**	**61.5**

Table 3: Standby current for "Try Me" mode

Before, and immediately after, the Interactive Distance Test, the MODEL-D measured about 300mA current drive while in standby state of the “Try Me” mode. After the interactive tests, while bringing Mr. Red back into the laboratory, the batteries were found to be quite warm, as though they had suffered a heavy, continuous discharge; thus, engineers believe that while handling the doll after hookup to the DI-158 but within several minutes, something inside the doll changed to cause the current to drop to a more-normal level.

The Mr. Red model was treated and handled the same as other two samples. 360° Test Labs tried changing the pose of Mr. Red (i.e.: laid down, seated, hung in the hand), applied several different physical jarring and shaking forces (including forcing the mouth to close and open), varied the applied voltage from 3V~ 4.5V, but to no avail. The average standby current became and remained a much-more-normal 2 to 5 mA instead of the previous 300+ mA when the standby current of MODEL-D was first measured.

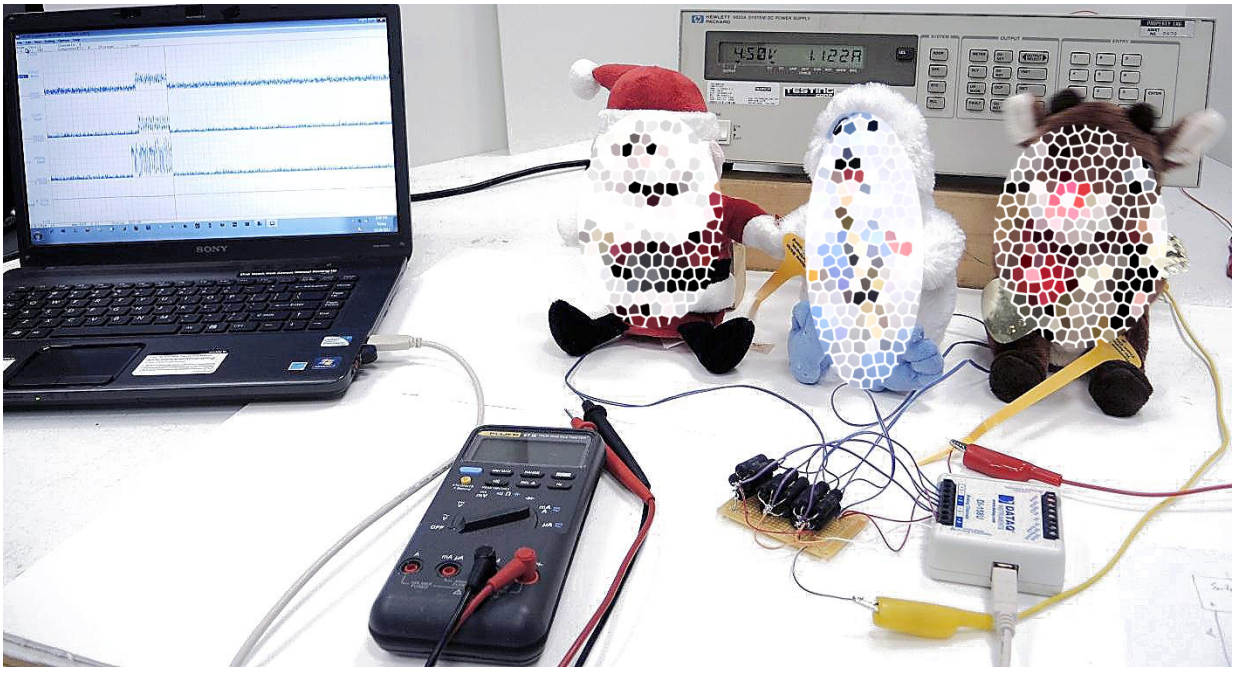


Figure 10: THE BAND during Current Measurement

To evaluate whether internal electronic circuitry or mechanical failure might be responsible, engineers disassembled Mr. Red, MODEL-D after further current measurements and recording for both electrical and mechanical inspection.

