NOISE WARS: PROJECTED CAPACITANCE STRIKES BACK AGAINST INTERNAL NOISE

JOHN CAREY • CYPRESS SEMICONDUCTOR CORP

IMAGE: SHUTTERSTOCK

CHARGER AND DISPLAY NOISE AFFECTS TOUCHSCREENS, BUT THERE ARE WAYS TO TACKLE THIS PROBLEM.

Today's users expect multitouch systems to perform with precision and still comply with demanding environmental standards. Designers face no small feat in meeting these requirements. With a rapidly changing internal environment in multitouch systems, the war for touchscreen dominance is effecting the emergence of new battlegrounds.

One current trend is the push toward thinner phones. Achieving this goal means direct lamination of capacitive-touch sensors to the display, moving the sensor inside the display, and overcoming many other challenges with antennas and ground loading. It is no longer acceptable to just throw a shield layer onto the sensor structure to block display noise. Such an approach adds too much cost and thickness.

Beyond displays, the prevalence of USB-charging connectors has made battery chargers into commodities, pulling every last cent from these devices. Capacitive-touchscreen ICs now sense picocoulombs of change in the presence of as much as 40V p-p ac noise. All of these factors add up to requirements for touchscreen ICs that are far more complex than what was required just last year. New innovations are needed, and so begin the noise wars.

AT A GLANCE

- Capacitive touchscreens are ubiquitous but prone to false and erratic response due to noise from the product in which they reside.
- Noise comes from both the internal dc/dc-converter subsystem and the display drivers.
- Whether dealing with noise from displays, chargers, antennas, or other sources, touchscreen ICs must perform with the same level of user experience.

CHARGER NOISE

Charger noise physically couples into the sensor through the battery charger during the presence of touch. Its effects include degraded accuracy or linearity of touch, false or phantom touches, or even an unresponsive or erratic touchscreen. The culprit is typically an after-market, low-cost charger. Although OEM-supplied chargers typically have tight specifications for noise, the widespread adoption of USB connectors for charging circuits has created a massive after-market opportunity. Fighting to compete in this segment, after-market manufacturers are making these chargers as cheap as possible. These low-cost electronics yield chargers that charge your phone but may inject so much noise into your touchscreen that the phone becomes unusable.

Two common battery chargers are the ringing-choke converter and the flyback converter. Flyback-converter chargers typically use PWM circuits; low-cost, self-oscillating ringing-choke converters use a variant of the flyback design (**Figure 1**).

The ringing-choke converter has neither a microcontroller nor a capacitor, yielding a lack of PWM control, a lower-cost transformer, fewer diodes, and lower-capacitance polarized-input capacitors. These eliminations equate to cost savings for the manufacturer but a noisy system for the customer. Some ringing-choke-converter chargers are on the verge of becoming broadband noise generators because they emit as much as 40V p-p noise ranging from 1 to almost 100 kHz. Most have periodic-noise tendencies with many harmonics. A good example is the so-called zero charger, which has a noise output of 10 to 25V p-p (**Figure 2**). This charger's output depends on the battery state itself. To address this phenomenon, many OEMs banded together to create EN (European Norm) specifications that govern the maximum noise levels a charger should emit at any frequency. EN 62684-2010 and EN 301489-34v1.1.1 govern these noise levels (**Figure 3**).

From 1 to 100 kHz, a charger should output no more than 1V p-p noise, and the levels degrade exponentially from that level as the frequency increases. None of the after-markets, however, conform to this stringent specification. As a result, OEMs now expect touchscreen ICs to deal with much higher noise. Some specifications require 40V p-p from 1 to 400 kHz, with 95V-p-p immunity in the 50- to 60-Hz range. Fortunately, specialized algorithms and methods can meet stringent requirements and provide more than 95V-p-p noise immunity to battery chargers. They achieve these levels through a variety of mediums, such as nonlinear filtering, frequency hopping, and other hardware techniques.

