

# There's a lot of smart electronics INSIDE A FURBY

*There's much more to a Furby than meets the eye.  
Let's peel back the fur and take a peek inside.*

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**A** child's toy might seem to be a strange subject for an electronics magazine like *Poptronics*. But as you'll soon see, it isn't. Packed inside a Furby's five-inch-high furry body is an amazing complexity of mechanical and electronic components—and software.

Unconvinced? How's this then? The software boasts the ability to actually change the toy's output behavior in response to the prefer-

ences of the child who owns it. Yes, the Furby can adaptively learn! When you consider the retail cost—just \$30, throw in a spoken vocabulary of 160 words (capable of being incorporated into no less than 1000 different phrases), and the ability of Furbys to automatically communicate with one another via a built-in infrared port, then you have state-of-the-art in a very unassuming package indeed!

**The Toy.** The Furby is a fur-covered pseudo-animal with fixed feet and a movable mouth, ears, and eyes. In addition, the Furby can rock forward on its base platform. The movable parts of the toy are mechanically driven by an internal electric motor (more on this in a moment) that operates the eyelids, opens and close the mouth, and waggles the ears up and down. Also hidden under the fur are pushbutton switch-

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*This Furby's head, stripped of its outer covering and fur; reveals the light sensor between the eyes. On either side are infrared transmitter and receiver LEDs. Furbys can automatically communicate with one another via this infrared link.*

es on the front and back as well as a switch inside the mouth that is triggered whenever the mouth is opened manually.

A big factor in the toy's success is its language skills, with an internal speaker able to clearly communicate "spoken" words and phrases. There are also additional inputs and outputs, but more about these later.

A short description of the toy does not do it justice; it is the way that it works which is so interesting. For example, as I write this, my Furby (yes, I bought one as part of the research for this story!) is "asleep." How do I know? Well, it made snoring noises, and then rocked forward and closed its eyes.

Loud noises or changes in light or other stimuli will not wake it. To rouse the beast, you must pick it up and tilt it to trigger an internal tilt switch. By the way, early Furbys were apparently much harder to put to sleep, requiring a certain sequence of events including lots of pats on the back. However, Furby manufacturer Tiger Electronics Ltd. changed

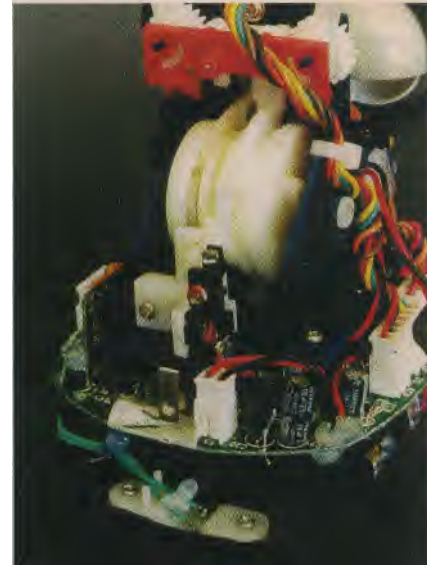
the design, fearing a backlash from exasperated parents. Furbys don't have an on/off switch, you see.

Here's an example of its behavior: I just picked up the toy and it said "Mmmmmmm, me love you." However, the last time I roused it from its sleep, it said "Sun's up."



*This photo shows just how jam-packed a Furby is inside. A semicircular PC board is located just above the battery compartment, with the mechanical module mounted on top of that. The sound-sensing microphone is hanging on its lead in the foreground.*

This lack of predictability in response to stimuli lifts the personality realism to a totally different plane compared to most toys. When awakened, it might have just as possibly said, "Me sleep again" or "Cock-a-doodle-do, big light!" Or it might have sneezed, giggled, or made one of many other sounds. Each Furby picks its own



*In this view, the horizontal axis camshaft can be seen, with plastic cranks moved by the cam lobes connecting to the eyes, ears, and mouth. The cam-position switch is located in the middle of this picture, with the reset switch at the bottom. The wiring harness is held in place with many globs of hot-melt glue.*

name from its available list of sounds (mine says "Me Too Loo"), and individual Furbys have differently pitched voices.