Chart: Electrical Behavior
In the chart on the following page, the current draw of the three dolls is graphed and shown as MODEL-A Channel 1; Channel 2 is MODEL-C; Channel 3 is MODEL-D; and Channel 4 is the DC voltage applied to the dolls from the HP 6622A power supply. Each horizontal division is 1 second, while the vertical divisions of each doll represents 100 mA (the graphs show 0.1 ampere because of the 0.1 ohm resistors used for current-sampling). The DC voltage chart is 8 volts full-scale (1.0 volt per vertical division).

360° Test Labs recorded the current drawn by all three dolls for a total of 3 activations, while different dolls were used to activate the others. In that chart MODEL-D has been triggered to activate the other dolls, which can be seen to begin performing after about 3 seconds, during which time period the dolls are evidently synchronizing to the lead doll's wireless transmissions.

In "Try Me" mode, the initiated doll will speak an introduction speech before beginning to sing. The introduction speech is about 18 seconds and the length of each song is about 32 seconds maximum. To perform the introduction speech again, at least 30 seconds must elapse before any doll is activated. If any doll is activated within less than 30 seconds, all dolls will perform the next song.

If more than 30 seconds elapse before another initiation, the introduction speech will again be spoken.

All three dolls stop if there is no further initiation.

In "On" mode, the activated doll will perform the first 3 seconds of a song, and then the other two dolls will pick up the rhythm, perfectly in tune and synchronization. After the performance, however, the three dolls do not begin another performance unless one of them is activated again.

Whether in "Try-Me" mode or "On" mode, when all three dolls are in standby (idling) mode, each draws an average current of 10 to 13 mA and a 10 - 17 mA current spike (duration measured at about 60 milliseconds) every 2 seconds, that is except Caribou. Caribou appears to be idling incorrectly in that its idling current is a more-or-less constant 60 mA or so.

That 10 - 17 mA current spike appears to be when the wireless transceiver within each doll is actuated into a "listening" mode by the doll's main microcontroller. If any doll has been activated during this 2-second time period, then that doll evidently is transmitting a wireless signal containing the information identifying the song, including a synchronization signal, to all other dolls within physical range (about 50 feet). After about 3 seconds of activation of any doll, all of the dolls will be in synchronization and will begin the performance for that particular doll.

Each doll has its own individual "voice" that predominates from that doll when all the dolls are performing. When a doll is the only one performing, however, all voices tend to be "sung", but the doll's own "voice" seems to be dominant. Caribou appears to play a piano or guitar, Mr. White appears to play a saxophone, and Mr. Red sings with a gruff, deep voice. There may also be other "voices" that engineers did not easily discern.

Current Measurement Profile

The following graph shows the measured current draw of the three dolls when first initiated by “Mr. Red” in the “Try Me” mode.