DISPLAY NOISE

Displays offer many challenges for projected-capacitive touchscreen systems because they can generate a lot of noise that can conduct directly into the capacitive-touchscreen sensor. To make matters more difficult, OEMs are demanding thinner industrial designs for their phone models, which means moving the touchscreen sensor closer to or even inside

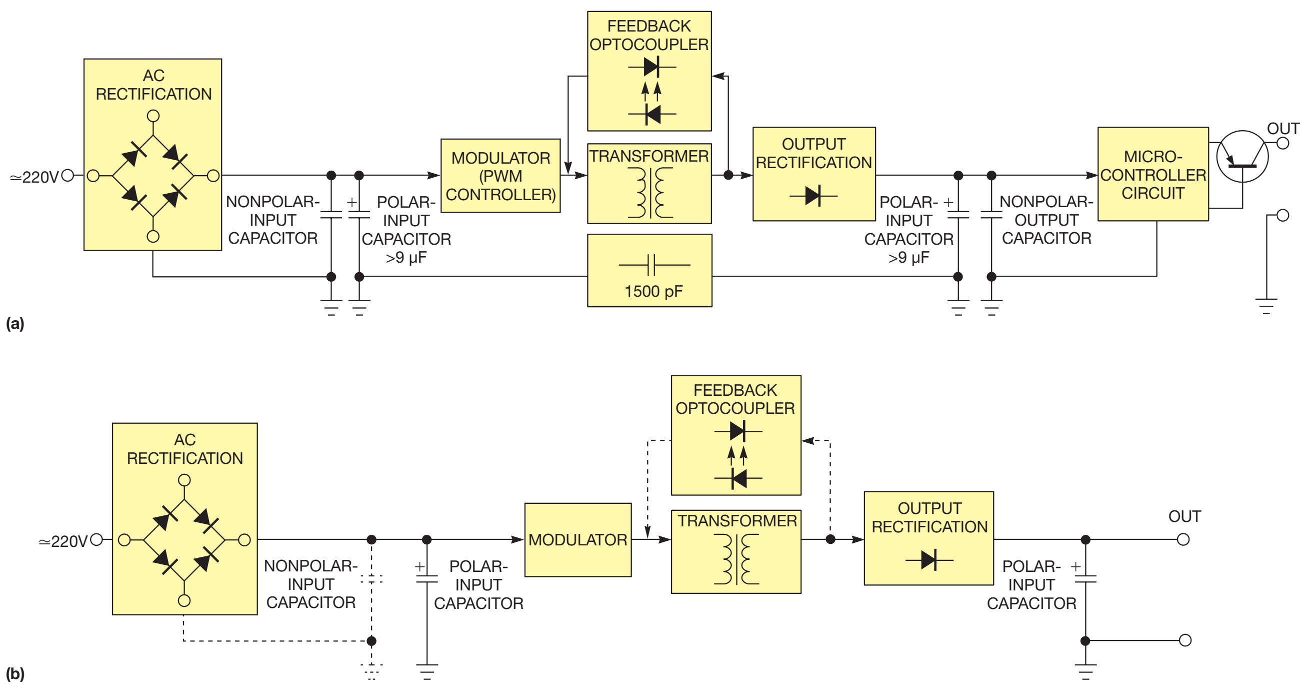

Figure 1 Flyback-converter chargers typically use PWM circuits (a), and low-cost, self-oscillating ringing-choke converters use a variant of the flyback design (b).

