**Smart Magnets for Precision Alignment in Product Design**

Correlated Magnetics Research creates specially engineered “smart” magnets for use in product design that are superior to conventional magnets. CMR’s technology includes proprietary magnetic patterns that produce more efficient magnets and have entirely new functions. CMR has also developed a software-controlled magnetization process enables precision control over the magnetic fields their magnets. We can these magnets “Polymagnets”. The result is that these unique magnets provide incredible holding force or alignment in the end product while eliminating issues related to conventional magnets.

Limitations of conventional magnets include lack of finesse in attraction feel, interference with credit cards and with sensitive electronic devices. One of Polymagnets' most innovative features is precision alignment. CMR offers self-aligning magnets that reject misalignment so that they will only come together and attach in one position.

**Using Magnets for Alignment**

Alignment is a natural application for magnets. Neodymium rare earth magnets have a high energy density, providing a lot of force in a small package. The limitation is the way conventional magnets interact.

**Conventional Magnets**

The red and blue magnets shown to the right of the graph below are both 50 millimeters long. The vertical axis in the graph indicates the force, and the horizontal axis indicates the lateral displacement. The white arrow on the top magnet shows the direction of movement of the magnets with respect to each other. The force is measured both in the normal direction, which is the holding force, and in the lateral direction, which is the shear force. The graph shows these magnets’ force curve (red line on graph) as a function of their lateral offset, and makes it clear that they have a high holding force even when they’re off center. This means that they are likely going to attract in the wrong place. And they are going to have a high frictional force holding them in that position.

![Conventional Magnet Forces vs. Lateral Displacement – 1mm Gap](image-url)
The lower curve (blue) on the chart above indicates the alignment force. While this pair of magnets provides 9 lbs of holding force at a one millimeter gap, at that same gap the peak alignment force is 1 lb.

The graph illustrates that conventional magnets don’t offer much help to product designers trying to align a system. It’s too easy for the magnets to pull the accessory and device together when they’re out of alignment. And the force in the shear direction is not going to overcome the frictional force.

Improving Alignment with Polymagnets
The Polymagnet pair shown below are the same size as the conventional magnets in the previous example. But these magnets have been engineered to incorporate a patented alignment pattern. CMR applies Barker correlation codes from communications theory to magnetic systems to greatly improve alignment performance. (See the section How it Works at the end of this document for more information about Barker codes and their application to magnets.)

Polymagnet Forces vs. Lateral Displacement – 1mm Gap

The above graph shows a strong peak force, the holding force, of a little over 11 lbs when the Polymagnets are in alignment. Moving to the right on the graph, indicating that the magnets are moved out of alignment, this force falls off very rapidly. At the offset around where the dot on the graph is, these magnets actually repel. In a system designed with these magnets, the components will actually feel like they’re floating until they are more closely aligned, at which point they’ll attach. The peak alignment force is 4.5 lbs.

This strong alignment force combined with the repel of the holding force when off center provides a feeling of self-alignment as the components come close together. There is very little positive holding force outside of the region where there is a strong alignment force (beyond about 18 mm of displacement). This eliminates the possibility of attachment when the components are misaligned.
Comparison
The image below shows a direct comparison between the conventional magnet and the Polymagnet.

Holding Force vs. Lateral Displacement – 1mm Gap

The conventional magnet has a high off peak holding force. When the conventional magnet is misaligned with its complementary magnet, there is a reduction in the holding force, but not a significant reduction. Therefore the accessory is going to come into contact with the device even when the parts are out of alignment. This will lead to frictional force, which will keep the products from coming into alignment. By contrast, the alignment Polymagnet has very little holding force when out of alignment. It even has a little bit of repel, minimizing friction until the accessory is close to alignment with the device.

The chart below compares the shear force of the conventional magnet and the Polymagnet.