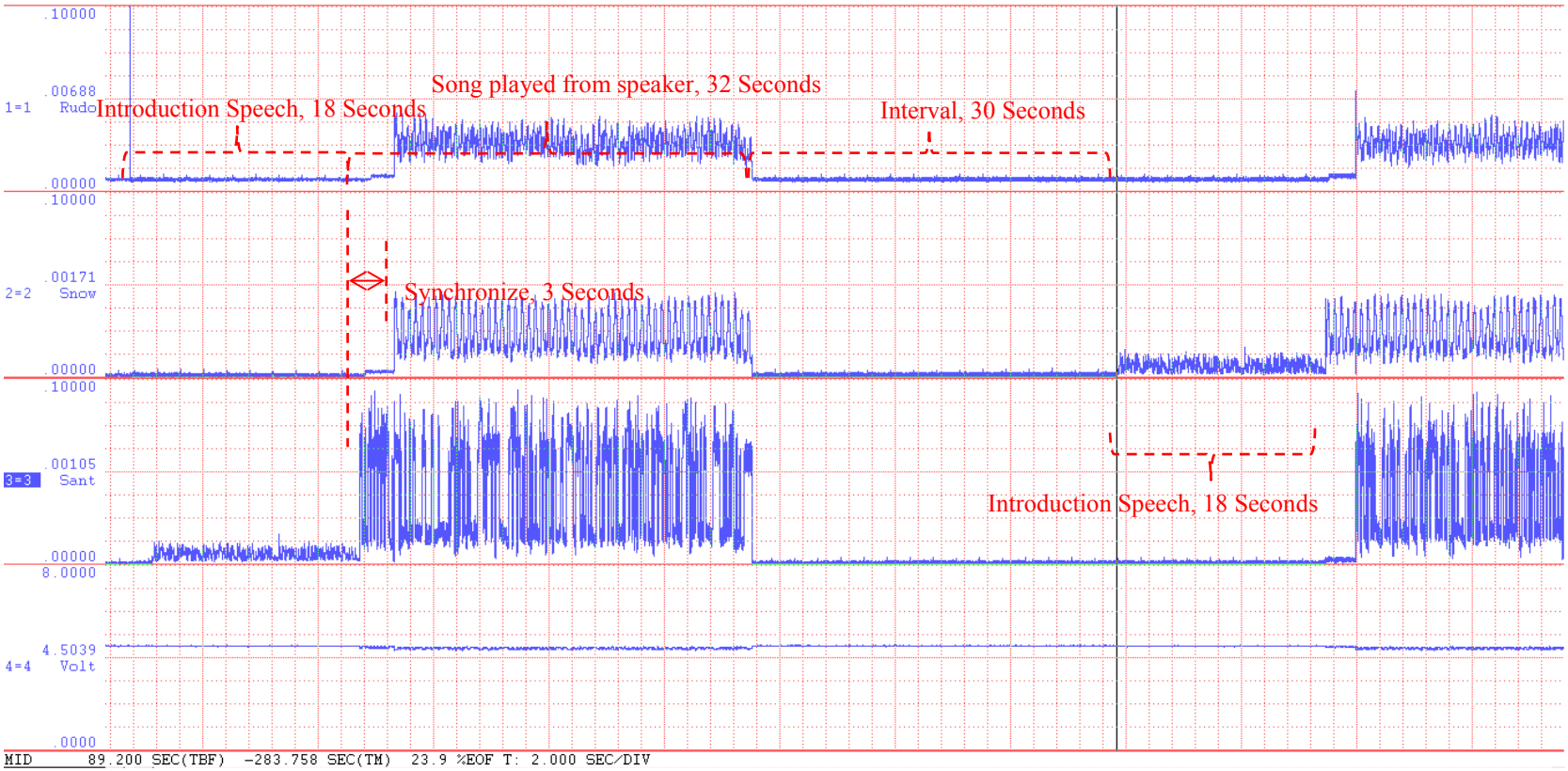


Figure 11: Try Me mode during current measurement, activated by MODEL-D

The DATAQ recorder allows measurement of each doll individually, which allows measuring each of the time periods: the Speech (18 seconds), Speech + Singing (50 seconds), and Speech + Sing + Standby (80 seconds). Measurement of average current was performed with a calibrated FLUKE 87-III DVM, which samples every 100ms to display average current draw. Figure 11 and Table 4 provide data with which engineers confirmed current consumption of each doll and the average reading. The measurements display current-draw behavior, which will allow calculation of the average ampere-hour power consumption of each doll. This, in turn, is used to calculate and estimate how long batteries should last under different activation scenarios.