If left unstimulated for a few minutes (no noises, no changes in light intensity, or no switches pressed), a Furby will sometimes say "Mmmmm ...boring!" If still ignored, it will go to sleep. When taken for a ride in a car, a Furby will say "Wheeeeeee!" whenever the car corners; and it will suggest that it wants to play "hide and seek" when the intensity of the light suddenly changes. When it is held upside down, it will initially giggle, which will sometimes

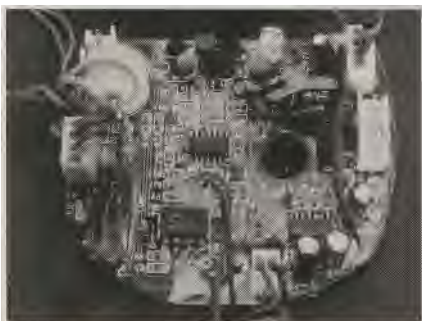


*The Furby's 2-inch speaker is capable of very clear sound reproduction.*

change to "I'm scared" if it is held in this position for too long.

**Games.** There are several games built into the toy. For example, to place a Furby into the "hide-and-peek" mode, you need to cover and uncover the light sensor located between the eyes three times, and then the front pressure switch is activated ("tummy tickled" in Furby-speak). The beast then needs to be hidden within a minute, following which it will be quiet for three minutes. Once this time has elapsed, it will start saying "nah, nah, nah" at intervals until it is found.

When batteries are first inserted into it, a Furby speaks no English words or phrases. Instead it speaks in "Furbish," and a dictionary with 44 entries lists the English translations. However, after a few hours of stimulation, the toy starts to speak some English; and after a day or two, it speaks mostly English. Note, however, that English words are not actually being learned; instead, it would appear that after Furbish phrases and words have been "spoken" a set number of times,



*The main PC board contains most of the electronic circuitry. The position sensor is at the upper left corner; while two daughter boards (each with a custom microprocessor) are located at the left.*

that word or phrase is replaced by English.

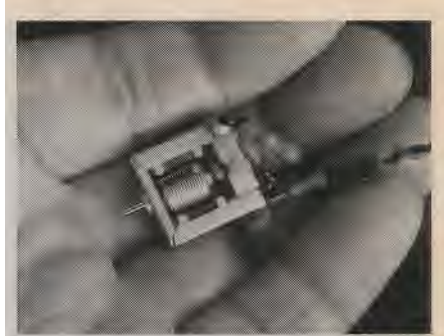
The developmental stage that the Furby has reached is maintained when the batteries are changed. However, there is a reset mechanism that can be activated to return a Furby to infancy!

If a Furby initiates a pattern of behavior (for example, it makes kissing sounds when the front "tickle" switch is activated), patting it on the back (i.e., activating the rear switch twice) will reinforce this behavior. Consequently, individual Furbys can adopt slightly different behaviors on the basis of their owner's preferences.

So you can see that, from a child's perspective, a Furby is a very attractive toy indeed. It has a distinct personality (sometimes with negative character traits like belching and breaking wind!) and initially has its own language but soon learns English. It has its own demands: if it isn't fed, a Furby becomes ill and sneezes a lot. It's easy to see why Furbys have become so popular.

**The Mechanics.** As mentioned earlier, an internal motor drives the movable parts of a Furby. This reversible DC motor is mounted to one side of a "movement module" positioned inside the top half of the toy. The motor drives a series of reduction spur gears that rotate a worm drive. The worm drive, in turn, acts on a large cog attached to a shaft that has a series of cam lobes. These lobes bear on connecting rods that move the eyelids, mouth, and ears, and rock the Furby backwards and forwards.