Shear Force vs. Lateral Displacement – 1mm Gap

The conventional magnet has very low alignment force. Again, remember that these two magnet pairs are the same size. These are essentially the same magnets, but one is coded with the alignment Polymagnet pattern. The alignment Polymagnet has much higher force in the shear direction, making a significant difference in how the system feels in a product.
**Smart Magnets in Action**

Alignment is a magnet-to-magnet application, so the Polymagnets are used in both a tablet device and the accessory in this example. Having two Polymagnet pairs separated by some distance in a product allows you to get a better alignment torque for the overall system. In many cases, Polymagnets eliminate the need for any kind of mechanical alignment features, thus providing a very clean design.

Polymagnets offer improved holding force and a more secure feel in the way the tablet and cover come together, providing a much better overall design. Components will perfectly align and never slam together.

**Improved User Experience**

The image below shows that when the cover and the tablet are offset, there is really no interaction between the magnets. There's no resistance to the motion and there's no interference, and the user can move the cover and tablet freely to a point where they're close to alignment. As the two components get close, the accessory will feel like it's floating above or away from the device. And when the pieces come within about a centimeter of one another, close to the proper alignment position, the highest alignment force is reached, increasing holding force. So at that point the accessory is pulled into the proper position and the components click together securely.
Applying the same concept to the Polymagnets in a two-dimensional array provides alignment and shear resistance in two directions. The force curve below shows the force as the magnets are offset in the x and y dimension with respect to each other. Notice that as the magnets are starting to slide over one another, the force turns into a repel force. This is similar to what happened with the alignment magnets discussed above. The magnets lightly push away from each other when they first start to engage, and then as they come into alignment there is a very strong attraction. These magnets have the added benefit of being able to maintain orientation in the system.
Rotational Alignment

Barker codes can also be used in circular arrangements. The magnets in the image below are about 25 millimeters in diameter and about 3 millimeters thick.

Holding Force (lbs) vs Angle (°) – 1.5mm Gap

The force curve shows that these Polymagnets have a single preferred location at basically zero degrees, and the holding force at that point is twice that of a conventional magnet of the same size. This is for a 1.5 mm gap. The horizontal axis on this curve indicates the degrees of rotation. As you move away from zero degrees and rotate towards 50 degrees, the holding force falls off rapidly and even goes to a repel force at greater than 50 degrees. These behaviors will hold a system together securely at the preferred location but make it easy to reconfigure by incorporating this twist release function.

The image below shows the alignment torque. The dot on the lower right graph indicates the high torque toward the preferred location. Between 0 and 75 degrees there is a torque back to zero; over 280 degrees there is a torque toward 360, again back to that zero point. These Polymagnets can be configured with multiple alignment points or détentes depending on behavior desired in a system. Note that for these magnets there is a wide area without a significant torque or holding force. This enables design of a system with a twist release feature that makes it easy to disengage an accessory from a device but easy to engage and twist into a position offering a high holding force.
**Force Characteristics**

The chart below shows the holding force. At zero degrees there is a high holding force—about 16 lbs. That force will decline with either a positive rotation or a negative rotation over a range of about 80 degrees total.
The torque curve in the next graph shows that there is a high torque at about 30 degrees but very little alignment force as you get closer to the equilibrium point. This is not unexpected and it often doesn't matter. But it is undesirable in tools, cameras, and other products where a high degree of precision is required. The lack of alignment torque can make the attachment feel sloppy. The interface needs to be more precise in these cases but still support ease of assembly and configurability.

**Improving Precision**

The torque curve indicated by the dot in the image below is the peak, about 30 degrees from the equilibrium point. Designing a system such that the magnets are held at this point provides an active clamp feature in the product. Some of the holding force is given up in this case, but the system interface is much more precise because of the active clamping.

The image below illustrates incorporating mechanical stops in a system that engage when the magnets are offset at that peak torque. This provides a positive stop, precise engagement and reconfigurability.
CMR applies this concept to rotational alignment magnets as well as linear magnets. The key is designing a stop such that the magnets will hold the system in tension at this peak force.