Unit: mA	Speech	Sing	Standby
MODEL-A	82	171	**138**
MODEL-C	36	142	**91**
MODEL-D	50	238	**161**

Table 4: Average Current Measurement during Activation period, mA

PRODUCT NUMBER	SIZE	NOMINAL VOLTAGE	RATED CAPACITY*	LOAD	WEIGHT		VOLUME		TYPICAL GRAVIMETRIC ENERGY DENSITY**		TYPICAL VOLUMETRIC ENERGY DENSITY	
		volts	ampere-hours	ohms	pounds	kilograms	cubic inches	liters	watt-hours per pound	watt-hours per kilogram	watt hours per cubic inch	watt hours per liter
MN1300	D	1.5	15.000	10	0.304	0.138	3.440	0.056	59.2	130	5.2	322
MN1400	C	1.5	7.800	20	0.143	0.065	1.640	0.027	65.5	144	5.7	347
MN1500	AA	1.5	2.850	43	0.052	0.024	0.510	0.008	65.8	143	6.7	428
MN2400	AAA	1.5	1.150	75	0.024	0.011	0.230	0.004	57.5	126	6.0	345
MN9100	N	1.5	0.800	100	0.021	0.010	0.210	0.003	45.7	96	4.6	320
7K67	J	6.0	0.580	340	0.075	0.034	0.960	0.016	37.2	82	2.9	174
MN908	Lantern	6.0	11.500	15	1.349	0.612	30.620	0.502	40.9	90	1.8	110
MN918	Lantern	6.0	24.000	9	2.800	1.270	75.880	1.243	41.1	91	1.5	93
MN1604	9V	9.0	0.580	620	0.101	0.046	1.390	0.023	41.4	91	3.0	182

* TO 0.8V per cell at 21°C (70°F).

** Based on 1.2 volt average operating voltage per cell at 21°C (70°F).

Figure 12: Duracell MN2400 Capacity

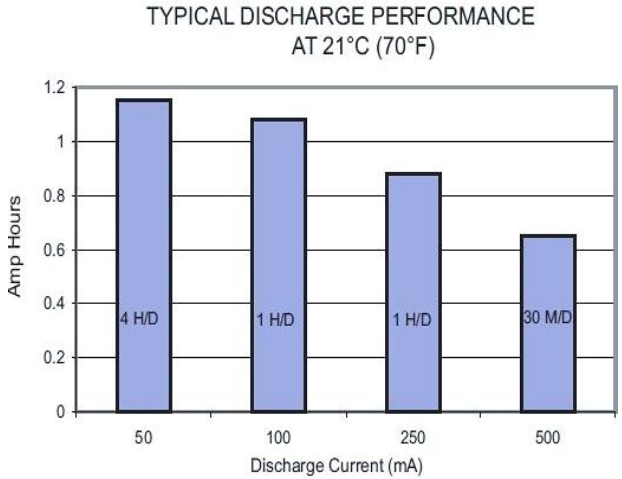


Figure 13: Typical Constant Current Discharge Characteristics

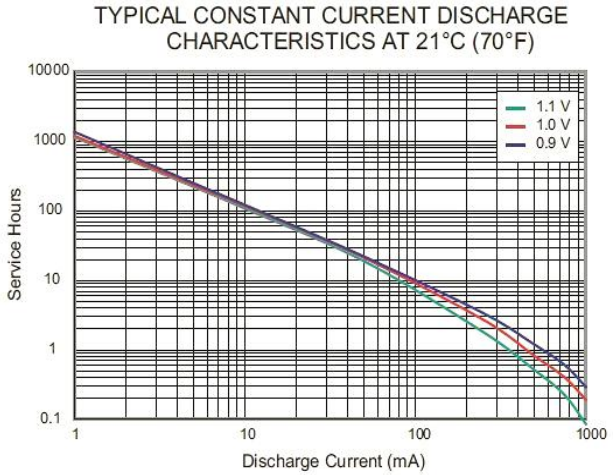


Figure 14: Typical Discharge Performance

Figures 12, 13 and 14 are from the Duracell official website:
http://media.duracell.com/media/en-US/pdf/gtcl/Technical_Bulletins/Alkaline%20Technical%20Bulletin.pdf

From Figure 12, the MN2400 Rated Capacity is 1.150 ampere-hours = 1150 milliampere-hours. By dividing average current for each "Try Me" mode behavior, average service hours for each was estimated.