Rotating the shaft in a single direction causes each moving part to be operated in sequence. Since each movable item has its own cam arranged so the lobe center angles do not overlap, each movable item can also be operated independently if the camshaft is rotated back and forth within a narrow rotational angle. For example, during "dancing" (where the Furby rocks back and forth), the shaft is rotated so that only the rocking motion lobe is operated. This position of the camshaft behaves as a "dead spot" for the lobes that drive the eyelids and



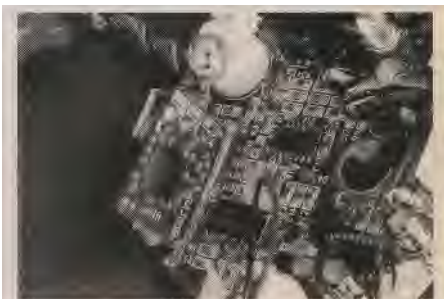
*The small reversible DC motor works hard for its living; if the toy is used for extended periods, a strong "electric-motor" smell is emitted!*

ears. During dancing, the eyes and ears stay still.

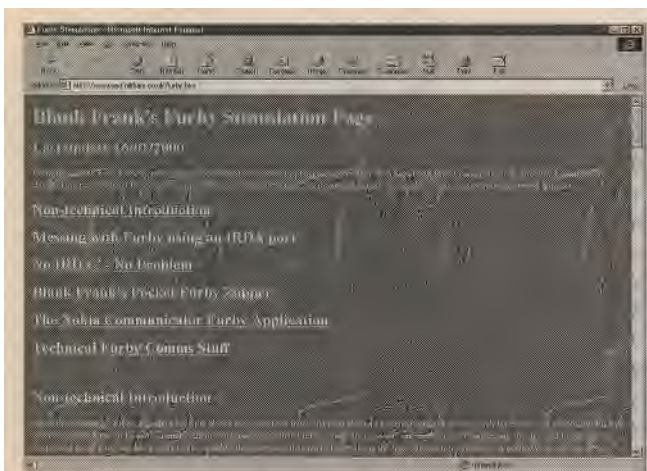
Because the main worm drive cannot transmit torque in the opposite direction (e.g., the motor cannot be turned by moving the ears), a slip mechanism is built into each movable body part. This mechanism allows these parts to be manually moved without causing damage.

The motor uses sprung copper leaves to transfer power to the commutator. Carbon brushes aren't used—instead there appears to be some type of conductive grease spread over the relevant area. This probably explains the strong "electric motor" smell if the toy has been operating continuously (e.g., held upside down) for some time.

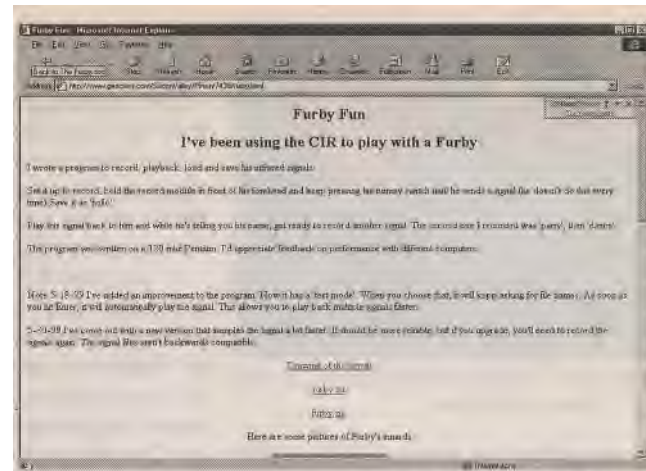
**The Electronics.** The electronics comprise a main, double-sided PC board with surface-mount and conventional components on it. Additionally, there are two small daughter PC boards mounted on the main board at right angles, each carrying a custom COB (chip on board) microcontroller. Serial data is transferred



*The microprocessors are custom designs, bonded directly to the PC board and encapsulated in black epoxy. With the Furby manufactured literally by the millions, this approach is very cost effective.*



There are entire Web Sites devoted to Furbys and hacking techniques. One of the best is "Blank Frank's Furby Stimulation Page" at [www.veg.nildram.co.uk/furby.html](http://www.veg.nildram.co.uk/furby.html).