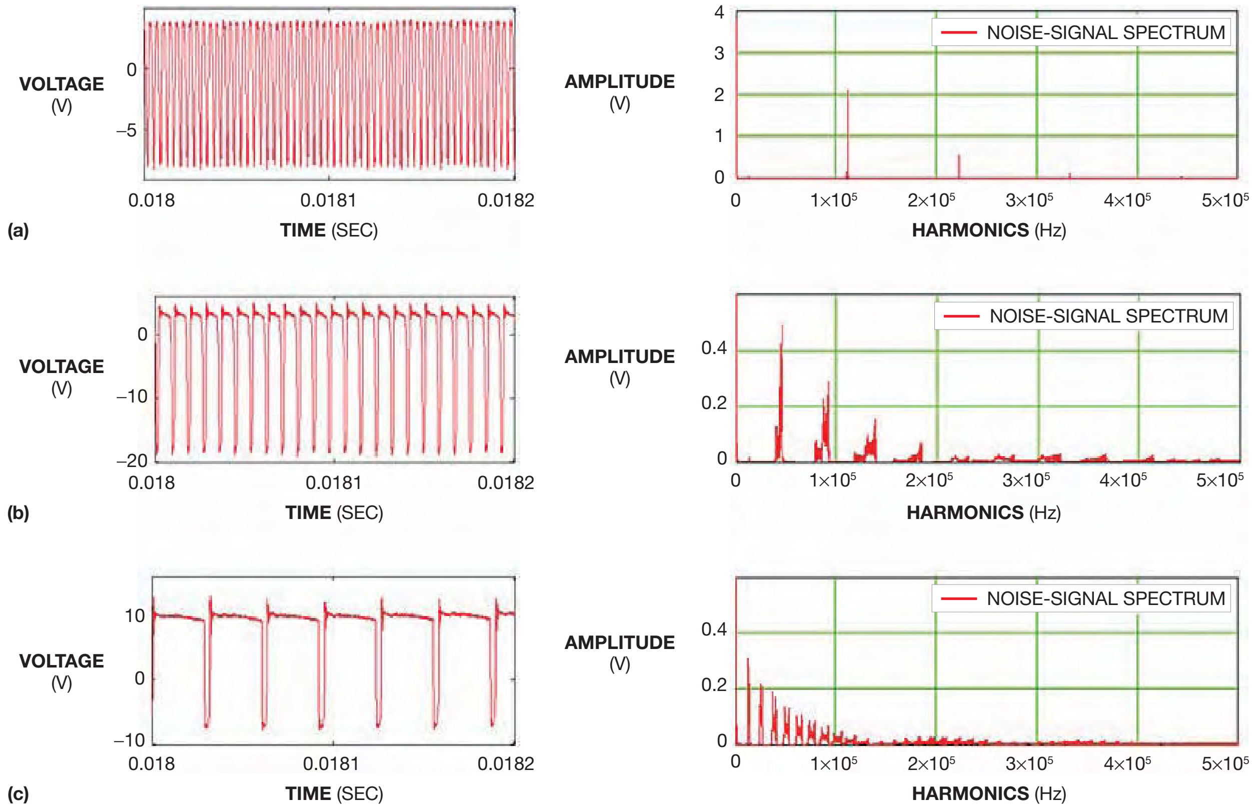

Figure 2 The noise of the "zero-charger" device differs at 0 (a), 50 (b), and 100% (c) loads.

the display. For years now, the industry has used a shield layer to protect the sensor from the noise that the display generates. This approach, though effective, adds both cost and thickness to a phone. The industry also uses a 0.3-mm-high air gap between the display and the sensor to allow the natural properties of air to dissipate the conducted noise from the display. However, as phones become thinner, neither of these options is appropriate for today's designs.

Fortunately, displays emit less noise than do chargers but are still difficult to handle. With a traditional TFT (thin-film-transistor) LCD, either a dc or an ac voltage drives the common electrode. An ac common-electrode layer typically lowers the operating voltage of the display driver and keeps a constant voltage across the liquid crystal. The ac common-electrode layer finds use in relatively low-cost displays, consumes more power, and has a noisier profile than do dc common-electrode layers (**Figure 4**).