- Standby = switch is always in "Try Me" mode, but doll **is not** activated by the hand button.
- Activation Cycle = switch is always "Try Me" mode and doll **is** activated by the hand button every 80 seconds.

Model	Standby Avg. Current (mA)	Standby (Hours)	Standby (Days)	Activation Cycle Avg. Current (mA)	Activation Cycle (Hours)	Activation Cycle (Days)	Total Activations
MODEL-C	10.7	107.3	4.5	91	12.6	0.5	567.0
MODEL-D	12.5	92.2	3.8	161	7.2	0.3	321.3
MODEL-A	61.5	18.7	0.8	138	8.3	0.3	373.5

Table 5: "Try Me" Mode Service Life -- always standby or activations every 80-seconds

Modeling of behaviors:
Each Duracell battery capacity is rated at 1.150 ampere-hours, or 1150 milliampere-hours; 1,150 milliampere-hours x 3,600 seconds = 4,140,000 milliampere-seconds. The following service life modeling assumes a typical store with 12 hours of daily operation. Assumed is that the doll is in "Try Me" mode and activated every 5 minutes (store open assumption), and then the doll is idled for 12 hours (store closed assumption).

Calculations of Mr. White, MODEL-C, will be shown as an example to estimate the battery life. The current values shown in the calculation are taken from Table 5 above; the results are summarized in Table 6 below.

Average current per second for every 5 minutes set Activation:

$$\frac{(10.72\ mA\ *\ 220\ sec)\ +(91\ mA\ *\ 80\ sec)}{300\ sec} = 32.13\ mA$$

Average current per second for 12 hours of activations at 5 min. intervals and 12 hours idle:

$$\frac{(32.13\ mA\ *\ 1800\ sec)\ +(10.72\ mA\ *1800\ sec)}{3600\ sec} = 21.424\ mA$$

Service Hours:

$$\frac{4140000\ \text{mA} - \text{seconds}}{\text{Avg. current per second for 12 hours of activations at 5 min. intervals \& 12 hours idle}} = 193241.22\ \text{Seconds} = 53.68\ Hours$$

Total Service Days:

$$\frac{53.68\ \text{Hours}}{24\ \text{Hours}} = 2.24\ Days, 12\ hours * 12\ Activations - hourly = 144\ times\ a\ day$$

Service Times:

$$2.24 * 144 = \text{About } \mathbf{322} \text{ times in total}$$

Model	MODEL-C	MODEL-D	MODEL-D (With 300 mA Standby Current)	MODEL-A
Est. Activations	322	214	25	96
Est. Service Days	2.2	1.5	0.2	0.7

Table 6: Modeled service life estimates for the tested dolls

Examination of Dolls:
In an attempt to discover the cause of Mr. Red's (MODEL-D) high current draw in idling mode when first received, engineers disassembled the doll. The internal components of MODEL-D are shown in the images of Figure 15. MODEL-D has some form of plastic fiber for stuffing, a motor module to activate the mouth, an electronic control module with battery pack, and an Activate pushbutton switch embedded in the left arm. When the "skin" is pulled loose to reveal the mechanism that causes the mouth to open and close, two sheets of plastic, one each inserted in the top and bottom, were found to not be glued very well on both top and bottom portions of the mouth. These sheets are activated by the motor module which causes them to oscillate open and closed. The activation pushbutton is held inside the left arm by two stitches.