This Web site, at [www.geocities.com/SiliconValley/Pines/7438/furby.html](http://www.geocities.com/SiliconValley/Pines/7438/furby.html) includes a program that lets you record, save, and play back a Furby's infrared signal.

between these two microcontrollers, which are run at 3.58 MHz.

A 93046 non-volatile EEPROM with 1K of storage is mounted on the main board. This probably contains the Furby's name, developmental state, and adaptive memory. It would appear that a separate chip is solely responsible for generating the sound output—perhaps this approach has been taken to allow easy implementation of Furbys that speak other languages.

The system's inputs and sensors are as follows:

- A reset switch (next to the battery compartment under the toy)
- A back switch (senses back pats)
- A front switch (senses tickling)
- A cam-position sensor (a small leaf switch)

- A gear-speed sensor (an LED and sensor blocked by a black plastic gear with four slots)
- A ball-tilt switch (detects level, tilt, and upside-down orientations)
- A light sensor behind a panel between the eyes
- An infrared-receiver LED (near the light sensor)
- A microswitch "feed sensor" behind the mouth

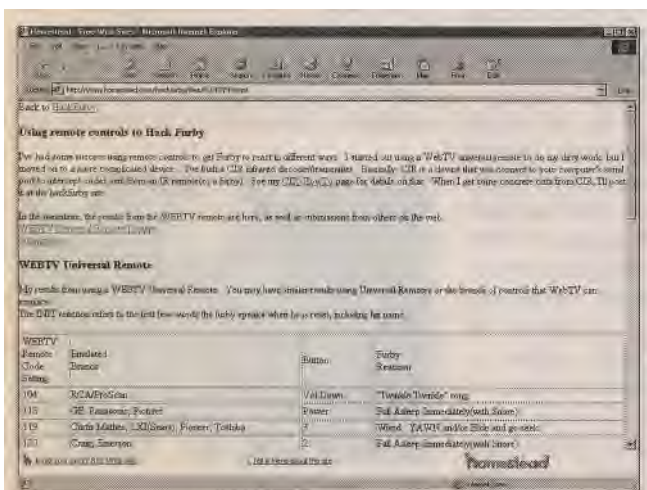
The outputs are as follows:

- A 2-inch loudspeaker with a clear plastic cone
- An infrared-transmitter LED (near the light sensor in the forehead)
- Forward and reverse motor operations.

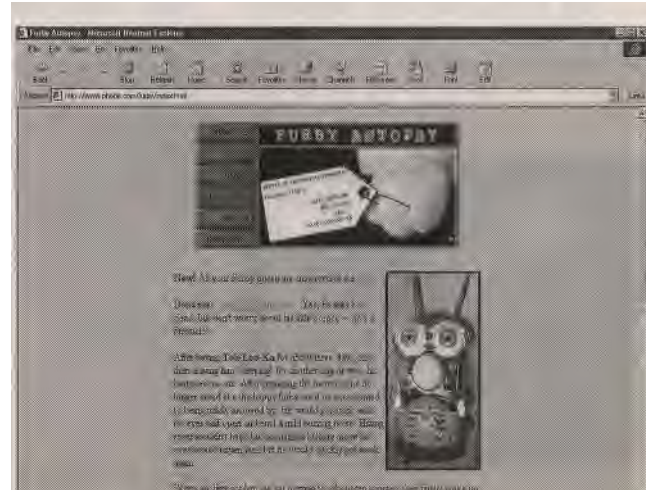
The motor is driven at battery

voltage (6 volts nominal), while a pair of diodes is used to provide 5.3-volt and 4.8-volt supplies for the rest of the circuitry.