Typical ac common-electrode displays have noise profiles of approxi-

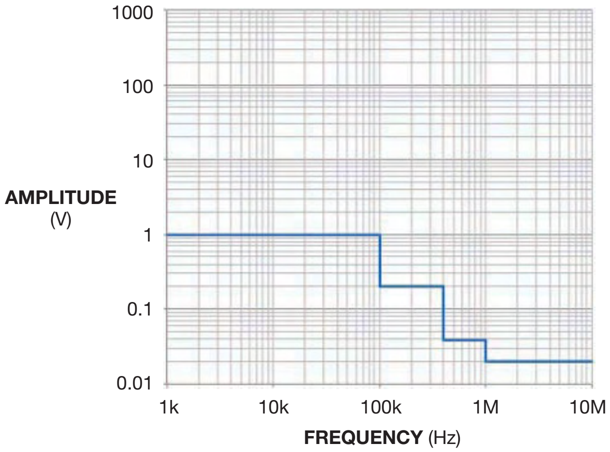

Figure 3 EN specifications govern the maximum noise levels a charger should emit at any frequency. EN 62684-2010 and EN 301489-34v1.1.1 govern these noise levels.

mately 10 to 30 kHz and 500 mV to 3V p-p, whereas a dc common-electrode display is often quieter. You can measure noise from a display simply by connecting an oscilloscope to a bit of copper tape at the top of the display, connecting ground to the display's circuit ground, and running the display to catch the waveforms.

The use of AMOLED (active-matrix organic-light-emitting-diode) technology is gaining traction in mobile phones because it has a wide viewing angle, bright colors, and deep contrast. AMOLED displays are also quiet, although this feature comes with a price (**Figure 5**). The AMOLED display in the **figure** outputs peak spikes of 30 mV p-p—1% of the noise from an ac common-electrode display, greatly easing touchscreen design. Integrating the sensor in the physical display to create an on- or in-cell topology is also straightforward with this type of display. However, AMOLED displays are more expensive than are traditional LCDs.

On-cell designs typically deposit the sensor layer on the color-filter glass in the display, bringing it closer to the chemistry of the display because it is inside the stackup. Both the

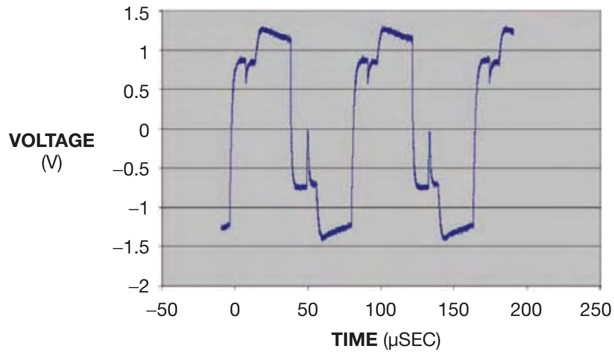

Figure 4 The ac electrode layer finds use in relatively low-cost displays, consumes more power, and has a noisier profile than do dc common-electrode layers.

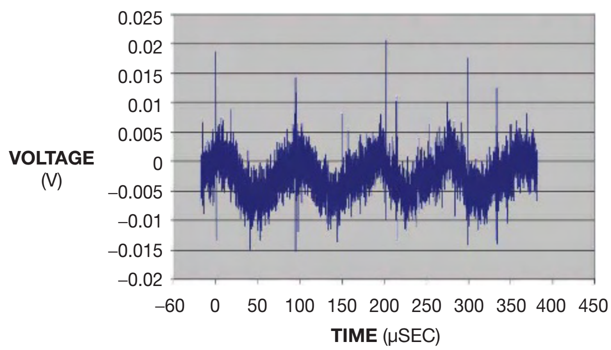

Figure 5 A typical AMOLED has a relatively small display-noise profile.

noise and the parasitic loading increase. However, AMOLED technology is inherently quiet and makes for a good platform for on- or in-cell sensors beneath the color-filter-glass design.