Figure 15: X240078-D Disassembly for Inspection

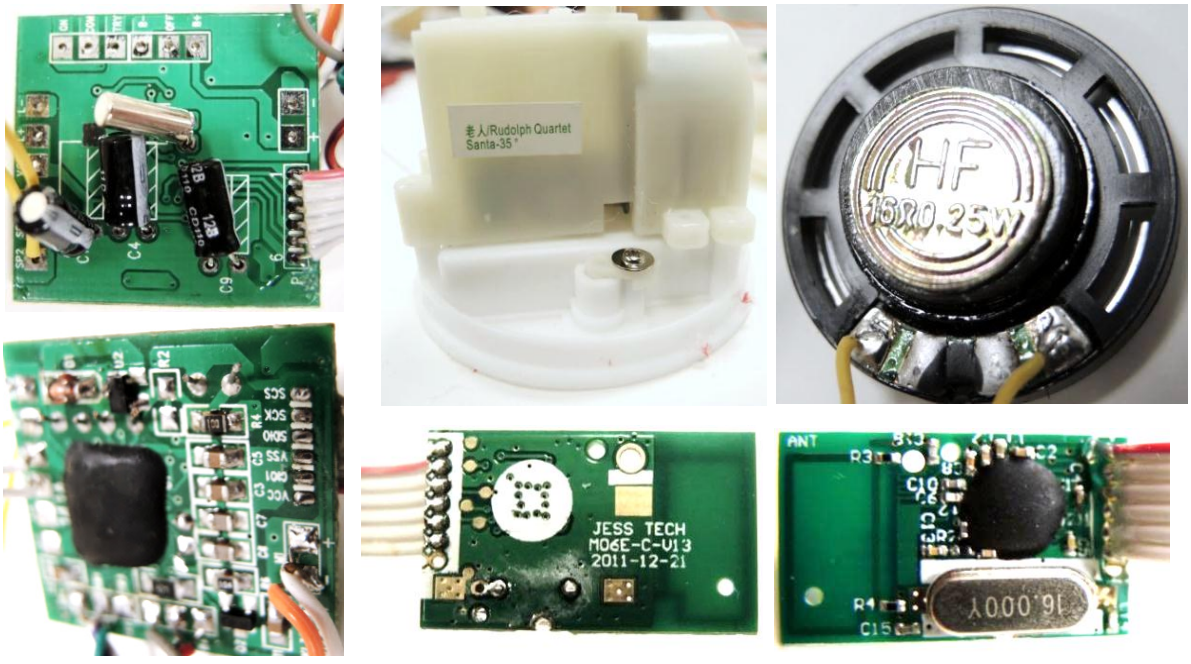


Figure 16: Components inside control unit of MODEL-D
Top left: control PCB (trace side), bottom left: control PCB (component side), top middle: gearbox, bottom middle: RF PCB (trace side), top right: HF speaker, bottom right: RF PCB

Inside the control module are two printed circuit boards and a 0.25 watt speaker. One PCB holds the wireless transceiver and antenna; the other provides interfaces for the wires interconnecting all the modules together, and apparently a microcontroller chip. Both the RF transceiver and the microcontroller are evidently a semiconductor die that is glued onto the PC boards and then potted with a hard black potting epoxy. It was not possible for engineers to determine what model RF transceiver or microcontroller is in use. Generally, observation shows fairly good components and assembly, with no outstanding issues.

After disassembly of MODEL-D, engineers still could not cause the 300 mA high idle current to reoccur; all current-consuming behavior is the same as before disassembly.

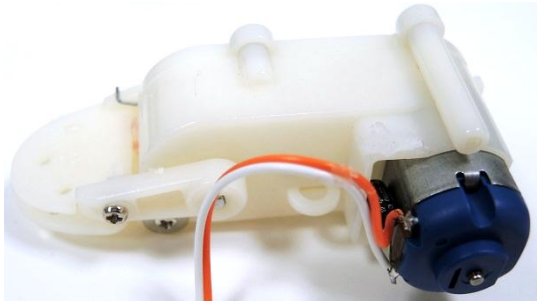


Figure 17: MODEL-D gearbox with motor

Engineers did find that the highest current draw occurs while the mouth is moving under activation. 360° Test Labs recorded the current draw, shown in Figure 18, in "Try Me" mode of MODEL-D. Each horizontal division represents 4 seconds, while each vertical division of the upper trace is 100 mA (the displayed scale on the left side of the upper graph should be multiplied times 10 due to the 0.1 ohm current-measurement resistor). The lower trace is the power supply voltage, 1 volt per vertical division.