**Infrared Communications.** One interesting aspect of the toy is its ability to use infrared transmissions to communicate with other Furbys. Furbys can normally communicate with each other when placed in close proximity, although my sample Furby steadfastly refused to communicate with another Furby whose access was arranged for just that purpose. Apparently, they are capable of transferring colds (the healthy Furby starts to sneeze as well) and developmental stages—a Furby can speak more English after being in contact with a more advanced Furby



Furbys include an infrared port for communication with other Furbys and can often be tricked into responding to IR remote controls. There's lots of information on this at [www.homestead.com/hackfurby/files/FURBYIR.html](http://www.homestead.com/hackfurby/files/FURBYIR.html).



What do you do if your Furby "dies?" Tie a "toe-tag" to him and conduct a thorough autopsy, of course. You can find out the cause of Toh Loo-Kah's untimely demise at [www.phobe.com/furby/cause.html](http://www.phobe.com/furby/cause.html).

## THE FURBY FILES

There's lots more information on the Furby on the Internet. Much of the information for this article was derived from the many Web sites devoted to the history, dissection, hacking, and electronics of the Furby. Here is a representative list to get you started in your quest for all knowledge Furbish:

[ai.tqn.com/compute/ai/library/weekly/aa101398.htm](http://ai.tqn.com/compute/ai/library/weekly/aa101398.htm)Furby

[freeload.homestead.com/\\_ksi0701961574651052/hackfurby/files/furby.pdf](http://freeload.homestead.com/_ksi0701961574651052/hackfurby/files/furby.pdf)

[www.blunenplune.com/~maznliz/marius/furby.htm](http://www.blunenplune.com/~maznliz/marius/furby.htm)

[www.geocities.com/SiliconValley/Pines/7438/furby.html](http://www.geocities.com/SiliconValley/Pines/7438/furby.html)

[www.homestead.com/hackfurby/files/FURBYIR.html](http://www.homestead.com/hackfurby/files/FURBYIR.html)

[www.phobe.com/furby/faq2.html](http://www.phobe.com/furby/faq2.html)

[www.veg.nildram.co.uk/furby.html](http://www.veg.nildram.co.uk/furby.html)

[www.wired.com/wired/archive/6.09/furby\\_pr.html](http://www.wired.com/wired/archive/6.09/furby_pr.html)

For the hackers, the infrared port also allows another pursuit—fooling a Furby into doing odd things by stimulating it with foreign infrared signals! IR-emitting devices that have been used for confusing Furbys include PC IRDA ports, purpose-built standalone Furby IR transmitters, the Palm III hand-

held computer with *OmniRemote* software, TV and VCR remote controls, and even a Nokia 9110 mobile phone!

If you want to find out how to do this, refer to the Web sites listed in the sidebar. That's right; there are entire Web sites devoted to Furbys and hacking techniques. Take a

look at "Blank Frank's Furby Stimulation Page" ([www.veg.nildram.co.uk/furby.htm](http://www.veg.nildram.co.uk/furby.htm)), for example. Among other things, he shows you how to control a Furby using a computer's IRDA port.

What, no IRDA port? Blank Frank's got that covered as well, with a simple circuit that you can build yourself.

For the technically minded, here's how Furbys communicate: they use IR pulses approximately 150-200 mS wide with a bit time of 2 mS. The communication packets consist of nine bits sent six times, with silence between each set of nine bits, giving a repeat rate of about 100 mS. The nine bits consist of a start bit, four data bits, and then the same four data bits inverted. There are a total of 16 different signals that can be communicated.

A few years ago, a self-learning toy that talked, communicated "intelligently" with other toys of the same type, and contained internal software that gave a very real simulation of "personality" would have been the stuff of dreams—especially at this price! Furbys show that not all electronic advances are confined to esoteric areas.