When designing sensors, a well-accepted sensor structure is to use a two-layer sensor, in which the transmitting lines are in the lower part of the sensor and the receiving lines are in the top. The receiving lines are sensitive to display noise, but the wide transmitting lines in the bottom of the sensor form a

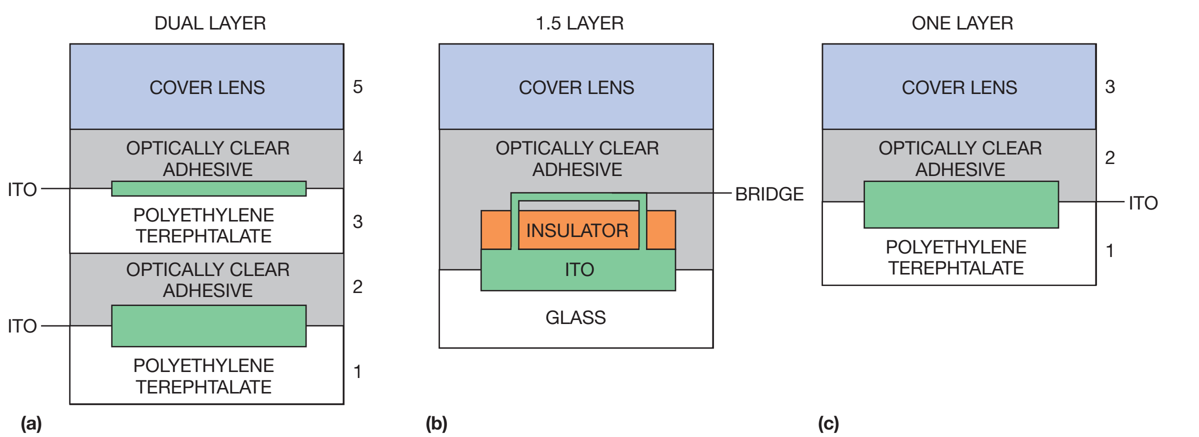

Figure 6 Touchscreen sensors using MH3 (a), diamonds (b), and proprietary technologies (c) use different stackups and materials.

barrier against the noise the display generates. This situation effectively builds a shield into the sensor pattern (**Figure 6**).

In an MH3 dual-layer stackup, the bottom layer of ITO (indium-tin oxide) acts as a shield to display noise. Unfortunately, glass-based sensors seldom use this approach, and it increases thickness and cost. The industry is pushing to build sensors on a single substrate layer with no shield. To enable true single-substrate-layer sensors without shielding requires the touchscreen IC to be resistant to display noise. This task is difficult because display noise can easily reach 3V p-p in ac and dc common-electrode displays.

You can mitigate display noise even in direct lamination—where the sensor structure is laminated to the top of the display with no air gap or shield—or display-integrated designs. An example is Cypress Semiconductor's Display Armor method to combat display noise. By integrating a built-in listening channel to the touchscreen device, touchscreen ICs can eliminate display noise by making advanced algorithmic decisions on what information is noise and what information is data. Detecting the noise source and latching onto the waveform allows you to make capacitive measurements during quiet times. These methods of reducing display noise result in advanced and thinner capacitive-touchscreen stackups at lower costs.

Aside from noisy displays and chargers, many other challenges face capacitive-touchscreen designers. For example, antennas are huge sources of noise challenges. With the increasing real-estate constraints within phones, components, such as antennas and touchscreen sensors, literally reside atop each other. Such design challenges can create issues in dealing with that portion of the touchscreen. Fortunately, the same innovations that are helping to reduce display and charger noise are also helping to reduce noise from other sources, such as antennas. Whether they use simple IIR (infinite-impulse-response) filters, advanced nonlinear-filtering methods, built-in noise-avoidance hardware, hopping capabilities, or any other methods, capacitive touchscreens enable some of the most advanced performance in embedded devices.

It is clear that noise immunity is one of the biggest concerns for designers. Whether dealing with noise from displays, chargers, antennas, or other sources, touchscreen ICs must perform with the same level of user experience. Innovation is happening daily in capacitive touch, and touchscreen ICs continue to wage the war against noise. **EDN**

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