Each test shows 18 seconds of introduction speech and singing, and then another song follows within 12 – 13 seconds. As can be seen, Mr. Red (MODEL-D) consumes an average of about 170 mA when the motor is operating without the jaw gearbox fully assembled; but the average current almost doubles with the gear box fully assembled with the mouth pieces while the peak current is almost 1 ampere.

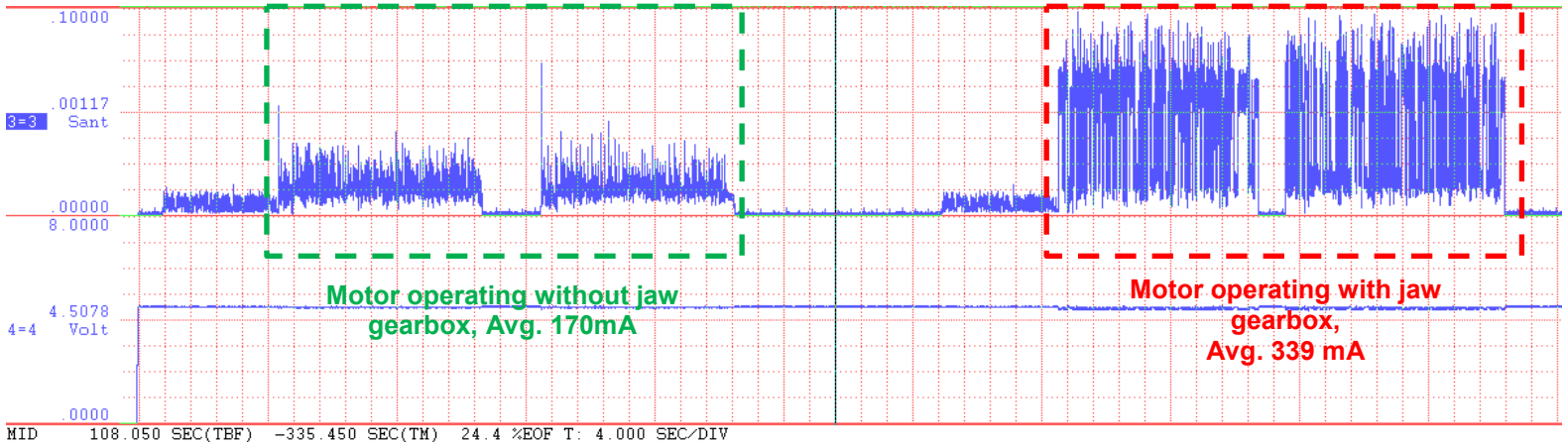
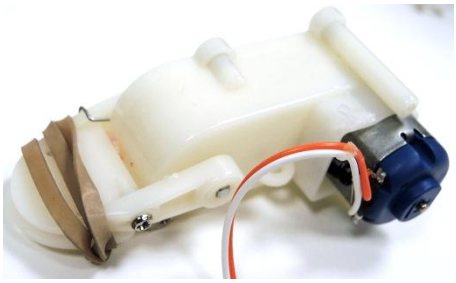


Figure 18: Model MODEL-D Activation without and with jar box current measurement



Since the jaw's gearbox is stuffed inside cotton, engineers measured the current while holding the mouth closed. Whether the jaw is forced to open or close, the current draw is about the same level.

Figure 19: MODEL-D locked jaw gearbox test

In Figure 20 below, it can be seen that gears within the gearbox are lubricated but the small gear attached to the motor shaft is not; this could cause a slightly higher currrent consumption due to additional friction.