**Polymagnet Alignment: How it works**

Correlated Magnetics Research makes Polymagnets with precision auto-alignment by applying Barker correlation codes and techniques commonly used in the world of radar. Here is a simplified explanation, including a bit of background information about correlation codes.

When mathematical waves or curves such as sine waves are in phase (i.e., when they line up), they are additive, meaning the sum of all the components is positive. Another way to say it is that if you add a mathematical curve to itself, the values reinforce one another. When they are out of phase, that is if you shift the curve and add the original curve to the shifted version, they can actually cancel each other out.

To further expand on this notion, imagine adding a sine wave to itself. All the 1/-1/1s become 1/-2/2s. Shift the curve by 1 unit, then add it to the original unshifted curve, and you get 0/0/0. Similarly, you can take patterns that have similar +1/-1 structures of varying length, and when aligned, the sum of all units equals the total number of units. When shifted or offset, the sum of all units is much lower (0 or 1). The Barker 7 sequence, for example, has 7 units. When aligned, the sum is 7; when offset, the sum is 0 or -1.

Barker correlation codes are unique sequences of +1s and -1s in a function such that when it is lined up with a copy of itself, the two functions resonate strongly with one another as described above, but when they are shifted, this resonance falls off dramatically. These sums in Polymagnets lead to preferred alignment, as described below.

The patented method used by Correlated Magnetics to program magnets involves applying these Barker code behaviors to pattern of magnetic north and south poles, which is also patented. Instead of curves being in and out of phase by time (communications theory), the patterns of magnetic north and south poles can be in and out of phase by position -- physically shifting or offsetting the poles past each other. When they all line up, they can attract one another. In the other positions, cancellation or repulsion occurs, depending on the pattern.

Applying Barker codes to program their magnets, Correlated Magnetics uses patterns of magnetic north and south poles instead of 1s and -1s to program how tightly the magnets attract and hold one another, how abruptly the attraction falls off as they are shifted with respect to one another, and more. Correlated Magnetics deliberately shifts the positions of several N and S poles on two magnets according to Barker code patterns.
patterns such that the magnets attract one another strongly when perfectly aligned, yet repel when slightly shifted. The pattern of norths and souths can even be reversed, causing the magnets to repel one another.

**Finding the Right Polymagnets**

The new capabilities made possible by Polymagnets opens up a wide range of new applications for magnetic attachment. Product designers can consult CMR’s Polymagnet catalog to make a selection appropriate for their product. The catalog offers standard Polymagnets with a range of alignment magnets in sizes suitable for mobile phones and accessories, smart tablets, boxes and various modular products. CMR has alignment magnets that are specifically tailored for tablet products, such as iPad accessories.

![Image showing Polymagnet sizes](image)

While the alignment magnets in the catalog can help designers meet many of their product needs, CMR has a team of magnetics engineers who can also create custom solution Polymagnets to meet special needs. Consult CMR’s website (www.polymagnet.com) for information on high performance Polymagnets that can give a product a great feel and a great user experience. For more information or to get started with product design, contact CMR’s technical sales reps, distributed throughout the country. They will help you find the right catalog magnet or help you get started on your custom magnetic solution.

**Custom Polymagnets**

Custom Polymagnets are also available. CMR can combine Polymagnet functions in a wide variety of ways to meet the needs of a specific product if the magnets offered in the Polymagnet Catalog are not the perfect fit.

**Next Steps In Designing a Polymagnet system**

Polymagnets are available in the Polymagnet Catalog in a variety of shapes and sizes, with a variety of functions, giving product designers a new tool for designing products. The catalog provides an excellent starting point for most products. Visit www.polymagnet.com for further information. To discuss a custom design project, please contact a CMR sales representative listed in the contact section of CMR’s website: www.polymagnet.com/contact

Polymagnets are an incredible design tool that provide new capability above and beyond the limitations of conventional magnets.