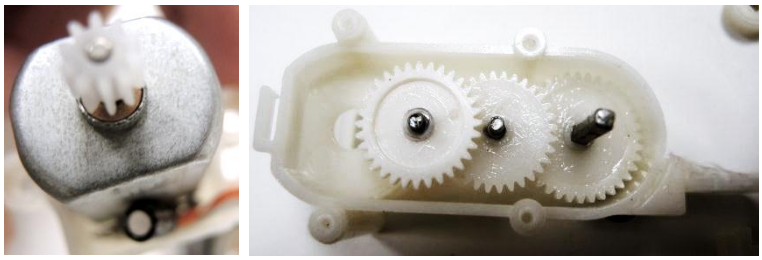


Figure 20: MODEL-D motor gear lubrication

Engineers also disassembled the MODEL-A and found all gears are lubricated inside its gearbox. The mechanical design is different from MODEL-D due to the different movement required. Close examination of Caribou's printed circuit boards (which appear identical to those within Mr. Red, although with different wiring due to the LED in Caribou's nose), did not reveal the cause of the continous 60+ milliampere current draw of Caribou.

Every module, such as the motor, speaker, LED, and wireless PC board, was disconnected from the microcontroller PC board, yet 60+ milliampere current draw of Caribou persisted. 360° Tet Labs suspects an assembly fault at the microcontroller under the black epoxy potting is the underlying cause, if not its logic / programming. Engineers believe that to emphasize the appropriate "voice" within each doll, each microcontroller most likely has slightly different programming.

Summary:

- MODEL-D and MODEL-A had depleted their batteries when they were received by 360° Test Labs; only MODEL-C (Mr. White) had any power remaining in its batteries. According to the service-hours estimation, if the batteries of all three dolls were replaced at the time of shipping, the condition of the received batteries can be explained by the service-hour estimation and shipping time. All three models stop working when batteries fall below about 2.8V~2.6V.

- The microcontroller in Caribou is still draining its batteries at a constant 60 – 62 mA. The product might need power management by either hardware or by firmware.

- Interactive function works very well on each model. The RF PCB might use the same design on each model and cost 3mA ~ 5 mA every 2 seconds to keep connection to other dolls.

- In modeling current-draw behavior for service-hours estimation, MODEL-C is presently the only model that can be displayed on the shelf for more than 2 days (12 hours display, activated every 5 minutes, or about 144 times a day, then allowed to idle the other 12 hours). With the same scenario, MODEL-D (Mr. Red) should last about 1.5 days, and MODEL-A (Caribou) about 0.7 days, which includes the present 60+ mA constant draw. Otherwise, if Caribou were not drawing that constant current, it should last about the same or slightly long than the Mr. White, or about 2.2 days. If the MODEL-D (Mr. Red) model consumes 300 mA while idling as it first did at 360° Test Labs, it will deplete its batteries in 0.2 days.

- After disassembly of Mr. Red (MODEL-D), 360° Test Labs observed that the fully-assembled gearbox causes 50% more current consumption than when it is not assembled. Although a small motor gear was not found lubricated, of higher concern is the strong spring used to automatically close the two plastic sheets that open the mouth. If the spring tension can be reduced, the current consumption of the motor-gearbox assembly might be greatly improved.

- Engineers believe that the constant current drawn by Mr. Red (300 mA) and Caribou (60 mA) may be due to an assembly issue when the semiconductor die were mounted on the PC boards, then wired to pads on the boards. It is thought that a pad may be miswired to the die; this connection between PC board pads and bare chips is normally done with very fine wire. 360° Test Labs believes that it is likely that Mr. Red is no longer drawing 300 mA because that wire has burned apart; but 60 mA in Caribou may not be enough to do the same. Logic / programming issues with the microcontroller might otherwise be suspected as the cause.